BCGA CODE OF PRACTICE 36

CRYOGENIC LIQUID STORAGE AT USERS' PREMISES

Revision 2: 2013

British Compressed Gases Association

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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 36, Revision 1, 2011. It was approved for publication at BCGA Technical Committee 146. This document was first published on 09/05/2013. For comments on this document contact the Association via the website www.bcga.co.uk.

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Appendixes:

* Throughout this publication the numbers in brackets refer to references in Section 9. Documents referenced are the edition current at the time of publication, unless otherwise stated.

TERMINOLOGY AND DEFINITIONS

System Relevant Fluid Danger Examination User Protective Device Owner	These terms are defined in the Pressure Systems Safety Regulations (7).
Access Apron	Indicates an area between the tank or fill point 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.
Cryogenic liquid	For the purpose of this document cryogenic liquid is liquid oxygen, nitrogen, helium and argon.
Liquid Transfer Area	Indicates an area adjacent to the tank or fill point 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.
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 will normally be subject to a vacuum.
Vessel	Indicates a pressure vessel, which may or may not be insulated.

BCGA CODE OF PRACTICE 36

BULK CRYOGENIC LIQUID STORAGE AT USERS' PREMISES

1. INTRODUCTION

The objective of the BCGA Code of Practice is to make reference where applicable to UK legislation and British Standards where these apply to cryogenic air gas systems and to take into account the specific practices of the UK industrial gas companies particularly in relation to safety distances.

This Code of Practice is based generally on the European Industrial Gases Association (EIGA) Document 115 (30), *Storage of cryogenic air gases at users' premises,* but in some instances gives more detailed requirements for the UK especially for tanks below 2,000 Litres. The British Compressed Gases Association (BCGA) is grateful for the active help and co-operation of the Health and Safety Executive (HSE). With the permission of EIGA, sections of the EIGA Document have also been duplicated.

The BCGA wishes to acknowledge the work done by the EIGA committee that prepared EIGA Document 115 (30).

The storage of cryogenic gases in the liquid state under pressure at users' premises not only provides an efficient way of storing gas, but improves safety when used in conjunction with a distribution system by eliminating the need for cylinder handling. However, the particular properties of cryogenic gases necessitate certain precautions to be taken and certain rules to be followed.

This document is intended for the guidance of those persons directly associated with the design, operation and maintenance of bulk liquid storage installations. It does not claim to cover the subject completely but gives advice and should be used with sound engineering judgment.

BCGA has also published Leaflet 12 (48), *Liquid gas storage tanks: Your responsibilities*, which is a simple user guide that advises users and owners of liquid gas storage tanks on their legal responsibilities and duty of care to ensure that the equipment is maintained and operated safely.

All new storage installations shall comply with this Code of Practice.

2. SCOPE

A cryogenic liquid storage system installation on a users' premises is defined for the purposes of this Code of Practice as the installed static liquid storage tank together with the control equipment and safety devices, vaporising equipment, the storage location, access apron and the liquid transfer area.

This document applies to static, vacuum insulated, tanks with an individual water capacity up to 125,000 litres operating at pressures greater than 0.5 bar above atmospheric pressure designed to store cryogenic liquids.

This document may also be used as guidance for installations in excess of 125,000 litres including multiple tanks operating as a single tank; applicable regulations may impose different safety distances and legal requirements e.g. The Control of Major Accident Hazards Regulations (COMAH) (6), see also HSE HSG 191 (15), *Emergency Planning for major accidents*.

For cylinder filling depots operated by gas suppliers, individual tank storage capacity is normally less than 125,000 litres. In such cases BCGA Code of Practice (CP) 20 (32) *Bulk liquid oxygen storage at production sites*, and BCGA CP 22 (33) *Bulk liquid argon or nitrogen storage at production sites,* should only apply to these systems when the tank is connected to a manufacturing plant. However the minimum safety distances, the provision for periodic inspection, testing and examination and the liquid transfer area specified in this Code of Practice may be applied.

Specifically excluded from this Code of Practice are:

(i) Transportable cryogenic liquid storage tanks (such as "liquid cylinders", cryogenic receptacles, containerised tanks, dewars and road tankers).

(ii) The storage of compressed gas cylinders. Refer to BCGA Guidance Note (GN) 02 (44).

The BCGA have published the following Codes of Practice for liquefied gas systems not covered by this Code:

BCGA CP 26 (36)	Bulk liquid carbon dioxide storage at users' premises
BCGA CP 27 (37)	Transportable vacuum insulated containers of not more than 1000 litres volume
BCGA CP 30 (38)	The safe use of liquid nitrogen dewars up to 50 litres

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 Liquefied Petroleum Gas (LPG) and Hydrogen.

3. GENERAL DESIGN CONSIDERATIONS

3.1 General

Gaseous oxygen, nitrogen, argon and helium are colourless, odourless and tasteless. Nitrogen, argon and helium are non-toxic but asphyxiant.

Oxygen is not toxic; it is slightly denser than air. It is not a flammable gas but vigorously supports combustion. Breathing pure oxygen at atmospheric pressure is not dangerous although exposure for several hours may cause temporary functional disorders to the lungs.

The following documents should be taken into consideration:

BCGA GN11 (45)	Use of gases in the workplace. The management of risks associated with reduced oxygen atmospheres.
EIGA Doc 4 (26)	Fire hazards of oxygen and oxygen enriched atmospheres
EIGA Doc 44 (29)	Hazards of inert gases.

3.2 Properties of nitrogen, argon, oxygen and helium

The physical properties of nitrogen, argon, oxygen and helium are given in Table 1:

	Nitrogen	Argon	Oxygen	Helium
Content in air Volume %	78.1	0.9	21	-
Gas density at 1.013 bar, 15 °C kg/m^3	1.19	1.69	1.36	0.1
Boiling temperature at 1.013 bar °C	-196	-186	-183	-269
Liquid density at 1.013 bar and boiling temperature kg/l	0.8	1.39	1.14	0.1
Gas volume of the liquid at ambient conditions l (gas) per l (liquid)	680	810	840	748

Table 1: Properties of cryogenic gases

Cold oxygen, nitrogen and argon vapours are heavier than air and may accumulate in pits and trenches.

3.3 Precautions

The properties of oxygen, nitrogen, argon, and helium justify the following special precautions:

3.4 Oxygen deficiency or enrichment of the atmosphere

The atmosphere normally contains 21 % by volume of oxygen. Enrichment may give rise to a significant increase in the rate of combustion. Many materials including some common metals which are not flammable in air, may burn in oxygen, when ignited. Detailed information on this subject is contained in EIGA Document 04 (26), *Fire hazards of oxygen and oxygen enriched atmospheres*.

Nitrogen, argon and helium will act as asphyxiants by displacing the oxygen from the atmosphere.

The hazards from oxygen enrichment or deficiency are explained in the BCGA / EIGA documents detailed in Section 3.1.

Good ventilation shall always be provided in places where liquid cryogenic gases are stored, used and / or transferred.

A risk assessment in accordance with the Confined Spaces Regulations (3) should be made where the use or leakage of these gases could affect the safety and health of persons in a confined space.

3.5 Cryogenic burns

Severe damage to the skin may be caused by contact with liquid cryogenic gases, and their cold gases or with uninsulated pipes or receptacles containing liquid cryogenic gases. For this reason appropriate personal protective equipment, including gloves and eye protection, shall be worn when handling equipment in liquid cryogenic gases service.

All the safety aspects of handling cryogenic liquid cannot be covered adequately in this Code of Practice. The reader is therefore referred to the British Cryoengineering Society, *Cryogenic Safety Manual* (49), for further information.

3.6 Air condensation

Ambient air may condense on uninsulated pipes and vessels containing liquid nitrogen and helium causing local oxygen enrichment of the atmosphere. Insulating materials should be chosen bearing in mind that oxygen enrichment may occur.

3.7 Oxygen service requirements

3.7.1 Material compatibility

All materials used shall be oxygen compatible. Particular attention shall be given to elastomers and soft sealing components. Consideration shall be given to the products of decomposition, especially in breathing gas, medical or food applications where toxins could give rise to danger. If using polytetrafluoroethylene (PTFE) tape it shall be in accordance with BS 7786 (20), *Specification for unsintered PTFE tapes for general use*.

3.7.2 Oil, grease, combustible material and other foreign matter

Most oils, grease and organic materials constitute a fire or explosion hazard in oxygen enriched atmospheres and must on no account be used on equipment which is intended for oxygen service. Only materials acceptable for the particular oxygen service application may be used. Sealing materials should be prevented from intruding in to the gas flow. Particular care should be taken with thread sealing compounds and tape.

All equipment for oxygen service shall be specifically designed and prepared.

3.7.3 Cleaning

Before putting equipment into service with oxygen, either for the first time or following maintenance, it is essential that all surfaces which may come into contact with an oxygen enriched environment are "clean for oxygen service", which means: dry and free from any loose or virtually loose constituents, such as slag, rust, weld residues, blasting materials and entirely free from hydrocarbons or other materials incompatible with oxygen.

The maintenance and assembly of equipment for oxygen shall be carried out under clean, oil free conditions. All tools and protective clothing (such as overalls, gloves and footwear) shall be clean and free of grease and oil, where gloves are not used, clean hands are essential.

Degreasing of an installation or parts of it demands the use of a degreasing agent which satisfies the following requirements:

- No or slow reaction with oxygen.
- No or low toxicity (low vapour pressure to keep vapour concentration below threshold limit).
- Material compatible with oxygen.

It is important that all traces of degreasing agents are removed from the system prior to commissioning with oxygen. Some agents, such as halogenated solvents, may be non-flammable in air, but can explode in oxygen enriched atmospheres or in liquid oxygen. Where the user or installer is unsure of the cleaning process to be used specialist cleaning companies should be employed. These companies should also take the responsibility for the supply of appropriately registered chemicals and the safe and legal disposal of used cleaning agents.

Good housekeeping is necessary to prevent contamination by loose debris or combustibles.

Nitrogen, argon, and helium do not react with oil or grease, but it is good practice to apply a high standard of cleanliness, although not as stringent as those required for oxygen installations.

Advice on the cleaning of oxygen systems is given in the following documents:

EIGA Doc 33 (28)	Cleaning of equipment for oxygen service. Guidelines gives practical guidance on how to prepare equipment for oxygen service.
BS IEC 60877 (24)	Code of Practice for procedures for ensuring the cleanliness of industrial process, measurement and control equipment for oxygen service.
BCGA Technical Report TR3 (43)	Replacement substances for the cleaning of oxygen system components. This Technical Report gives information about cleaning oxygen system components without the use of chemical solvents.

3.8 Embrittlement of materials

Many materials, such as some carbon steels and plastics, are brittle at very low temperatures and the use of an appropriate material for the service conditions prevailing is essential.

Metals suitable for cryogenic liquid service include 9 % nickel steel, 18/8 stainless steel and other austenitic stainless steels, copper and its alloys and aluminium alloys.

PTFE is the most widely used plastic material for sealing purposes in cryogenic service but other reinforced plastics are also used. For further information on materials see BS 5429 (18), *Code of Practice for safe operation of small-scale storage facilities for cryogenic liquids*.

3.9 Fire precautions

The storage of cryogenic liquids shall be considered in the site fire risk assessment. Inert gases do not pose a risk of fire enhancement but do present a risk of container rupture due to over pressure. Oxygen is not a flammable gas but vigorously supports combustion. Refer to The Regulatory Reform (Fire Safety) Order (9).

Oxygen is within the scope of The Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) (8) and requires a risk assessment in accordance with these regulations. Guidance on DSEAR Risk Assessment is available in BCGA GN 13 (46).

Flammable substances and combustible materials should not be stored or allowed to accumulate in the vicinity of cryogenic liquid installations. This is particularly important for oxygen storage where a leak could cause spontaneous combustion of accumulated materials.

3.10 Hot work

No hot work shall be performed in the immediate vicinity of the installation without a Permit to Work. See Section 8 - Training.

3.11 Ignition sources

Smoking and naked flames shall be prohibited within the minimum safety distances specified in Section 4.3.

For electrical equipment, see the safety distance diagram for oxygen storage in Appendix 3.

3.12 Insulation materials

The components used in insulating all cryogenic equipment shall be compatible for oxygen service. This is because cryogenic equipment can cause local areas of oxygen enrichment by preferentially condensing oxygen from the air.

3.13 Regulation and codes

This Code of Practice describes minimum requirements. All relevant statutory regulations shall be applied and relevant Codes of Practice, standards and specifications shall be taken into account in the designs and installations covered by this Code of Practice. See Section 9 - References.

4. LAYOUT AND DESIGN FEATURES

4.1 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 planning controls. If so, the siting of any proposed installation shall be discussed and agreed with the local authority and appropriate sections of the Health and Safety Executive.

4.2 Design and manufacture of the tank

Tanks and associated equipment 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 (5).

Tanks containing a gas at a pressure of less than 0.5 bar above atmospheric pressure are not covered by the Pressure Equipment Regulations (5). However, in order to comply with regulation 4 of The Provision and Use of Work Equipment Regulations (4), the tank should be properly designed and properly constructed from suitable material so as to prevent danger. This is best guaranteed by adherence to a recognised design standard for this type of tank and its intended use.

Where appropriate, tanks shall be designed to withstand wind loads in accordance with the appropriate design codes e.g. BS EN 1991 (17), *Eurocode 1. Actions on structures. General actions. Wind actions*.

4.2.1 Materials

All components shall be constructed from materials compatible with the liquefied gas in service, and with the temperature and pressure conditions to which they will be subjected.

All materials of construction for tanks which may be used for oxygen service shall be oxygen compatible, including all insulation, getters, piping, valves, gaskets, seals and instruments.

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.

4.2.2 Tank pressure relief devices

Each tank shall have pressure relief devices on both the inner vessel and outer jacket.

Inner vessels shall be protected by at least two independent safety devices. Typically, a pressure relief valve and a separate bursting disc will be fitted. Combinations of smaller capacity relief valves can be used to achieve the required rate of relief. Safety relief systems should comply with BS EN 13648 (21), *Cryogenic vessels. Safety devices for protection against excessive pressure*.

EIGA Document 24 (27), *Vacuum insulated cryogenic storage tank systems pressure protection devices*, provides a code of practice for pressure protection devices for static cryogenic vacuum insulated storage tanks.

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

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

(b) Flash gas from filling operations of road tankers.

(c) Malfunction of control valves in pressure raising systems; or

(d) Any other foreseeable source of energy input into the vessel i.e. fire, pump recycle systems.

Consideration shall be given to the provision of secondary relief devices, such as bursting discs, depending on the degree of risk associated with the installation and prevailing climatic or environmental conditions, e.g. icing due to high humidity, corrosion etc.

At least one online pressure relief valve (or combination of small relief valves) shall have a capacity and set-point that will prevent the pressure within the vessel exceeding the maximum allowable working pressure in accordance with the applicable vessel design code. The combined capacity of all online relief devices shall be sufficient to prevent the test pressure of the tank being exceeded, in the event of loss of vacuum combined with the pressure-build up system failing in the open position.

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

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.

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 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 affect 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.

Outer jackets shall be fitted with a device to relieve pressure increase in the event of a leak from the inner vessel. 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.

4.2.3 Markings

The tank shall be marked in accordance with the requirements set out in paragraph 3.3 of schedule 2 of the Pressure Equipment Regulations (5). The safe operating limits should be readily accessible.

4.3 Minimum safety distances

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

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

(b) the tank outer jacket, or

(c) the tank nozzles.

Minimum safety distances are intended to:

(i) Protect personnel from exposure to hazardous atmospheres and to prevent fire enhancement in the event of a release of liquid oxygen.

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

The minimum safety distances given in this Code of Practice are based on experience and calculations of minor release. The minimum safety distances given 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 3 are intended to protect the storage installation as well as personnel and the environment. They are considered to give protection against risks involved, according to practical experience, in the normal operation of 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 methodology (using HSE fatality rates) indicates an acceptable level of risk.

Consideration shall be given for provision to divert any spillage towards the safest available area.

Where the required minimum safety distance cannot be achieved, a permanent physical partition may be used. The safety distance may then be measured around the ends of the partition to the installation. Such partitions should be of at least 60 minutes' fire-resisting construction, imperforate and constructed of materials such as solid masonry or concrete. They should be not less than 2.5 metres high. See also HSE L136 (13), *DSEAR Approved Code of Practice* and BS 476 (16), *Fire tests on building materials and structures*.

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. Where access is required for maintenance, a minimum clearance of 0.6 metres shall be maintained between the barrier or wall and the installation to allow free access and egress 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.

4.4 Location of the installation

Consideration shall be given to the consequences of any liquid spillage 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. Although the rate of gas discharge is small, precautions shall be taken to avoid the build up of dangerous atmospheres.

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:

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

(b) the installation is within an enclosed space of adequate size such that using the calculation in Appendix 6, the release of gas will not result in an atmosphere with an oxygen concentration outside the limits of 19.5 % and 23.5 %.

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: (a) and (b) 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 6 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 oxygen monitors 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:

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

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

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

(iv) 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:

(A) Inside structures with two or more sides and a roof.

(B) Enclosed on three or more sides.

(C) Below ground level or where there are pits, ditches and other ground depressions.

4.4.1 Gas detection

Asphyxiant or oxygen 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.

Oxygen monitoring shall be considered where there is a risk of oxygen levels depleting below 19.5 % or above 23.5 % in a workplace.

Detector displays and warning signs shall be sited so that they are clearly visible to personnel before entering the affected area.

Detection equipment should be installed, maintained and tested in accordance with the manufacturers recommendations.

Guidance on assessing ventilation requirements is given in Appendix 6.

4.4.2 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 (25), *Protection against lightning*.

Flame proof, explosion proof, or other forms of classified electrical equipment are not necessary for cryogenic liquid systems since the products are not classified as flammable gases according to BS EN 60079 (22), *Explosive atmospheres. Electrical installations design, selection and erection*. Where applicable, electrical equipment, which is necessary for the installation shall be to BS EN 60529 (23), *Specification for degrees of protection provided by enclosures*, 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.

4.4.3 Installation level and slope

Where liquid cryogenic storage tanks are required to be installed at an elevated level, they shall be supported by purpose designed structures which should withstand or be protected from damage by cryogenic liquid spillage.

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

Where liquid oxygen storage tanks are required to be installed on a slope, consideration shall be given for the prevention of directing hazardous materials, such as oil, towards the oxygen installation or of directing any oxygen spillage towards locations where people are at risk or towards hazardous materials.

4.4.4 Position of gas vents

Vents, including those of safety relief devices, shall vent to a safe place in the open and comply with the safety distances shown in Appendix 3. They shall be directed so as not to impinge on personnel, occupied buildings and structural steelwork.

Oxygen vents shall be so positioned that the flow from them cannot mix with that from flammable gas or liquid vents.

Consideration shall be given to the prevention of accumulation of water, including that from condensation, in vent outlets.

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

4.4.5 Vapour clouds

Vapour clouds may be formed during normal operation of a cryogenic system e.g. 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 an enriched or depleted oxygen atmosphere.

Vapour clouds from releases are generally low lying (typically below waist height). Such vapour clouds may be quite extensive depending on weather conditions and persons working below ground or at low level in the vicinity may be 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 oxygen enrichment / deficiency or decreased visibility e.g. crossing roads. The prevailing wind direction and the topography shall be taken into account.

In the case of oxygen refer to:

(i) BCGA Technical Report 1 (41), *A method for estimating the off-site risks from bulk storage of liquefied oxygen.*

(ii) BCGA Technical Report 2 (42), *The probability of fatality in oxygen enriched atmospheres due to spillage of liquid oxygen*.

In the case of nitrogen and argon refer to:

(iii) BCGA Guidance Note 11 (45), *Reduced oxygen atmospheres. The management of risk associated with reduced oxygen atmospheres resulting from the use of gases in the workplace*.

4.4.6 Liquid 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 be in a walled enclosure from which the escape of liquid or heavy 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.

The road tanker transfer area for oxygen installations shall be made of concrete or any other suitable non-porous non-combustible material. This also includes any expansion joints.

See Appendix 4 for a diagrammatic view of a liquid transfer area.

4.4.7 Ventilation of ancillary equipment enclosure

Where pumps and / or vaporising equipment are located in enclosures, these shall be properly ventilated. Openings used for access and/or free or forced ventilation shall lead to a place where there is free escape for cold vapour and, in the case of oxygen, where there will be no accumulation of combustible material liable to form a hazard.

Personnel and equipment should be protected from any oxygen pump fire by means of barriers or suitable shielding. Openings used for access and / or free or forced ventilation shall lead to a place where there is free escape for cold vapour and where there will be no accumulation of combustible material, liable to form a hazard.

4.4.8 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 etc. to ensure these are easily accessible. Equipment, pipework and cables should be installed so as to minimise hazards e.g. tripping, and allow safe access and egress to the installation.

4.4.9 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 of the pressure relief devices. (See Section 6.1.2).

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.

4.4.10 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.

4.4.11 Secondary isolation valves

A secondary means of isolation should be provided for those lines greater than 9 mm nominal bore which

(i) emanate from below the normal liquid level and

(ii) have only one means of isolation between the tank and the atmosphere (such as liquid filling lines),

to prevent any large spillage of liquid 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 non-return valve.

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

4.4.12 Couplings

In certain cases, filling the incorrect fluid into a tank may create an unsafe condition; therefore liquid fill connections should be different for the product categories detailed in Table 2.

Nitrogen / Argon
Oxygen / Medical Oxygen
Helium

Table 2: Product Categories

4.4.13 Backflow prevention

Consideration should be given to the fitting of suitable devices to prevent backflow and possible contamination or over-pressurisation from the user system.

4.4.14 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 3 will apply regardless of the position of the fence.

The height of the fence shall be a minimum of 1.8 m.

Timber or other readily combustible materials shall not be used for fencing around oxygen tanks.

Any gates should be outward opening and wide enough to provide for an easy access and exit of personnel.

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. Where installed, all emergency exits are to open in the direction of escape and are to 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 are not to obstruct any other escape route. These exits are to be properly identified by signage, and maintained in a serviceable condition at all times. Any emergency exit gate should be, at least, 0.8 m wide.

4.4.15 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, etc.

The position of ambient vaporisers can severely affect their performance, as they rely on the free movement of air.

4.4.16 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 resulting from wind, snow, earthquake etc.

In the case of oxygen:

(i) The foundation on which the equipment is installed shall be made of concrete or any other suitable, non-flammable, and non-porous material.

(ii) Expansion joint materials shall be acceptable for use with liquid oxygen, however the design should avoid joints within 1 m of the hose coupling points and any operational discharge points.

Accumulation of water shall be avoided.

4.4.17 Bolting down

Generally, tanks below 2,000 litres do not need bolting down and therefore do not have any provision for bolting down.

Many factors determine whether a tank needs to be bolted down. The following are some of the main factors that should be considered:

(i) Seismic activity.

(ii) Wind speed.

(iii) Topography (nature of surrounding terrain).

(iv) Ground roughness (open or protection provided).

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

(vi) The potential to tip the foundation.

The principles of BS EN 1991 (17) shall be followed to determine bolting down requirements.

4.4.18 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 cryogenic liquids.

Any modifications shall be carried out in accordance with the applicable design code and in consultation with the gas supplier.

5. ACCESS TO THE INSTALLATION

5.1 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.

5.2 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. See Figure 1.

5.3 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.

5.4 Notices and instructions

5.4.1 General precautions

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

(i) LIQUID NITROGEN / ARGON / OXYGEN / HELIUM (as appropriate)

(ii) NO SMOKING *

(iii) NO NAKED LIGHTS *

(iv) NO STORAGE OF OIL, GREASE OR COMBUSTIBLE MATERIALS *

(v) AUTHORISED PERSONS ONLY

(vi) EXTREME COLD HAZARD

In addition for argon, nitrogen, and helium storage installation

(vi) ASPHYXIATION HAZARD

In addition for oxygen storage installation

(vii) OXIDISING SUBSTANCE

* Although nitrogen / argon / helium are inert gases it is recommended that smoking and open flames are prohibited within the immediate area to avoid the possibility of causing fire.

A pictograph should be used instead of written notices wherever possible. For examples see Figure 1.

Potential Asphyxiating Atmosphere	Cryogenic Liquid	Oxidising Substance	No naked flames	No Smoking	No Unauthorised Access

Figure 1: Examples of pictographs

These signs shall comply with The Health and Safety (Safety Signs and Signals) Regulations (2) and with BS ISO 7010 (19), *Graphical symbols. Safety colours and safety signs. Registered safety signs*.

A sign shall be displayed showing:

(a) Gas supplier's name and local address.

(b) Gas supplier's emergency phone number.

This information should also be available at a control point.

5.4.2 Identification of contents

The storage tank shall be clearly labelled "LIQUID NITROGEN"; "LIQUID ARGON", "LIQUID HELIUM" or "LIQUID OXYGEN" as appropriate.

The storage tank or compound should be clearly labelled with the appropriate UN number(s) as defined in the United Nations Model Regulations for the Transport of Dangerous Goods (11).

The connection fittings of multi-storage installations or long fill lines shall also be clearly marked with gas name or symbol in order to avoid confusion (see also 4.4.12).

5.4.3 Legibility of notices

All displayed notices shall be kept legible, visible and up-to-date at all times.

5.4.4 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 require the following information in additional to the above:

(i) The product name shall be followed by the appropriate 'E' number as detailed in Table 3:

Product	'E' Number
Carbon Dioxide	290
Nitrogen	941
Argon	938
Oxygen	948
Helium	939
Nitrous Oxide	942

Table 3: Food Additive 'E' Numbers

(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.

5.4.5 Operating and emergency instructions

Operating and emergency instructions shall be provided by the gas supplier and shall be available and understood by the user before commissioning the installation.

These instructions shall be kept up-to-date.

6. TESTING AND COMMISSIONING

6.1 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.

6.1.1 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 attached to 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 (14), *Safety requirements for pressure testing*.

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 (14) 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.

6.1.2 Pressure relief devices

A check shall be made to ensure that all transport locking devices have been removed from pressure relief devices of 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 devices shall be fitted.

6.2 Adjustment of controlling devices

The controlling devices shall be adjusted to the required operating conditions of the system and be subjected to a functional test.

6.3 Posting of notices

Notices (see Section 5.4) shall be posted before putting the installation into service.

6.4 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 visual check has been made to ensure that back-feed from the system into the container, e.g. 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 use.

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

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

(vii) An ageing pressure equipment assessment in accordance with BCGA CP39 (39), *In-service requirements of pressure equipment installed at user premises*, has been conducted to identify the in-service requirements.

(viii) A written scheme of examination, in accordance with the Pressure Systems Safety Regulations (PSSR) (7), has been drawn up by a competent person. A written scheme of examination shall be required for the system. 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 PSSR (7) Schedule 2). Additional information is available in BCGA CP 23 (34), *Application of the Pressure Systems Safety Regulations 2000 to industrial and medical pressure systems installed at user premises*.

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

In addition, procedures shall be in place to ensure the following significant risks are addressed:

(a) Thermal shock.

(b) Rapid pressure rise.

(c) Contamination in oxygen systems leading to auto ignition.

(d) Noise.

(e) Gas release.

6.5 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 8.

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

Handover documents shall include a minimum of:

(a) A manual covering operation and care of the installation.

(b) A Safety Data Sheet, which gives information in accordance with the requirements of the Chemicals (Hazard Information and Packaging for Supply) Regulations (10) and the European regulation on the Registration, Evaluation, Authorisation and restriction of Chemicals (REACH) (12) and which deals with the prevention of accidents arising from the uncontrolled escape of product from the installation.

7. OPERATION AND MAINTENANCE

7.1 Operation of the installation

7.1.1 Putting into Service (first filling)

The gas supplier shall:

(i) Ensure that the user understands his responsibilities under the PSSR (7) and has made arrangements for them to be fulfilled.

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

When a tank is to be filled for the first time, the following checks shall be made in addition to those required in Section 6.4:

(a) Check that all appropriate documentation for the particular tank and accessories is available.

(b) Check that valves, relief devices and accessories are appropriate for the intended service, comply with the process flow diagram and are appropriately marked.

(c) Check that all valves are easy to operate.

The tank shall be cooled down and filled according to the manufacturer's recommendations. Steps should be taken to avoid uncontrolled pressure rise due to rapid liquid evaporation.

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.

EIGA Document 151 (31), *Prevention of excessive pressure during filling of cryogenic vessels*, provides guidance to the filler / owner of either transportable or static cryogenic tanks, detailing the systems and procedures that can be used to prevent them being over pressurized, during filling.

7.1.2 Operating personnel and procedures

Only authorised persons shall be allowed to 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 these 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.

7.1.3 Operating difficulty or emergency

If during the operation of the installation an excursion occurs outside the safe operating limits of the system (e.g. overpressure, rapid temperature change), or mechanical damage, this shall be reported immediately to the gas supplier and/or tank owner so that a decision about the continued use of the tank can be made and a programme of inspection drawn up by a competent person and implemented.

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.

7.2 In service inspection and maintenance

All aspects of in service inspections and maintenance are addressed in BCGA CP39 (39) and the details for cryogenic systems are contained in BCGA CP39, Module 1 (40), *In-service requirements of cryogenic storage system at user premises*.

Storage tanks are required to be rigorously inspected and approved by the Competent Person during manufacture and thereafter be periodically endorsed by the Competent Person as being fit for continued service. BCGA CP 25 (35), *Revalidation of cryogenic static storage tanks,* provides guidelines for the periodic revalidation of cryogenic liquid storage tanks which can be incorporated into either the Written Schemes of Examination under the PSSR (7), or company maintenance and inspection programmes.

BCGA Leaflet 11 (47), *Safety checks for vacuum insulated storage tanks,* provides a simple user guide to daily safety checks which should be carried out on vacuum insulated storage tanks.

BCGA Leaflet 12 (48) is a simple user guide that advises users and owners of liquid gas storage tanks on their legal responsibilities and duty of care to ensure that the equipment is maintained and operated safely.

8. TRAINING

8.1 Training of personnel

All personnel directly involved in the commissioning, operation and maintenance of liquid cryogenic storage systems shall be fully informed regarding the hazards associated with cryogenic gases and properly trained as applicable to operate or maintain the equipment.

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 gases.

(ii) Site safety regulations.

(iii) Emergency procedures.

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

(v) First aid treatment for cryogenic burns.

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.

8.2 Emergency procedures

Emergency procedures shall be prepared by the user to cover the eventuality of a spillage of liquid cryogenic gases so that persons likely to be affected shall know the actions required to minimise the adverse effects of such spillage.

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 liquid spillage has been isolated, oxygen enrichment / depletion checks should be carried out in any enclosed areas where the vapour cloud may have entered. This includes basements, pits and confined spaces.

9. REFERENCES

1.	SI 1992 No.1978	The Food Additives Labelling Regulations 1992
2.	SI 1996 No. 341	The Health & Safety (Safety Signs and Signals). Regulations 1996.
3.	SI 1997 No. 1713	The Confined Spaces Regulations 1997
4.	SI 1998 No. 2306	The Provision and Use of Work Equipment Regulations 1998.
5.	SI 1999 No. 2001	The Pressure Equipment Regulations 1999.
6.	SI 1999 No. 743	The Control of Major Accident Hazards Regulations 1999 (COMAH).
7.	SI 2000 No. 128	The Pressure Systems Safety Regulations 2000.
8.	SI 2002 No. 2776	The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR).
9.	SI 2005 No. 1541	The Regulatory Reform (Fire Safety) Order 2005.
10.	SI 2009 No. 716	The Chemicals (Hazard Information and Packaging for Supply) Regulations 2009. (CHIP 4) CHIP 4 brings national legislation into line with the transitional arrangements set out in European Regulation (EC) No 1272/2008 on Classification, Labelling and

		Packaging of Substances and Mixtures – known as the CLP Regulation.
11.	United Nations	Model Regulations on the Recommendations on the Transport of Dangerous Goods.
12.	EC Regulation No 1907/2006	Registration, Evaluation, Authorisation and restriction of CHemicals (REACH).
13.	HSE L136	DSEAR Approved Code of Practice and guidance. Control and mitigation measures.
14.	HSE GN GS4	Safety requirements for pressure testing.
15.	HSE HSG 191	Emergency Planning for major accidents. COMAH Regulations 1999.
16.	BS 476	Fire tests on building materials and structures.
17.	BS EN 1991	Eurocode 1. Actions on structures. General actions. Wind actions.
18.	BS 5429	Code of Practice for safe operation of small-scale storage facilities for cryogenic liquids.
19.	BS ISO 7010	Graphical symbols. Safety colours and safety signs. Registered safety signs.
20.	BS 7786	Specification for unsintered PTFE tapes for general use.
21.	BS EN 13648	Cryogenic vessels. Safety devices for protection against excessive pressure.
22.	BS EN 60079 Part 14	Explosive atmospheres. Electrical installations design, selection and erection.
23.	BS EN 60529	Specification for degrees of protection provided by enclosures (IP code).
24.	BS IEC 60877	Procedures for ensuring the cleanliness of industrial process-measurement and control equipment in oxygen service.
25.	BS EN 62305	Protection against lightning.
26.	EIGA Document No. 04	Fire hazards of oxygen and oxygen enriched atmospheres.
27.	EIGA Document No. 24	Vacuum insulated cryogenic storage tank systems pressure protection devices.
28.	EIGA Document No. 33	Cleaning of equipment for oxygen service - guideline.

29.	EIGA Document No. 44	Hazards of inert gases and oxygen depletion.
30.	EIGA Document No. 115	Storage of cryogenic air gases at users' premises.
31.	EIGA Document No. 151	Prevention of excessive pressure during filling of cryogenic vessels.
32.	BCGA Code of Practice 20	Bulk liquid oxygen storage at production sites.
33.	BCGA Code of Practice 22	Bulk liquid argon or nitrogen storage at production sites.
34.	BCGA Code of Practice 23	Application of the Pressure Systems Safety Regulations 2000 to industrial and medical pressure systems installed at user premises.
35.	BCGA Code of Practice 25	Revalidation of cryogenic static storage tanks.
36.	BCGA Code of Practice 26	Bulk liquid carbon dioxide storage at users' premises.
37.	BCGA Code of Practice 27	Transportable vacuum insulated containers of not more than 1000 litres volume.
38.	BCGA Code of Practice 30	The safe use of liquid nitrogen dewars up to 50 Litres
39.	CGA Code of Practice 39	In-service requirements of pressure equipment installed at user premises.
40.	CGA Code of Practice 39, Module 1	In-service requirements of cryogenic storage system at user premises.
41.	BCGA Technical Report 1	A method for estimating the off-site risks from bulk storage of liquefied oxygen.
42.	BCGA Technical Report 2	The probability of fatality in oxygen enriched atmospheres due to spillage of liquid oxygen.
43.	BCGA Technical Report 3	Replacement substances for the cleaning of oxygen system components.
44.	BCGA Guidance Note 2	Guidance for the storage of gas cylinders in the workplace.
45.	BCGA Guidance	Reduced oxygen atmospheres. The management of risk

	Note 11	associated with reduced oxygen atmospheres resulting from the use of gases in the workplace.
46.	BCGA Guidance Note 13	DSEAR Risk Assessment.
47.	BCGA Leaflet 11	Safety checks for vacuum insulated storage tanks.
48.	BCGA Leaflet 12	Liquid gas storage tanks: Your responsibilities.
49.	British Cryoengineering Society	Cryogenic Safety Manual. *Available through the British Cryogenics Council*

Further information can be obtained from:

UK Legislation	www.legislation.gov.uk
Health and Safety Executive	www.hse.gov.uk
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 British Cryogenics Council	http://bcryo.org.uk

HAZARDS FROM ASPHYXIATION

Nitrogen and argon may produce local oxygen-deficient atmospheres, which will produce asphyxia if breathed. This is especially true in confined spaces.

Atmospheres containing less than 18 % oxygen are potentially dangerous and entry into atmospheres containing less than 19.5 % is not recommended.

Atmospheres containing less than 10 % oxygen can cause brain damage and death.

Asphyxia due to oxygen deficiency is often rapid with no prior warning to the victim. A general indication of what is liable to happen in oxygen deficient atmospheres is given in Table 4. It should be appreciated that the reactions of some individuals can be very different from those shown.

Oxygen Content (Vol %)	**Effects and Symptoms** (at atmospheric pressure)
11-14	Diminution of physical and intellectual performance without person's knowledge.
8-11	Possibility of fainting after a short period without prior warning.
6-8	Fainting within a few minutes; resuscitation possible if carried out immediately.
0-6	Fainting almost immediate; death ensues; brain damage even if rescued.

Table 4: The effects of oxygen deficiency

The victim may well not be aware of the asphyxia. If any of the following symptoms appear in situations where asphyxia is possible and breathing apparatus is not in use, immediately move the affected person to the open air, following up with artificial respiration if necessary.

(i) Rapid and gasping breathing.
(ii) Rapid fatigue.
(iii) Nausea.
(iv) Vomiting.
(v) Collapse or incapacity to move.
(vi) Unusual behaviour.

Attempts to rescue affected persons from confined spaces or where oxygen deficient atmospheres may be present should only be made by persons trained in the use of breathing apparatus and confined space entry procedures.

Further details of the hazards of asphyxiation can be found in BCGA GN 11 (45).

HAZARDS FROM OXYGEN ENRICHMENT

Fire hazards from oxygen enrichment

Oxygen reacts with most elements. The initiation, speed, vigour and extent of these reactions depend in particular upon:

(i) The concentration, temperature and pressure of the reactants.
(ii) Ignition energy and mode of ignition.

Reaction mechanism

The mechanism of these reactions is complicated and depends, among other things, upon the nature of the substances concerned, their physical state, geometric configuration, concentration and manner of ignition. This too influences the speed of reaction, which can vary from slow combustion to an explosion.

Combustibility of materials

Oxygen enrichment of the atmosphere, even by a few percent, considerably increases the risk of fire. Materials which do not burn in air, including fireproofing materials, may burn vigorously or even spontaneously in enriched air.

Combustion characteristics

Oxygen enrichment alters considerably the characteristics of combustion.

Materials ignite more easily and sparks which would normally be regarded as harmless can cause fire. The resulting flames are much hotter and are propagated at much greater speed.

Hydrocarbon oils and grease

Oil and grease are particularly hazardous in the presence of oxygen as they ignite spontaneously and burn with explosive violence. They should NEVER be used to lubricate oxygen or enriched air equipment. Special lubricants with which oxygen can be used under certain conditions are available.

Smoking

Burning accidents, that occur, are often started by the lighting of a cigarette. Therefore it is impossible to over-emphasise the danger of smoking in oxygen-enriched atmospheres or where oxygen enrichment can occur. In all such areas smoking shall be forbidden.

MINIMUM SAFETY DISTANCES

Explanatory notes
The following descriptors are used in the safety distance diagrams, with examples of the risks.

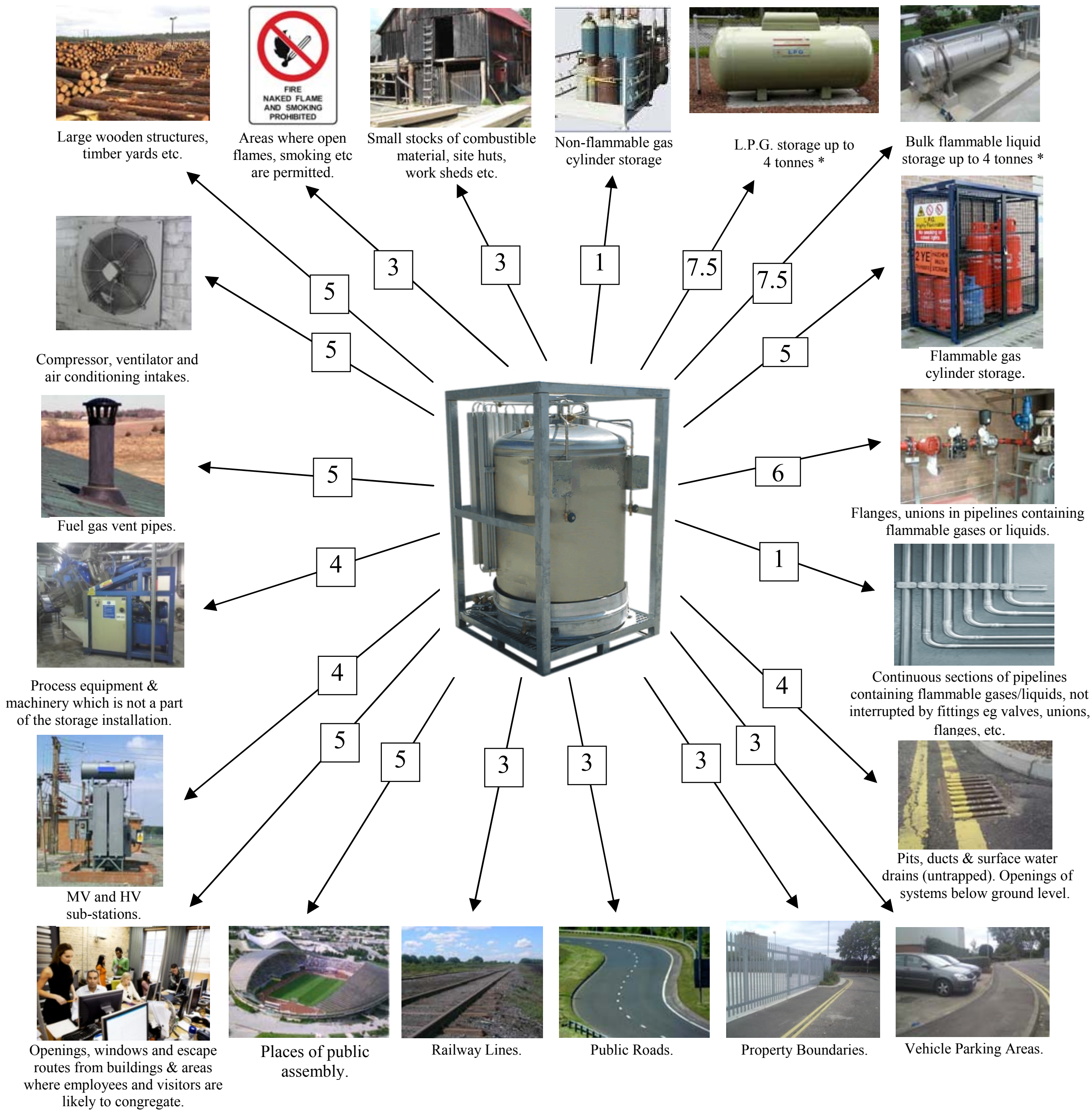
Descriptors	Liquid oxygen	Liquid inert gases
Large wooden structures, timber yards etc.	Spontaneous combustion from leaking product. Thermal radiation from fire.	Thermal radiation from fire.
Compressor, ventilator and air conditioning intakes.	Compressor - Spontaneous combustion from leaking product. Ventilator and air conditioning intakes – oxygen enriched atmosphere from leaking product, increased fire risk and danger to personnel. Embrittlement of equipment.	Ventilator and air conditioning intakes – oxygen deficient atmosphere from leaking product and danger to personnel. Embrittlement of equipment.
Fuel gas vent pipes.	Spontaneous combustion from leaking product. Thermal radiation from fire.	Thermal radiation from fire.
Process equipment & machinery which is not a part of the storage installation.	Spontaneous combustion from leaking product. Malfunction / contamination from leaking product entering process equipment. Embrittlement of equipment.	Malfunction / contamination from leaking product entering process equipment. Embrittlement of equipment.
Medium Voltage (MV) and High Voltage (HV) sub-stations.	Spontaneous combustion from leaking product. Embrittlement of equipment. Thermal radiation from fire.	Embrittlement of equipment. Thermal radiation from fire.
Openings, windows and escape routes from buildings & areas where employees and visitors are likely to congregate.	Oxygen enriched atmosphere from leaking product, increased fire risk, danger to personnel. Thermal radiation from fire.	Oxygen deficient atmosphere from leaking product, danger to personnel. Thermal radiation from fire.
Places of public assembly.	Oxygen enriched atmosphere from leaking product, increased fire risk, danger to personnel.	Oxygen deficient atmosphere from leaking product, danger to personnel.
Railway Lines.	Oxygen enriched atmosphere from leaking product, increased fire risk. Embrittlement of equipment.	Oxygen deficient atmosphere from leaking product. Embrittlement of equipment.

Public roads.	Oxygen enriched atmosphere from leaking product, increased fire risk, danger to personnel. Embrittlement of equipment. Reduced visibility from major product release.	Oxygen deficient atmosphere from leaking product, danger to personnel. Embrittlement of equipment. Reduced visibility from major product release.
Property boundaries	Oxygen enriched atmosphere from leaking product, increased fire risk, danger to personnel. Embrittlement of equipment. Reduced visibility from major product release.	Oxygen deficient atmosphere from leaking product, danger to personnel. Embrittlement of equipment. Reduced visibility from major product release.
Vehicle parking areas.	Spontaneous combustion from leaking product. Ventilator and air conditioning intakes – oxygen enriched atmosphere from leaking product, increased fire risk, danger to personnel. Embrittlement of equipment. Reduced visibility from major product release. Accessibility to the tank controls.	Ventilator and air conditioning intakes – oxygen deficient atmosphere from leaking product, danger to personnel. Embrittlement of equipment. Reduced visibility from major product release. Accessibility to the tank controls.
Pits, ducts & surface water drains (untrapped). Openings of systems below ground level.	Spontaneous combustion from leaking product. Oxygen enriched atmosphere from leaking product, increased fire risk, danger to personnel. Embrittlement of equipment.	Oxygen deficient 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.	Embrittlement of equipment.
Flanges, unions in pipelines containing flammable gases or liquids.	Spontaneous combustion from leaking product. Thermal radiation from fire. Embrittlement of equipment.	Thermal radiation from fire. Embrittlement of equipment.

Flammable gas cylinder storage.	Spontaneous combustion from leaking product. Thermal radiation from fire. Embrittlement of equipment.	Thermal radiation from fire. Embrittlement of equipment.
Bulk flammable liquid storage up to 4 tonnes.	Spontaneous combustion from leaking product. Thermal radiation from fire. Embrittlement of equipment.	Thermal radiation from fire. Embrittlement of equipment.
LPG storage up to 4 tonnes.	Spontaneous combustion from leaking product. Thermal radiation from fire. Embrittlement of equipment.	Thermal radiation from fire. Embrittlement of equipment.
Non-flammable gas cylinder storage.	Embrittlement of equipment.	Embrittlement of equipment.
Small stocks of combustible material, site huts, work sheds etc.	Spontaneous combustion from leaking product. Thermal radiation from fire.	Thermal radiation from fire.
Areas where open flames, smoking etc are permitted.	Spontaneous combustion from leaking product. Oxygen enriched atmosphere from leaking product, increased fire risk, danger to personnel.	Oxygen deficient atmosphere from leaking product, danger to personnel.

Safety Distance between oxygen tanks up to 2,000 litres water capacity and typical hazards.

Distances in metres

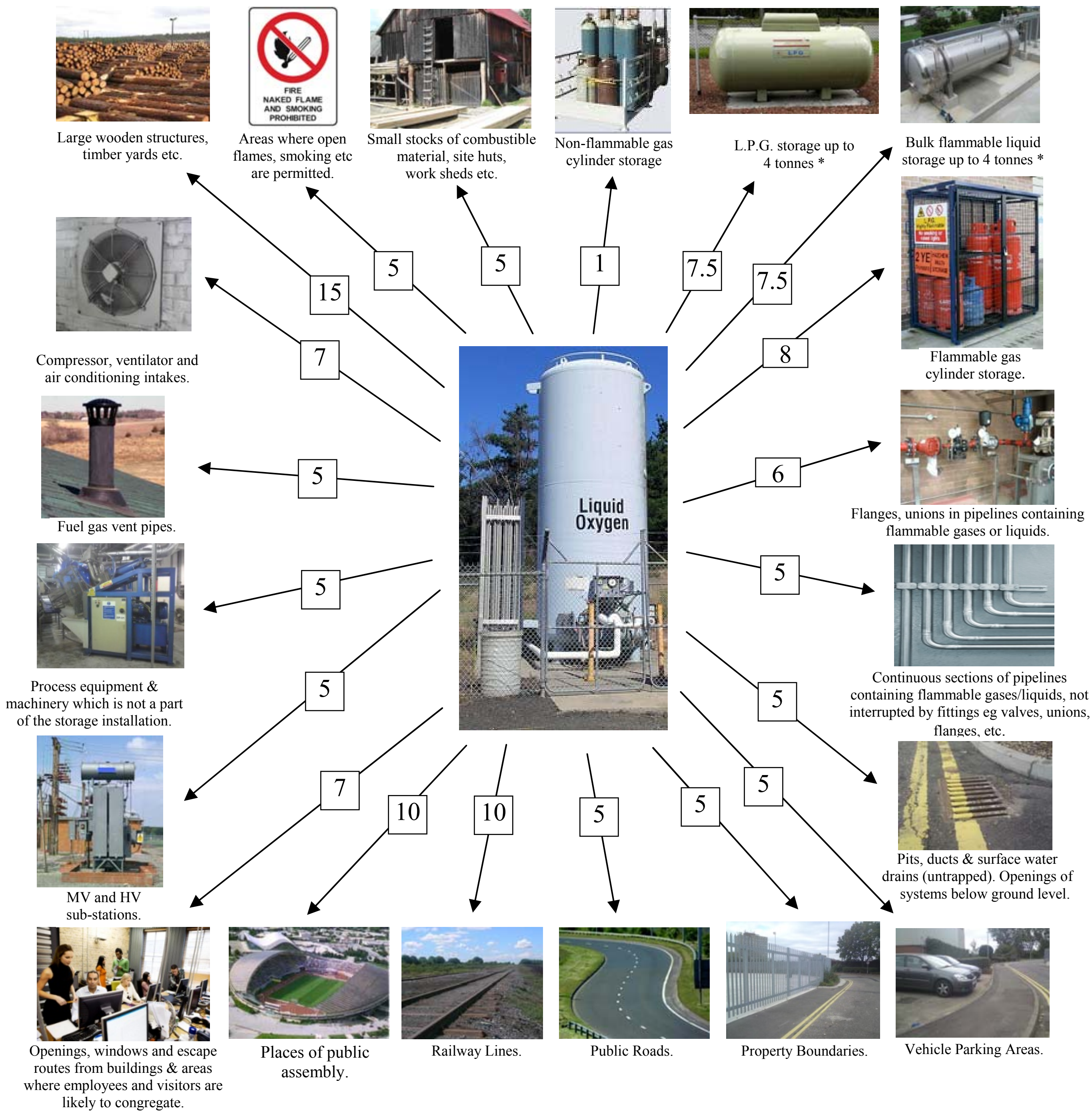


NOTE: Assumed maximum oxygen liquid phase pipework diameter DN 15 (1/2″ nominal bore) and flammable gas / liquid pipe up to DN25 (1″ nominal bore).

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

Distance between oxygen tanks from 2,000 litres to 20,000 litres water capacity and typical hazards.

Distances in metres

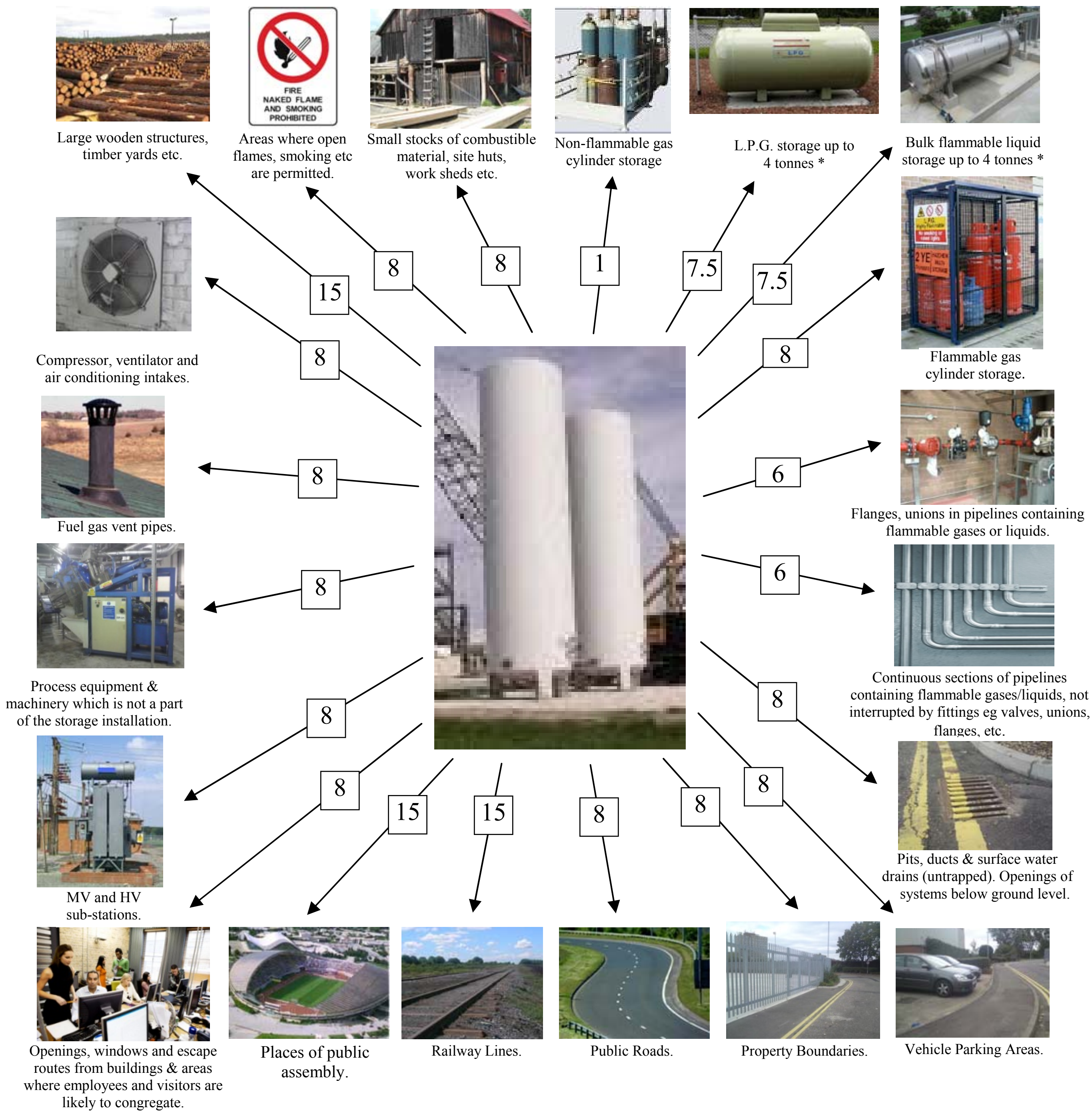


NOTE: Assumed maximum oxygen liquid phase pipework diameter DN 40 (1½″ nominal bore) and flammable gas / liquid pipe up to DN25 (1″ nominal bore).

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

Distance between oxygen tanks from 20,000 litres up to 125,000 litres water capacity and typical hazards.

Distances in metres

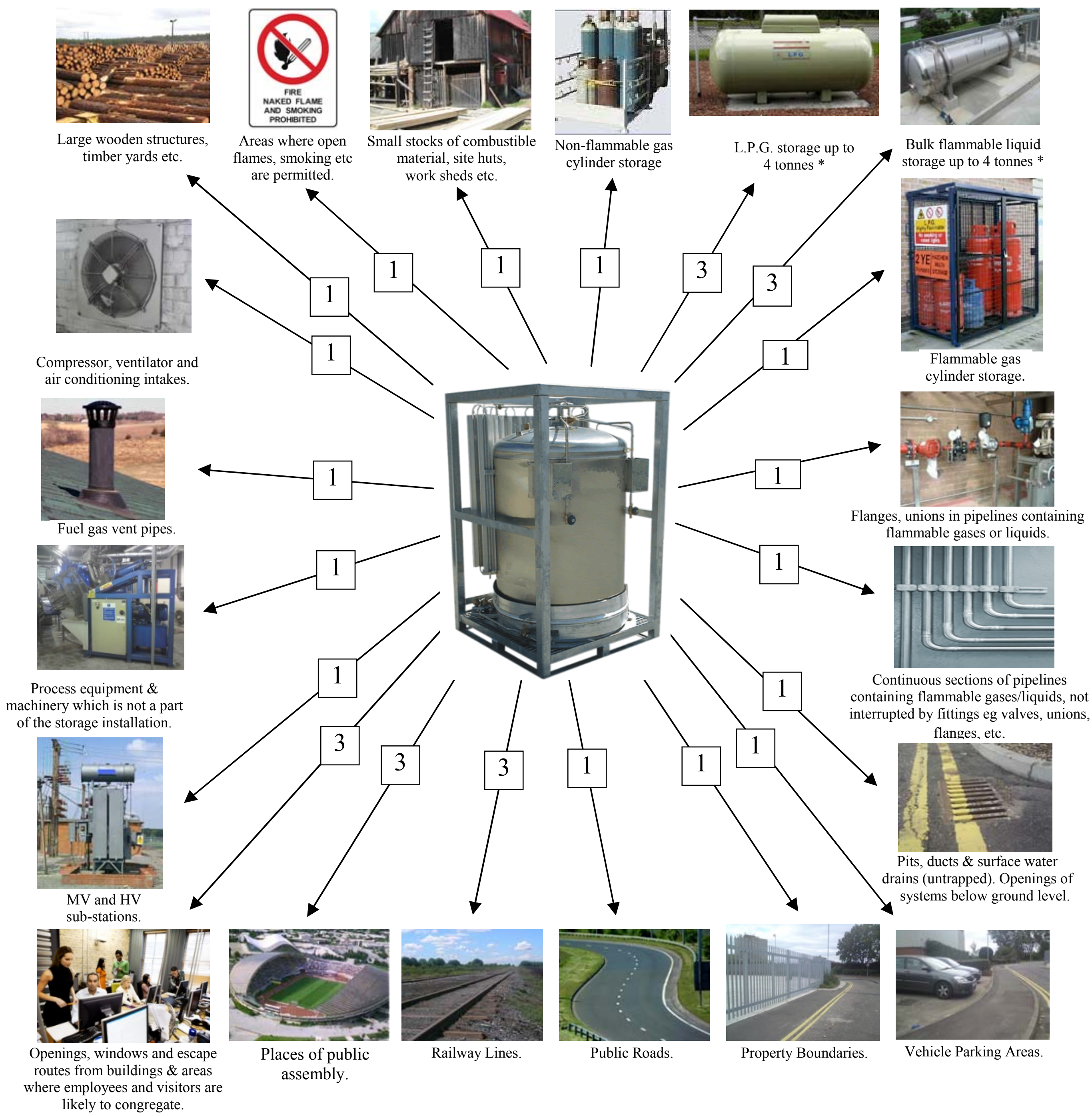


NOTE: Assumed maximum oxygen liquid phase pipework diameter DN 40 (1½″ nominal bore) and flammable gas / liquid pipe up to DN25 (1″ nominal bore).

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

Distance between nitrogen, argon and helium tanks up to 2,000 litres water capacity and typical hazards.

Distances in metres

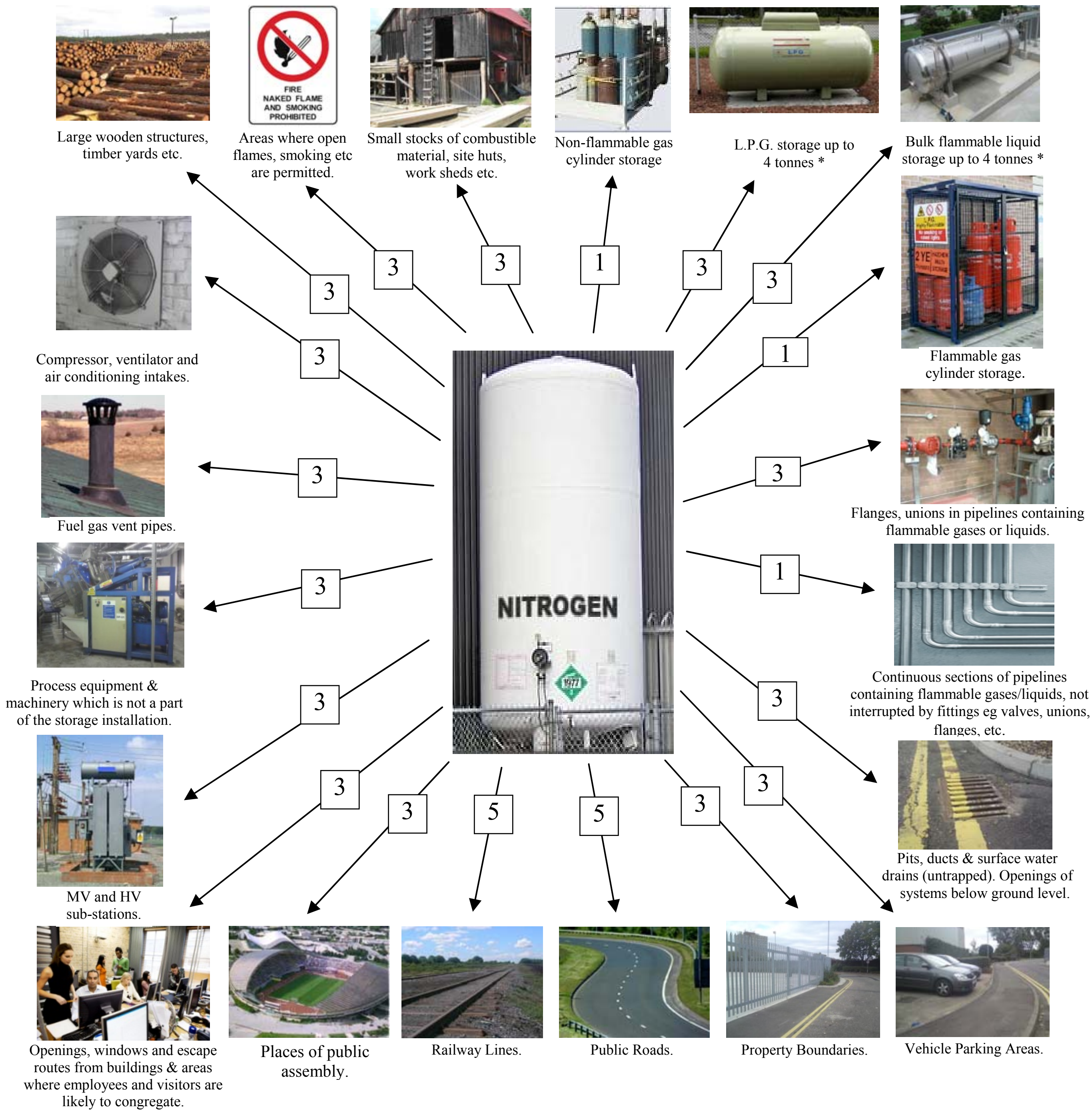


NOTE: Assumed maximum liquid phase pipework diameter DN 15 (1/2″ nominal bore) and flammable gas / liquid pipe up to DN25 (1″ nominal bore).

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

Distance between nitrogen, argon and helium tanks from 2,000 litres to 125,000 litres water capacity and typical hazards.

Distances in metres



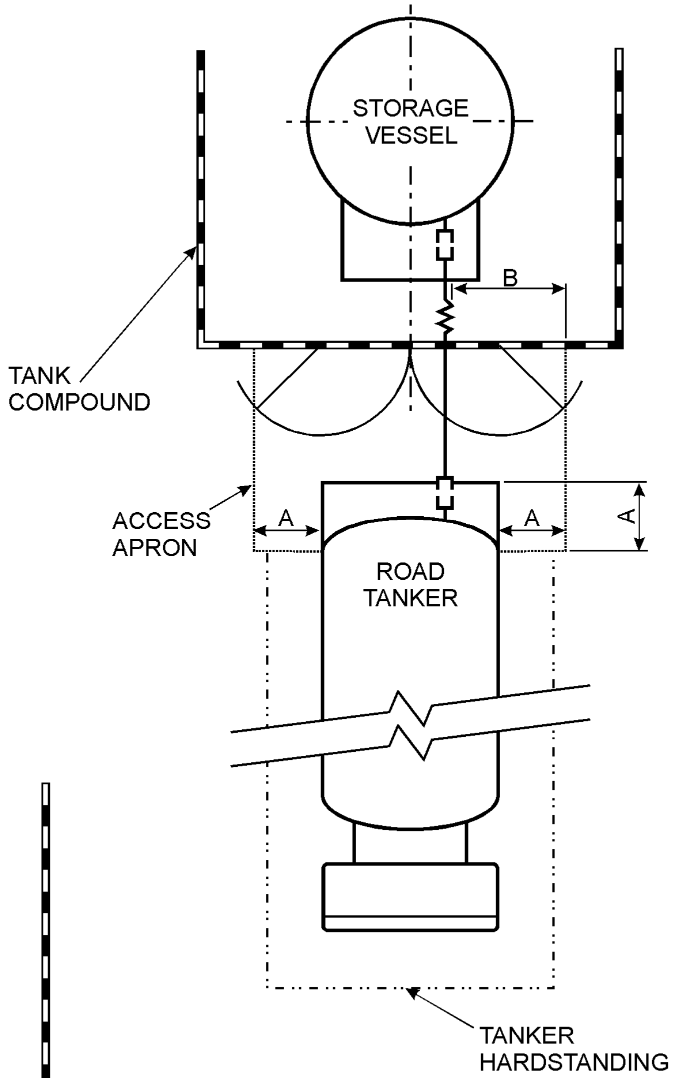
NOTE: Assumed maximum liquid phase pipework diameter DN 50 (2″ nominal bore) and flammable gas / liquid pipe up to DN25 (1″ nominal bore).

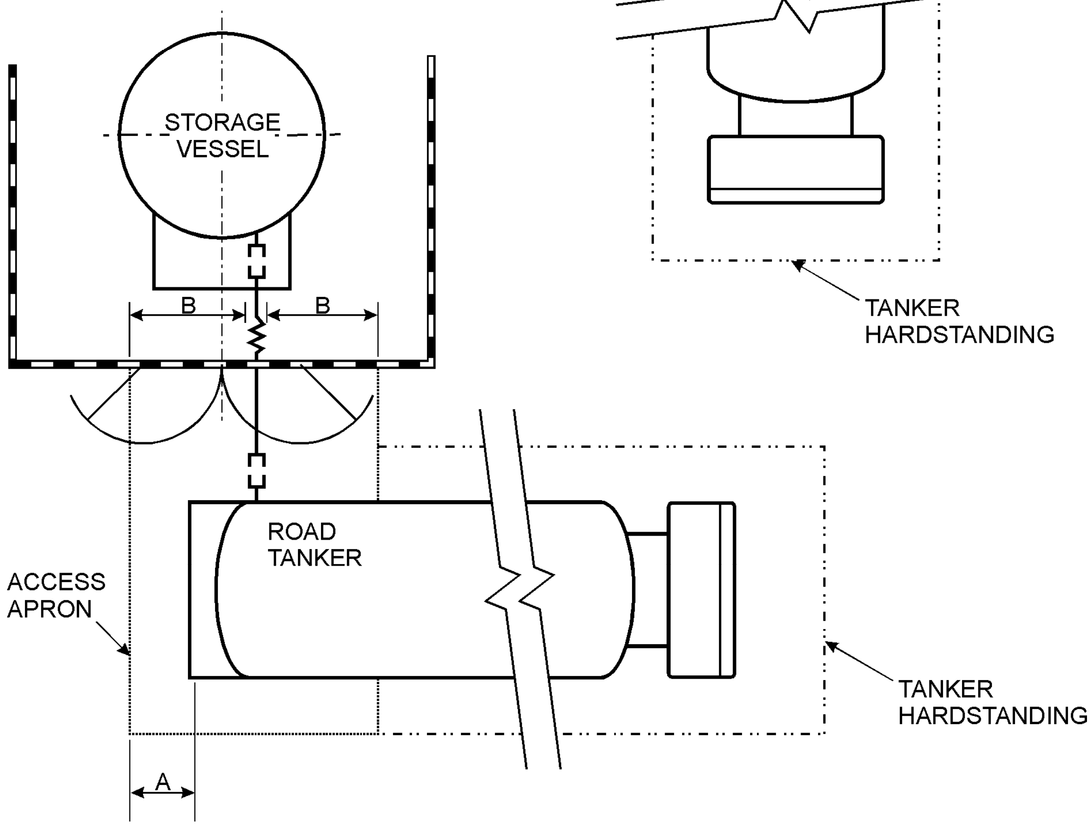
* For LPG or flammable liquid tanks above 4 tonnes a risk assessment shall be carried out to establish the safe separation distance.

PLAN VIEW OF 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 non-porous material.





"BURNS" DUE TO VERY COLD LIQUEFIED GASES

The temperature of liquefied gases varies. The boiling points, i.e. the temperatures at which the liquefied gas vaporises, are detailed in Table 5.

Oxygen	-183 ^{o}C
Argon	-186 ^{o}C
Nitrogen	-196 ^{o}C
Helium	-269 ^{o}C

Table 5: Liquefied gas temperatures

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 becomes 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 liquids 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 uninsulated 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. There usually is sufficient warning by local pain whilst the freezing action is taking place. Re-warming with lukewarm water at 42 ^{o}C to 44 ^{o}C (107 ^{o}F to 111 ^{o}F) is generally 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 CONTACT 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; (295 K)). 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.

NOTE: The above text has been reproduced with the permission of the British Cryoengineering Society from its “Cryogenics Safety Manual” (49).

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, application etc.

Ventilation can be natural or provided by forced ventilation. 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 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.

For handling (storing, filling, withdrawal, etc.) transportable 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 etc. 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. The density of the gas should also be taken into consideration (the main opening at the highest point of the location for gases lighter than air, or at ground level for gases heavier than air).

For more than 2 changes per hour a forced ventilation system is necessary. Different regulations may recommend or require for different situations a specific number of air changes per hour, e.g. 5, 10, 20 etc.

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:

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

For long periods (t tending to infinity):

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

Where:

Ct	=	Oxygen concentration after defined time
C_∞	=	Oxygen concentration after long periods (days)
L	=	Gas release rate, m^3/h
Vr	=	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	=	$\frac{Vr}{L + n\,Vr}$

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 oxygen concentration in the room may then be calculated from the following formula:

$$Cox = \frac{100 \text{ x } Vo}{V_R}$$

Where:

Cox	=	Resulting oxygen concentration, %
V_R	=	The volume of free air in the workplace, m^3 (volume of workplace less volume of solid objects)
V_O	=	The volume of oxygen, m^3

For asphyxiant gases:

V_O = 0.21 (V_R − Vg)

For oxygen:

V_O = 0.21 (V_R - Vg) + Vg

Vg	=	Maximum gas release, m^3	
	=	Liquid volume capacity of the vessel (m^3) x gas expansion factor, fg	
fg	=	Carbon dioxide	543
	=	Nitrous oxide	665
	=	Nitrogen	683
	=	Helium	739
	=	Argon	824
	=	Oxygen	842

Worked example

Calculate the oxygen concentration resulting from spilling 50 litres of liquid oxygen into a room of 300 m^3 volume:

V_R = Room volume
= 300 m^3

Vg = Gas release from vaporised liquid

$$= \frac{50}{1000} \times 842$$

= 42 m^3

Vo = Volume of oxygen
= 0.21 (V_R - Vg) + Vg
= 0.21 x (300 - 42) + 42
= 96.2 m^3

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

$$= \frac{100 \times 96.2}{300}$$

= 32.1 %

British Compressed Gases Association
www.bcga.co.uk