BCGA GUIDANCE NOTE 11

REDUCED OXYGEN ATMOSPHERES

The management of risk associated with reduced oxygen atmospheres resulting from the use of gases in the workplace

Revision 3: 2012

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.

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* Throughout this publication the numbers in brackets refer to references in Section 8. Documents referenced are the edition current at the time of publication.

TERMINOLOGY AND DEFINITIONS

Confined space
: Any place, including room, chamber, tank, vat, silo, pit, trench, pipe, sewer, flue, well, or other similar space in which, by virtue of its enclosed nature, there arises a reasonably foreseeable specified risk.

It has two defining features:

1. It is a place which is substantially, (though not always entirely) enclosed.
2. There will be a reasonably foreseeable risk of serious injury from; flammable or toxic atmosphere, oxygen deficient or enriched oxygen atmosphere.

This document ONLY addresses the hazards of a reduced level of oxygen within the space or nearby.

Gas
: The volatile state of a substance, with no definite shape or volume of its own. References to gas in this publication can also mean gases.

Gas density
: Mass per unit volume for a gas at specified temperature and pressure. Refer to table at the end of document or Safety Data Sheet.

Gas expansion ratio
: Liquid to gas volume expansion conversion – volume of gas generated from 1 volume of liquid.

Flammable gas
: Any gas that will burn in the presence of oxygen. A gas whose combustible or flammable properties make it suitable for heating, welding or cutting. These gases can also have other uses, e.g. butane as a propellant etc.

Hazard
: Any substance, condition or equipment that has the potential to cause harm to an individual or the environment.

Inert gas
: A gas that is neither toxic nor flammable, which does not support human life and which reacts scarcely or not at all with other substances.

Liquefiable gas
: A gas that can be liquefied by pressure at ambient temperature e.g. carbon dioxide, propane.

May
: Indicates an option available to the user of this Guidance Note.

Permanent gas
: A gas that cannot be liquefied by pressure at ambient temperature.

Reduced oxygen atmosphere — Is one where the level of oxygen is reduced (or depleted) below the normal concentration in air i.e. approximately 21 %.

Risk — The risk associated with any particular "hazard" is commonly defined as the "likelihood" (or probability) of the hazard condition arising multiplied by "a measure of the potential consequences", e.g. injury or death.

Risk assessment — A formal assessment of a workplace or operation, performed in order to identify hazards and evaluate the extent of risk presented by the hazard, for the purpose of either eliminating the risk or establishing suitable controls to reduce the risk to an acceptable level.

Shall — Indicates a mandatory requirement for compliance with this Guidance Note.

Should — Indicates a preferred requirement but is not mandatory for compliance with this Guidance Note.

Toxic gas — Any gas that, by nature of its chemistry, has a harmful effect on humans. This includes gases that may be harmful due to their corrosive properties.

Workplace — Any premises, part of a premises or area that is made available to any person as a place of work and includes:

1. Any place within the premises to which such person has access while at work; and
2. Any room, lobby, corridor, staircase etc. where facilities are provided for use in connection with the workplace.

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REDUCED OXYGEN ATMOSPHERES

The management of risk associated with reduced oxygen atmospheres resulting from the use of gases in the workplace

1. SCOPE

This document provides guidance that can be used in the assessment of risk associated with the use of gases in the workplace, on appropriate control measures to be considered at any workplace where gases are commercially produced, stored or used and, to identify where reduced oxygen atmospheres could occur. This document is not intended to provide guidance on the control of work in areas defined as "confined spaces", including hypoxic air environments.

Accidents due to reduced oxygen atmospheres occur unexpectedly and the reactions of people in the workplace may be incorrect. Furthermore, when such an accident does occur, it is always serious, and sometimes fatal.

This document does not consider in detail other gas properties such as flammability, toxicity, etc, which are referenced where appropriate to draw attention to the possibility that these properties may present a greater danger than oxygen depletion. However, it should be noted that all gases, other than oxygen or air, may result in asphyxiation. Other hazards associated with the use of the gases, such as pressure, manual handling, storage etc. are not discussed in this document.

2. GENERAL

Gases may enter the workplace through a variety of means, e.g. gas from cylinders, dewars or other cryogenic containers, pressure vessels, dry ice containers, pipelines. In order to review the hazard presented by these gases one needs to consider the various methods and mechanisms of release from these gas sources:

2.1 Normal release during storage.

(i) Evaporation directly from non-pressurised cryogenic containers, e.g. dewars and biostore freezers.

(ii) Gaseous release from excess pressure control devices fitted to pressurised cryogenic containers.

(iii) Dry ice sublimation.

2.2 Normal release during use of the gas.

(i) Liquid container filling.

(ii) Welding (shielding and purge gas venting).

(iii) Purging or gas blanketing.

(iv) Chilling and freezing operations.

(v) Gases remaining after emptying or purging a tank or vessel.

(vi) Combustion processes (e.g. gas welding and cutting; localised / workplace heating / mobile heaters) will consume atmospheric oxygen as well as using the oxygen supply from the cylinder or pipeline and the products of combustion may include carbon dioxide and carbon monoxide. These processes should be carried out in a well-ventilated workplace.

2.3 Unintentional release from:

(i) Leaking pipework, valves, etc.

(ii) Bursting discs and tank relief valves.

(iii) Liquid gas / dry ice spillage.

(iv) Instrument gas systems which use inert gas(es).

In assessing the risk of oxygen depletion in the workplace it should be noted that mechanisms other than the use and storage of gases may result in depleted oxygen atmospheres. These mechanisms may include biological action (fermentation, decomposition) and chemical action (combustion, rusting).

There are also workplaces where the use of a controlled, low-oxygen maintained atmosphere is required. An example being a Hypoxic Fire Suppression System, designed to maintain a low oxygen environment to reduce the risk of fire by providing conditions where common materials cannot ignite or burn due to a lack of oxygen. The atmosphere in these environments typically contains approximately 15 % oxygen and 85 % nitrogen by volume. Where such systems are in use the oxygen deficient atmosphere is a significant physiological hazard for humans. Risk assessment, the use of control systems to provide a safe atmosphere as well as health assessment and related controls are required to ensure people occupying these spaces are safe. Refer to EIGA Safety Information Sheet 29 (9).

2.4 The effects of a reduced oxygen atmosphere.

Oxygen is the only gas that supports life. The normal concentration in the air that we breathe is approximately 21 %.

If the oxygen concentration in the workplace atmosphere decreases there is an increase in the degree of hazard and potentially an increased risk of asphyxiation.

Any depletion of oxygen concentration below 21 % should be regarded with concern and fully investigated:

(i) As a minimum the oxygen concentration in the workplace should be maintained above 19.5 %.

(ii) Atmospheres containing less than 18 % oxygen are potentially dangerous and entry into such areas must be prohibited unless appropriate safety controls are adopted.

(iii) The risk of unconsciousness followed by brain damage or death due to asphyxia is greatly increased at oxygen concentrations below 10 %.

(iv) Immediate loss of consciousness occurs with less than 6 % of oxygen.

(v) Inhalation of only 2 breaths of nitrogen, or other inert gas containing no oxygen, causes immediate loss of consciousness and death within 2 minutes.

NOTE: Where the ambient pressure varies significantly from normal atmospheric pressure, for example in diving or mining activities, the calculation of safe oxygen concentration must take this into account. For advice on this topic it is recommended that the gas supplier be contacted.

The likelihood of a reduced oxygen atmosphere occurring in the work place is dependent upon many factors including:

(a) The volume of free air within the work place.

(b) The workplace ventilation and air circulation rates.

(c) The properties of the gas being used in or escaping into the work place – density.

(d) Liquid / gas expansion ratio, etc.

(e) Volume of the gas released.

(f) The rate at which the gas is released.

Knowing the density of the gas relative to air will suggest where the gas may accumulate, e.g. a gas with a density greater than air will tend to fall and collect in the lower areas of the workplace. In addition, it should be remembered that the temperature of a gas will affect it's density such that gases normally regarded as being lighter than air may in fact be heavier than air when very cold, i.e. cold gases may initially accumulate in low lying areas.

It should be noted that where cryogenic liquids are used, large volumes of gas are produced from small quantities of liquid as the liquid evaporates. For example, 1.5

litres of liquid nitrogen can reduce the oxygen concentration within a typical lift (1.5 m x 1.5 m x 2.5 m) to below 18 %. Expansion ratios from liquid to gas are typically of the order of 1:700; the specific expansion ratio for the gas to be assessed should be established from the safety data sheet in order to make a proper assessment.

Properties of some common gases are given in the Table of Properties shown in Appendix 2.

3. CALCULATIONS FOR DETERMINING THE POTENTIAL DEPLETION OF OXYGEN OR ACCUMULATION OF GASES IN THE WORKPLACE

The calculations detailed below are used as illustrations to demonstrate the potential of an asphyxiation hazard arising when using, or storing, gases in the workplace. The methods assume uniform distribution of the gas within the workplace atmosphere and consequently can under-estimate the actual degree of hazard. It is, therefore, essential that all assessments are carried out by a competent person and in particular that they consider the possibility of a localised accumulation of gas.

Some gases have other hazardous properties, e.g. toxicity which can cause acute or chronic ill health, or flammability which may give rise to an explosive atmosphere. These hazards may be relevant at concentrations much lower than those which cause an asphyxiant atmosphere (refer to Appendix 1 for examples). The safety data sheet should be checked to identify hazards other than asphyxia and the concentrations at which the hazard becomes dangerous. Where such hazards are identified, an assessment should be conducted to establish whether asphyxia or the other hazard represents the greater risk.

3.1 Calculations

Calculations 1a & 1b below assume all the gas is instantly and uniformly released into the workplace. Calculation 2 establishes the concentration over time for a sustained gas release. None of the calculations makes any allowance for variable gas concentrations through the workplace and local oxygen concentrations could therefore be lower than that calculated.

Where more than one gas is being used in the workplace, a separate assessment should be made for each gas to quantify the individual levels of risk and a common assessment should be made to establish the total cumulative risk. In most circumstances the cumulative risk is not the sum of the individual risks, unless the failure of one system causes the failure of others or hazardous events occur simultaneously.

Calculation 1a or 1b should be performed to establish the potential of a reduced oxygen atmosphere in the workplace resulting from the displacement of oxygen by the sudden release of all available gases e.g. all of the gases from within the room or piped in from an external source such as an outside bulk storage tank or gas store. If it is not reasonably foreseeable that all of the gas will be suddenly released into the workplace Calculation 2 should be performed to establish the consequence from a sustained release through normal use or accident.

If the result of the first calculation shows the oxygen concentration to be maintained at or above 19.5 % then there is no requirement to perform Calculation 2. However, appropriate control measures should be employed as identified by the risk assessment. Any change to the workplace conditions, e.g. increased gas volumes, reduction of free-air volume, etc. will require the risk assessment to be reviewed.

Where the calculations identify the potential for the creation of an unsafe atmosphere, steps should be taken to eliminate or reduce the level of risk to as low a level as is reasonably practicable. The measures taken will depend upon the extent of the hazard as well as the type of workplace. In all cases the hierarchy of controls should always be applied. Regardless of the result of this calculation, all employees who work within a workplace where gases are used or stored should receive appropriate health and safety information, instruction, training and supervision.

An emergency procedure for dealing with an unintentional gas release / ventilation system failure should be established and communicated to all affected persons.

3.2 Calculation 1a

For gas receptacles containing permanent gases excluding liquefiable gases

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

Where:

Cox = Resulting oxygen concentration

V_O = The volume of oxygen, m^3

= 0.21 (V_R − Volume of gas in cylinder)

V_R = The volume of free air in the workplace, m^3 (volume of workplace less volume of solid objects)

$$\text{Volume of gas in cylinder, m}^3 = \frac{\text{Water capacity of cylinder (litres) x Fill pressure (bar)}}{1000}$$

3.3 Calculation 1b

For receptacles containing liquefied gas or cryogenic liquids

$$C_{ox} = \frac{100 \times V_O}{V_R}$$

Where:

Cox	=	Resulting oxygen concentration
Vo	=	The volume of oxygen, m^3
	=	$0.21\ (V_R - V_G)$
VR	=	The volume of free air in the workplace, m^3 (volume of workplace less volume of solid objects)
VG	=	Maximum volume of gas at room temperature and pressure, m^3
	=	$\dfrac{\text{mass of liquid in cylinder / container, kg}}{\rho_g}$
	=	Volume of liquid in cylinder / container *, litres x F_g
ρ_g	=	Density of gas at room temperature and pressure, kg/m^3 (see table Appendix 2)
F_g	=	Gas expansion ratio (see table Appendix 2)

* When in doubt use the volume of the cylinder / container as a worst case.

3.4 Calculation 2

This method is used to establish the hazard resulting from a gradual release of product into the workplace, e.g. where an instantaneous release of all the available gases is unlikely to occur due to system design / method of use but where a build-up of an unsafe atmosphere can occur over a period of time.

The gas release rate under normal operating conditions, e.g. MIG / TIG welding, gas blanketing etc., must be taken as the maximum possible flow during operation.

To establish the gas release for an abnormal situation, e.g. a severed low-pressure hose, the gas release rate will be equal to the maximum flow achievable through the pressure-reducing valve. This figure should be obtained from the manufacturer of the pressure-reducing valve.

This equation gives the oxygen concentration after time t:

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

and for long periods (t tending to infinity):

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

Where:

C_t = Oxygen concentration after defined time

C_{∞} = Oxygen concentration after long periods (days)

L = Gas release rate, m^3/h

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

n = The number of workplace air changes per hour

t = Time, hours

e = 2.72

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

Multiplying the result from the above by 100 will express the oxygen concentration (C) as a percentage of the work place free air volume.

$$C_{\infty} \times 100 = C$$

Worked examples of the above methods are given in Appendix 1.

3.5 Pressurised cryogenic vessels used to supply gas

In addition to the gas released through the use point, gas may be released through the pressure safety devices fitted to the vessel. In the case of all static storage vessels the relief devices should be piped away to a safe external location. Due consideration shall be given to gas vented from pressure safety devices on portable storage vessels located in the workplace without provision for external exhaust. If gas is not being withdrawn from such vessels, or the withdrawal rate is less than the normal evaporation rate, the gas released through the pressure relief valve can equal the normal evaporation rate of the vessel as specified by the manufacturer.

NOTE: The evaporation rate will increase as the efficiency of the insulation deteriorates. It is, therefore, prudent to double the manufacturer's stated evaporation rate for the purposes of the risk assessment.

In addition to pressure relief valves portable cryogenic vessels are normally fitted with bursting discs. When these operate all the positive gas pressure in the vessel will be released. The volume of gas released will depend upon the quantity of liquid in the vessel and the pressure.

Consideration should also be given to the possible release of liquid product in to the workplace, which will lead to the formation of a large volume of gas, the consequence of which must be assessed.

3.6 Non-pressurised cryogenic tanks / dewars stored or used in the workplace

When filling dewars or flasks, approximately 10 % of the liquid transferred will evaporate. The volume of gas released will, therefore, be 10 % of the transferred liquid multiplied by the volume expansion ratio for the gas. Refer to BCGA CP 30 (10) for guidance on safe storage, filling and the use of dewars and flasks. Dewars and flasks are non-pressurised and therefore release gas directly into the workplace through normal evaporation whenever they contain liquid. The volume of gas released will be the normal evaporation rate of the dewar / flask specified by the manufacturer.

NOTE: The evaporation rate will increase as the efficiency of the insulation deteriorates. It is, therefore, prudent to double the manufacturer's stated evaporation rate for the purposes of the risk assessment. BCGA TIS 27 (11) provides a model risk assessment for the safe use of liquid nitrogen dewars.

Consideration should also be given to the accidental release or spillage of liquid product.

4. RISK REDUCTION - CONTROL MEASURES AND PREVENTIVE ACTION

The control measures taken to mitigate the effects of any particular hazard should follow the principles of the "hierarchy of controls", i.e. **ESRICPD**.

Eliminate the hazard, don't do it.
Substitute a different process, supply source or material that poses a lesser hazard.
Reduce the hazard by using less of it; lower pressure; less volume.
Isolate the hazard from the work area; a different room operated remotely; enclosure
Control the hazard by means of engineering controls; gas detectors linked to shutdown
Personal Protective Equipment used to protect the individual; breathing apparatus.
Documentation and procedures defining a safe system of work.

In this hierarchy the most effective and reliable means of control is at the top and least effective at the bottom.

4.1 Preventive measures

Preventive measures are the measures that will reduce the probability of an asphyxiating atmosphere developing. Preventive measures include the examples described in the following sections:

4.1.1 Preventing gases entering the workplace

Where possible gas should be prevented from entering the workplace unintentionally, this can be achieved by:

(i) Carrying out operations that use gases outside in the open air or in discrete areas isolated from the general workplace.

(ii) Where possible, store cylinders and tanks outside and pipe gas in to the workplace at the lowest possible pressure suitable for the operation.

(iii) Correct specification of gas / pressure equipment.

(iv) Regular maintenance (testing pressure equipment for leaks) and inspection of gas/pressure equipment.

(v) Ensuring that the gas exhausts from machines and pressure relief valves are vented externally.

(vi) Correct location and installation of gas equipment (refer to the relevant BCGA documents – Section 8).

4.1.2 Suitable locations for pressurised vessels

Whenever reasonably practicable pressurised vessels shall be sited externally in a well-ventilated area. Where a suitable external location is not reasonably practicable, vessels may be installed internally provided that the following minimum precautions are taken:

(i) The installation is within a space of adequate size such that when using Calculation 1 (see Section 3) the release of gas cannot produce an atmosphere with an oxygen concentration below 18 % or create an otherwise hazardous atmosphere, e.g. toxic or flammable.

(ii) The exhaust of the main vessel pressure relief valves, where applicable, are piped away to a fixed safe external location.

(iii) An additional pressure control device is fitted (at a setting less than safety valve setting) connected via the vent valve, with the gas directed to a safe area. The vent valve shall remain open when this measure has been adopted. Any additional gas vent lines shall also be piped to a safe area.

(iv) The storage area should be adequately signed and access restricted to trained, authorised, personnel. Where appropriate, additional control measures such as gas detectors and personal monitors should be used.

If it is necessary to have vessels installed internally then, locations must be well ventilated (forced or natural) and should be chosen in the following order of preference:

(a) At or above ground level sealed from other areas of normal occupancy.

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

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

(d) Below ground level sealed from other areas of normal occupancy.

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

To allow the tank to be filled remotely and vented in an emergency, the trycock / vent exhaust shall be piped away to a fixed, safe, external location that is visible from the fill connection.

In addition, the 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).

4.13 Workplace ventilation

If the prevention of gas release into the workplace is not practicable because of the process being undertaken e.g. inert gas welding, shrink fitting etc., the accumulation of gas should be prevented. This is achieved by providing appropriate ventilation either by localised forced extraction to an external location or ensuring the number of workplace air changes will prevent the accumulation of gas.

The key guidance on ventilation systems can be found in the Health and Safety Executive (HSE) guidance HSG 37 (6) and HSG 54 (7). Key aspects include:

(i) Gas detection and/or oxygen monitoring with visible alarm.

(ii) Indication that the ventilation system is working effectively.

(iii) Interlock arrangements between the gas supply and the ventilation system.

(iv) Gas exhaust lines should be clearly identified and piped to a safe, external, well-ventilated area.

Building size, ventilation capacity, system pressures etc. must each be determined for specific cases to which the following guidelines apply.

(a) Ventilation should be continuous or interlocked with the gas supply such that the ventilation system operates whenever gas is being supplied. Interlocks functionality should be checked routinely (The Control of Substances Hazardous to Health Regulations (COSHH) (4) require verification at least every 14 months).

(b) The ventilation system design should ensure adequate airflow around the normal operating area to prevent an asphyxiating atmosphere.

(c) Devices indicating the effective operation of the ventilation system (air flow) should be included in the design. Indicating devices may include:

- Warning lights.
- “Streamers” in the fan outlet.
- Audible alarm on failure.
- Flow switches in the suction channels (ideally, monitoring should not rely only upon secondary controls like “power on” to the fan motor).

(d) Gas exhaust lines should be clearly identified and piped to a safe, external, well-ventilated area.

4.2 Control measures

Control measures are the measures that will:

(i) Assist in ensuring people do not enter or remain in areas where an asphyxiating atmosphere may exist in the absence of preventative measures.

(ii) Warn of the development of an unsafe atmosphere.

And include:

4.2.1 Gas detection / oxygen depletion monitoring equipment

If preventative measures are not practicable or an additional level of safety is required, appropriate gas detection or monitoring equipment that incorporates warning alarms should be considered to test the workplace atmosphere before entry and during occupancy. Fixed equipment is preferable to personal equipment, as this will protect people in the workplace. Attention must be drawn to the fact that a gas detector / monitor alone does not provide absolute protection, since such equipment can malfunction, be unexpectedly out of calibration or be incorrectly positioned. Testing of oxygen content should therefore, be considered only as an aid to the detection of unsafe atmospheres. The following provides some guidance on the selection of appropriate equipment.

Before detector / monitoring equipment is specified the site shall be assessed to establish what gases present a hazard, the level of risk involved, where the gases may originate from and accumulate to (taking into consideration the properties of the gas) and an appropriate location for the detector / monitor measurement head. Where a gas is present that presents an additional hazard (e.g. toxicity or flammability) at concentrations lower than that which causes oxygen depletion a detector for that gas AND an oxygen depletion monitor should be used to test the atmosphere before entry. The workplace atmosphere shall be checked for the most hazardous gas first.

The selection of the type of apparatus depends upon the nature of the work in the place to be monitored (presence of dust, temperature and humidity, high magnetic fields, multiple detectors, portable equipment etc.).

Oxygen depletion monitors should be considered in a workplace where a significant risk of depleted oxygen levels has been identified. Gas detector / monitor displays and warning signs shall be sited so that they are clearly visible to personnel before entering the affected area. Detection equipment should be subject to a formal planned maintenance schedule that includes the calibration of detectors, alarm and interlock checks, the routine replacement of components.

4.2.2 Special Control Measures for Confined Spaces

All workplaces should be subject to a full risk assessment. Any workplace designated as a "confined space" as a result of this process should be suitably signed and subject to specific control measures before entry.

A confined space can be any space of an enclosed nature where there is a risk of death or serious injury from hazardous substances or dangerous conditions (e.g. lack of oxygen, build up of toxic or flammable gas). As part of their normal work it may be necessary for employees to enter a workplace environment that has been designated as a "confined space".

Some confined spaces are fairly easy to identify, e.g. enclosures with limited openings:

- Storage tanks;

- Silos;
- Reaction vessels;
- Enclosed drains;
- Sewers.

Others may be less obvious, but can be equally dangerous, for example:

- Open-topped chambers;
- Vats;
- Combustion chambers in furnaces etc.;
- Ductwork;
- Unventilated or poorly ventilated rooms;
- Spaces not designed for continuous worker occupancy.

It is not possible to provide a comprehensive list of confined spaces. Some places may become confined spaces when work is carried out, or during their construction, fabrication or subsequent modification. However, it is important to note that even a large open topped vessel may represent a hazard, i.e. if it has contained an inert gas denser than air it may contain an unsafe atmosphere below the level of the vessel wall that will not be removed by natural ventilation. (e.g. tank bunds etc.). Care should be taken not to lean into such spaces.

Specific control measures that may be employed before entering a confined space are:

(i) Analysis of the space for oxygen, flammable or toxic gases.

(ii) Purging of the space with air; in the specific case of flammable gases, an inert gas purge must be used first to prevent any explosion risk and then a subsequent purge with air.

(iii) Use of Permit to Work.

(iv) Isolation, disconnection, spading of pipework.

(v) Interlock control devices.

(vi) Use of breathing apparatus.

(vii) Emergency plan.

Entry in to confined spaces is a legislated activity covered by the Confined Spaces Regulations (2).

4.2.3 System / equipment maintenance

To confirm that a pressure system is safe and complies with the Pressure Systems Safety Regulations (PSSR) (3) a competent person must, generally, have examined it before use in accordance with the written scheme. Thereafter there will be a schedule of routine inspections in accordance with the written scheme. The PSSR Regulations also require that equipment is subject to routine maintenance over and above that required by the written scheme.

In addition the business should have in place a routine of regular checks by the operating staff. For example, this can be according to a defined programme, such as once per shift, or before using any piece of equipment.

This is particularly important if the pressure system is inside a confined space, or close to a confined space, as leaks leading to a lack of oxygen, or other hazards, can result.

Workstations in workshops, on vehicles or in other workplaces where gases are used must be operated and inspected under the requirements of the relevant Statutory Provisions, e.g. The Health and Safety at Work Act (1).

In particular, these workstations and the equipment used in the working environment must be maintained effectively to ensure safety. This will require inspection on a regular basis. The frequency of inspection should be based on operating conditions, national requirements and the local work instructions.

This inspection procedure, including pre-use checks for equipment, must be carried out by a person who has sufficient theoretical knowledge of the functioning of the equipment, the gases used, the potential hazards and defects that may occur and their importance to the integrity and safety of the equipment.

An integral part of the inspection programme is to maintain in a serviceable condition the various safety devices associated with the use of these gases and equipment.

4.2.4 Special engineering controls

The calculations detailed in earlier sections of this guidance note can be used to establish the potential asphyxiation hazards associated with the use of gases in the working environment. Special engineering controls should be considered as part of the overall risk assessment. This includes specific safety devices, which are available to protect both the user of the gases and the equipment itself.

4.2.5 Compressed gas cylinders

Typical uses of these gases in the workplace are for welding (gas and electric), gas and plasma arc cutting, purging and safety blanket requirements in various processes.

Simple pre-use checks of mechanical and flexible joints for leaks prevent the build up of these gases in the workplace. These checks should ensure that the equipment has been installed correctly and fitted with, for example:

(i) Non-return valves.

(ii) Regulators fitted with built in over pressure protection.

Good working practices during the activity being carried out, e.g. welding, can also prevent the build up of these gases. This could include the use of gas economisers on the equipment, and turning off the backing, purge or shield gas when no longer required.

4.2.6 Liquefied gases

Should the use of liquefied gas be in close proximity to the workplace (open windows in buildings, breather bricks in buildings, adjacent ventilation equipment), the gas released can enter these occupied workplaces (exacerbated by the typically high liquid to gas expansion ratio).

If, for operational requirements, multiple tanks are installed, the potential volume of liquid unintentionally released can be reduced by fitting simple interlock devices to prevent inadvertent use of more than one system at a time.

Anti-tow away protection for flexible hoses may be fitted to prevent liquid spillage due to inadvertent movement of vessel / delivery vehicle from point of connection without disconnecting the hoses. The fitting of excess flow valves can also prevent excessive spillage.

The risk assessment needs to consider the location of pipe work for liquid lines. Vent pipes and equipment exhaust ports should also be located in safe places as part of the overall risk assessment.

When transporting liquefied gas in containers such as Dewars and small tanks, from workplace to workplace, the risk assessment needs to take into account the potential manual handling hazards present from moving heavy equipment.

Where this equipment is fitted with overpressure protection such as relief valves and bursting discs, consideration should be given to the possibility of these devices operating and creating an asphyxiating risk whilst being transported.

5. INFORMATION, INSTRUCTION, TRAINING AND SUPERVISION

The employer is responsible for providing sufficient information, training, instruction and supervision to ensure the health and safety of all those involved in the handling and use of gases, including the associated plant and equipment used with them.

Key points:

(i) Hazards of the gases.

(ii) How they are being used – and how they shouldn't be used.

(iii) Precautions required, e.g. the use of gas detectors.

(iv) Additional training may be required for specific working environments.

(v) Emergency / incident procedures including adequate first aid provision.

Where contractors are being employed they should receive similar instruction and, in particular, should be informed of any specific gas hazards in their work area. These instructions may form part of a Permit to Work.

Labelling of the gas containers is the responsibility of the gas supplier. The label identifies the cylinder contents and users should understand the risks associated in handling each product.

More detailed information is provided on the Safety Data Sheet that is provided by the supplier.

Appendix 2 lists reference material available for specific gases / applications.

For further information contact the gas supplier.

6. EMERGENCY PROCEDURES

Basic Rules.

Emergency procedures should be established where gases may create a dangerous environment. These should cover:

(i) Evacuating the workplace, assembly areas and role call.

(ii) Safe isolation of the gases; use of automated or remote shutdown.

(iii) Ventilation of the workplace.

(iv) Alert of Emergency services.

(v) Rescue of victims in a safe manner.

When working in a confined spaces, if a person suddenly collapses and no longer gives any sign of life, always assume that the person may lack oxygen due to the presence of an asphyxiating atmosphere.

WARNING: Do not hurry to help them without thinking – the risk is that you will become the second victim. **Get proper assistance and support, and work according to the confined space entry procedures and emergency plan**.

7. OTHER PROPERTIES OF GASES WHICH MAY ALTER THE WORKPLACE ATMOSPHERE

All gases except air and oxygen will act as asphyxiants by the displacement of atmospheric oxygen, however, other hazards associated with these gases may present a much greater risk, e.g. oxidant, flammable, toxic, pyrophoric and radioactive properties.

Control of gas usage, in conjunction with adequate ventilation, is a key aspect in the management of hazards and reduction in workplace risk levels. Where there is insufficient ventilation to maintain a normal air atmosphere in a workplace then situations may arise where for example:

(i) Unused flammable gases escape into the working environment and the explosive limits of these gases in air will be reached. Once this happens any source of ignition in the workplace, from a naked flame to static electricity, present a potential for ignition and explosion. Some gases, for example hydrogen, require very low energy sources to ignite a flammable mixture. The Dangerous Substances and Explosive Atmosphere Regulations (DSEAR) (5), cover situations where flammable atmospheres may arise.

(ii) If both oxygen and flammable gases are escaping the risk of quickly creating an explosive gas mixture is greatly enhanced by the presence of abnormally high oxygen levels. Explosive limits for flammable gases in oxygen are significantly different from those in air (see Appendix 2 Table of Properties).

(iii) The products of incomplete combustion, such as carbon monoxide, may accumulate and create a toxic atmosphere.

(iv) The release of oxygen leads to oxygen enrichment. In these circumstances any combustion processes will be enhanced and materials that do not normally burn in air may burn in an oxygen rich atmosphere. Escapes of nitrous oxide and also chlorine will strongly support any local combustion. For specific guidance on this subject consult EIGA Document 04 (8).

Releases of toxic gases or carbon dioxide will result in serious health effects before the reduction of oxygen in the work place drops to a dangerous level. Consult the suppliers Safety Data Sheet or the gas cylinder label.

8. REFERENCES *

	Document Number	Title
1.		The Health and Safety at Work etc. Act 1974.
2.	SI 1997 No. 1713	Confined Spaces Regulations 1997.
3.	SI 2000 No. 128	Pressure Systems Safety Regulations 2000 (PSSR).
4.	SI 2002 No. 2677	The Control of Substances Hazardous to Health Regulations 2002 (COSHH).
5.	SI 2002 No. 2776	Dangerous Substances and Explosives Atmospheres Regulations 2002 (DSEAR).
6.	HSE HSG 37	An introduction to local exhaust ventilation.
7.	HSE HSG 54	Maintenance, examination and testing and testing of local exhaust ventilation.
8.	EIGA IGC Document 04	Fire hazards of oxygen and oxygen enriched atmospheres.
9.	EIGA Safety Information Sheet 29	Oxygen deficiency hazard associated with hypoxic fire suppression systems using nitrogen injection.
10.	BCGA Code of Practice 30	The safe use of liquid nitrogen dewars up to 50 Litres.
11.	BCGA Technical Information Sheet 27	Model risk assessment for the safe use of liquid nitrogen dewars.

Further Reading:

HSE L101, ACOP	Safe work in confined spaces. Confined Spaces Regulations 1997.
BCGA Code of Practice 4	Industrial gas cylinder manifolds and distribution pipe work (excluding acetylene).
BCGA Code of Practice 18	The safe storage handling and use of special gases in the micro electronic and other industries.
BCGA Code of Practice 26	Bulk liquid carbon dioxide storage at users' premises.
BCGA Code of Practice 36	Cryogenic liquid storage at users' premises.

BCGA Guidance Note 2	Guidance for the storage of gas cylinders in the workplace.
BCGA Guidance Note 9	Application of the confined spaces regulations to the drinks dispense industry.

Further information can be obtained from:

Health and Safety Executive	www.hse.gov.uk
HSE Books	www.hsebooks.co.uk
UK Legislation	www.legislation.gov.uk
European Industrial Gases Association (EIGA)	www.eiga.eu
British Compressed Gases Association (BCGA)	www.bcga.co.uk

EXAMPLE CALCULATIONS - Evaluating degree of hazard

Calculation 1A: Example

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

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

Where:

$V_R = 75\ m^3$

$V_O = 0.21\ (V_R\ -$ Volume of gas in cylinder)

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

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

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

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

Calculation 1B: Example (1)

One liquid nitrogen 50 litre tank being used in a workplace with a free air volume of 75 m^3.

$V_R = 75 \text{ m}^3$

$V_O = 0.21\left(75 - \left(\frac{50 \times 690}{1000}\right)\right) = 0.21(75 - 34.5) = 8.51 \text{ m}^3$

Resulting oxygen concentration $C_{ox} = \frac{100 \times 8.51}{75} = 11.35\ \%$

This oxygen concentration is clearly below the minimum recommended by the HSE and would represent an immediate threat to life. The instantaneous loss of the full contents of a 50 litre liquid tank is a very unlikely event, and the probability that this could occur needs to be assessed for the specific activity being undertaken. Preventative measures will be necessary where such a loss of contents is reasonably foreseeable.

Calculation 1B: Example (2)

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

$V_R = 75 \text{ m}^3$

$V_O = 0.21\ (75 - (6.35 / 1.87)) = 0.21\ (75 - 3.4) = 15.0 \text{ m}^3$

Resulting oxygen concentration (C_{ox}) = (100 x 15) / 75 = 20 %

This oxygen concentration is above the minimum recommended by the HSE. However carbon dioxide is mildly toxic and therefore 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. The volume of carbon dioxide from this 6.35 kg cylinder could produce a concentration of 4.5 % in case of complete loss via, for example, a bursting disc failure. This would produce a dangerous atmosphere and preventive measures are necessary.

Calculation 2: Example

An inert gas is being used in a work place with a free air volume of 26 m^3, the gas flow rate is 1.1 m^3/h, the air changes are 0.4 per hour and the time taken to complete the job is 2 hours.

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

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

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

L = 1.1

V_r = 26

n = 0.4

t = 2

e = 2.72

$$m = \frac{Vr}{L + nVr} = \frac{26}{1.1 + (0.4 * 26)} = 2.26$$

$$C_t = 0.21 + \left[\frac{0.21n}{\left(\frac{L+n}{Vr}\right)} - 0.21 \right] \left[1 - e^{-t/m} \right] = 0.21 + \left[\frac{0.21 \text{ x } 0.4}{\left(\frac{1.1+0.4}{26}\right)} - 0.21 \right] \left[1 - e^{-2/2.26} \right]$$

$$= 0.21 + \left[\frac{0.084}{(0.0423 + 0.4)} - 0.21 \right] \left[1 - e^{-0.88496} \right] = 0.21 + [0.1899 - 0.21] \text{ x } [1 - 0.4125]$$

$$= 0.21 + [- 0.0201 \text{ x } 0.5875]$$

Therefore: C_t = **0.1982**

The concentration of oxygen in the air is 19.8 %.

The oxygen concentration in the workplace has dropped to 19.8 %, which is above the minimum recommended by the BCGA (19.5 %) and above the level where the BCGA recommends evacuation of the workplace (18 %).

Table of Properties

The table below details some frequently used gases. Many applications use gas mixtures for example, arc welding shielding gases and medical gases. In all cases for information on the risks you should consult the Safety Data Sheet.

Gas	Category	Special Risks	Flammability in air %	Flammability in oxygen %	Liquid to gas expansion ratio[1]	Density of gas kg/m3 @ 15 °C	Relative Density of gas (air = 1)
Acetylene	Flammable	Unstable above 22 psig	2.5 – 100 [2]	2.8 – 9.3			0.9
Ammonia	Toxic	Also flammable and corrosive	15 - 27	14 – 79			0.6
Argon	Inert	Asphyxiant	n/a	n/a	0.83	1.69	1.4
Butane	Flammable		1.9 – 8.5	1.8 - 40			2.1
Carbon dioxide	Toxic	Also asphyxiant	n/a	n/a	c.0.54 / 0.44[3]	1.87	1.5
Chlorine	Toxic	Strongly supports combustion, also corrosive	n/a	n/a			2.5
Helium	Inert	Asphyxiant	n/a	n/a	0.754	0.17	0.14
Hydrogen	Flammable	Highly flammable burns with clear flame	4 - 74	4 – 94		0.09	0.07
Methane	Flammable		5.4 - 15	5 - 60		0.68	0.6
Nitrogen	Inert	Asphyxiant	n/a	n/a	0.69	1.19	0.97
Nitrous oxide	Oxidant		n/a	n/a			1.5
Oxygen	Oxidant	Fire in enriched atmospheres	n/a	n/a	0.85	1.36	1.1
Propane	Flammable		2.2 – 9.5	2.3 - 45			1.5
Sulphur dioxide	Toxic	Also corrosive	n/a	n/a			2.3

NOTES:

1. m^3 of gas at 1.013 bar abs and 15 °C produced from 1 litre of liquid.
2. As pure acetylene can ignite by decomposition above about 2 bars the upper limit is 100 % if the ignition source is of sufficient energy.
3. 0.54 from saturated liquid at -20 °C and 0.44 from saturated liquid in a cylinder at 15 °C.

British Compressed Gases Association
www.bcga.co.uk