



**GUIDANCE NOTE 11**

**THE MANAGEMENT OF RISK WHEN  
USING GASES IN ENCLOSED  
WORKPLACES**

**REVISION 4: 2018**

---

**British Compressed Gases Association**

## **GUIDANCE NOTE 11**

### **THE MANAGEMENT OF RISK WHEN USING GASES IN ENCLOSED WORKPLACES**

**REVISION 4: 2018**

Copyright © 2018 by British Compressed Gases Association. First printed 2002. All rights reserved. No part of this publications may be reproduced without the express permission of the publisher:

#### **BRITISH COMPRESSED GASES ASSOCIATION**

Registered office: 4a Mallard Way, Pride Park, Derby, UK. DE24 8GX  
Company Number: 71798, England



Website:  
[www.bcga.co.uk](http://www.bcga.co.uk)

ISSN 2398 – 936X

## 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, food and medical gases, and we produce a host of publications to this end. BCGA also provides advice and makes representations on behalf of its Members to regulatory bodies, including the UK Government.

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

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

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

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

This document has been prepared by BCGA Technical Sub-Committee 6. This document replaces BCGA Guidance Note 11, Revision 3: 2012. It was approved for publication at BCGA Technical Committee 157. This document was first published on 05/02/2018. For comments on this document contact the Association via the website [www.bcgaco.uk](http://www.bcgaco.uk).

## CONTENTS

<b>Section</b>	<b>Title</b>	<b>Page</b>
	TERMINOLOGY AND DEFINITIONS	1
1.	INTRODUCTION	4
2.	SCOPE	4
3.	ASSESSING THE RISKS ASSOCIATED WITH GASES IN THE WORKPLACE	5
4.	THE PRESENCE AND IDENTIFICATION OF GASES	6
5.	HAZARDS FROM GASES	7
5.1	General hazards	7
5.1.1	Asphyxia	7
5.1.2	Health effects	8
5.1.3	Density	8
5.1.4	Cryogenics	8
5.2	Class 2, Division 2.1, Flammable	9
5.3	Class 2, Division 2.2, Non-flammable, Non-toxic	10
5.3.1	Inert gases	10
5.3.2	Carbon dioxide – additional hazards	10
5.3.3	Oxidising gases	11
5.3.4	Oxygen enrichment	12
5.4	Class 2, Division 2.3, Toxic	13
5.4.1	Toxic gases	13
5.4.2	Corrosive gases	13
6.	SOURCES OF GAS RELEASE	14
6.1	Managed low-oxygen environments	15
6.2	Pressurised tanks	16
6.3	Non-pressurised cryogenic receptacles	16
7.	WORKPLACES AT RISK	16
8.	WHO IS AT RISK	17
9.	EVALUATION OF RISK	17
9.1	Preliminary risk assessment	18
9.2	Detailed risk assessment	20
9.3	Calculations for risk assessment	21
9.4	Risk evaluation	22
10.	IDENTIFYING RISK CONTROL MEASURES	23
10.1	Elimination	24
10.2	Substitution	24
10.3	Engineering controls	24

10.4	Administrative controls	25
10.5	Personal protective equipment	26
11.	EMERGENCY SITUATIONS	26
12.	REFERENCES *	28
<b>Appendixes:</b>		
Appendix 1	Example Calculations	31
Appendix 2	Workplace ventilation	35
Appendix 3	Atmospheric monitoring equipment	37
Appendix 4	Work in confined spaces	40
Appendix 5	Considerations for cryogenic or liquefied gases	42

\* Throughout this publication the numbers in brackets refer to references in Section 12. Documents referenced are the edition current at the time of publication, unless otherwise stated.

## TERMINOLOGY AND DEFINITIONS

Asphyxia	An extreme condition caused by a lack of oxygen. It may be accompanied by an excess of carbon dioxide in the blood (hypercapnia). Produced by interference with respiration or insufficient oxygen in the air.
Confined space	<p>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.</p> <p>It has two defining features:</p> <ol style="list-style-type: none"><li>(i) It is a place which is substantially, (though not always entirely) enclosed.</li><li>(ii) There will be a reasonably foreseeable risk of serious injury from; flammable or toxic atmosphere, oxygen deficient or enriched oxygen atmosphere.</li></ol> <p>[as defined in the <i>Confined Spaces Regulations</i> (3)]</p>
Cryogenic liquid	<p>Temperatures below 120 K (-153 °C) should be referred to as cryogenic temperatures.</p> <p><i>Source: History and Origins of Cryogenics Oxford science publications edited by Ralph G Scurlock. Page 4 recommendations on low temperature terminology 1971 13<sup>th</sup> International Congress of Refrigeration.</i></p> <p><i>Reasoning; Temperatures below 120 K can generally only be reached by refrigerating machines which incorporate gas expansion and regenerative or recuperative heat exchange. To attain temperatures above 120 K a working fluid can be chosen with a critical temperature above ambient so there is no necessity for heat exchange.</i></p>
Dry ice	The solid form of carbon dioxide.
Evaporation rate	The rate at which the phase state change occurs.
Gas	<p>Gas is a substance which:</p> <ul style="list-style-type: none"><li>• at 50 °C has a vapour pressure greater than 300 kPa (3 bar);</li><li>or</li><li>• is completely gaseous at 20 °C at the standard pressure of 101.3 kPa</li></ul>
Gas density	<p>Mass per unit volume for a gas at specified temperature and pressure.</p> <p>Refer to the gas Safety Data Sheet.</p>

Gas expansion ratio	Liquid to gas volume expansion conversion – volume of gas generated from 1 volume of liquid.
Flammable gas	<p>Gases which at 20 °C and a standard pressure of 101.3 kPa:</p> <ul style="list-style-type: none"> <li>• Are ignitable when in a mixture of 13 % or less by volume with air; or</li> <li>• Have a flammable range with air of at least 12 percentage points regardless of the lower flammability limit.</li> </ul>
Fusible gases	A gas which is flammable and which has the ability to transport a flame from one place to another, even though the presence of the gas may in some cases only be a thin ‘strand’ or column.
Hazard	Any substance, condition or equipment that has the potential to cause harm to an individual or the environment.
Hypoxia	A condition where the human body, or a region of the body, is deprived of adequate oxygen.
Inert gas	A gas that is neither toxic nor flammable, but which does not support human life and which reacts scarcely or not at all with other substances.
Liquefiable gas	<p>A gas which when under pressure is partially liquid at temperatures above -50 °C.</p> <p>High pressure liquefied gas: a gas with a critical temperature above -50 °C and equal to or below +65 °C.</p> <p>Low pressure liquefied gas: a gas with a critical temperature above +65 °C.</p>
Lower explosive limit (LEL)	The lowest concentration (percentage) of a gas or a vapour in air capable of producing a flash of fire in the presence of an ignition source.
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.
Pyrophoric gas	Pyrophoric gases can ignite and combust on contact with air (or oxidants). Under some conditions, ignition may not occur, resulting in the formation of a mixture of the pyrophoric gas with air or oxidant gas, which may be unstable and potentially explosive.
Reduced oxygen atmosphere	An atmosphere where the level of oxygen is reduced (or depleted) below the normal concentration in air, that is, nominally 20.9 % measured by volume.

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”, for example, 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 and may also indicate a mandatory requirement within UK law.
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.
Upper explosive limit (UEL)	Highest concentration (percentage) of a gas or a vapour in air capable of producing a flash of fire in the presence of an ignition source.
Workplace	Any premises, part of a premises or area that is made available to any person as a place of work and includes: <ul style="list-style-type: none"> <li>• Any place within the premises to which such person has access while at work; and</li> <li>• Any room, lobby, corridor, staircase etc. where facilities are provided for use in connection with the workplace.</li> </ul>
Workplace Exposure Limits (WEL)	Occupational exposure limits which are set in order to help protect the health of workers. Workplace Exposure Limits are concentrations of hazardous substances in the air, averaged over a specified period of time, referred to as a time-weighted average. Two time periods are used: <ul style="list-style-type: none"> <li>• Long-term exposure limit (8 hours); and</li> <li>• Short-term exposure limit (15 minutes).</li> </ul> <p>Refer to HSE EH 40 (8), <i>Workplace exposure limits</i>.</p>

# GUIDANCE NOTE 11

## THE MANAGEMENT OF RISK WHEN USING GASES IN ENCLOSED WORKPLACES

### 1. INTRODUCTION

The key to successful safety management is the assessment and management of risk. The *Management of Health & Safety at Work Regulations* (4) require all employers to assess risk and try to anticipate what can go wrong, then to implement control measures to reduce the risk. As such, safety management focuses on prevention.

This document provides guidance that can be used in the assessment of risk associated with gases in enclosed workplaces, to identify where hazardous atmospheres may occur and the appropriate control measures.

Ambient air is primarily composed of two gases; nitrogen at approximately 78 % and oxygen at 20.9 %. Changes to the air composition can result in a potentially hazardous atmosphere. Human senses cannot detect different compositions in the atmosphere and are not a valid indicator.

Changes to the composition of the air will occur from the release of gas(es) into the local environment. Examples include evaporation, leakage and process exhaust. There is also the potential for gases to enter the workplace from external sources. Examples include the release of gases from neighbour sites, or concentrations of naturally occurring gases. The changes will be more pronounced in an enclosed space and where there is inadequate ventilation.

It should also be borne in mind that even before the introduction of stored gases into certain workplace situations, gases and low oxygen concentrations may have been generated within an enclosed space by natural decay mechanisms such as the production of hydrogen sulphide from stagnant water, or the corrosion (oxidation) of some metals which can deplete the available oxygen. Atmospheric checking prior to entry to an enclosed space is therefore vital.

Incidents can occur unexpectedly, and may be serious, and sometimes fatal. All personnel accessing an enclosed workplace should be aware of the hazard(s) associated with non-respirable atmospheres and be given the necessary equipment, information, instruction and training.

The British Compressed Gases Association (BCGA) provide a model risk assessment in support of this document, refer to BCGA Technical Information Sheet (TIS) 35 (34), *Model risk assessment for the management of the atmosphere in the workplace when using gases*.

This Guidance Note is intended for use in conjunction with current guidance and information produced by the Health and Safety Executive (HSE) and other related bodies and trade associations.

### 2. SCOPE

This document identifies potential hazards from the escape, leak or accumulation of gases into the workplace and the associated risks. It also provides guidance for risk reduction measures to

be considered. The document scope includes all gases, whether compressed, liquefied, refrigerated or dissolved.

Other hazards associated with the use of the gases, such as pressure, manual handling, storage etc. are not discussed in detail in this document, but information is available in other BCGA documents.

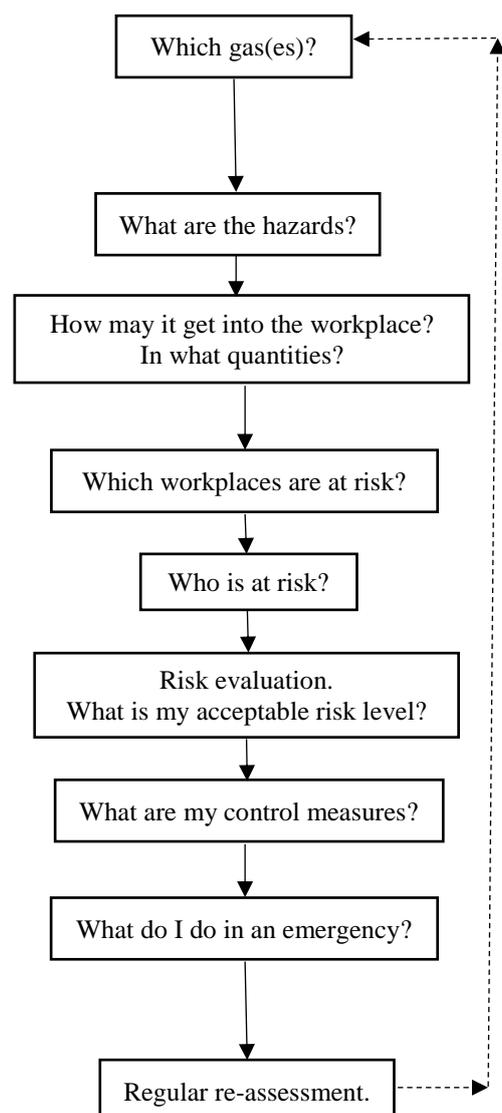
The scope of this document does not cover specialist activities, for example, diving, hyperbaric conditions or deep mining, where the atmospheric pressure varies from normal ambient surface conditions.

### 3. ASSESSING THE RISKS ASSOCIATED WITH GASES IN THE WORKPLACE

*The Management of Health and Safety at Work Regulations* (4), as well as other legislation, such as the *Confined Spaces Regulations* (3), require employers to conduct risk assessments for their activities.

When you are considering the risks associated with the use of gases in the workplace there are several steps to be taken:

- Identify which gases you store / use on site, or which you may encounter, for example, they enter site from an external source; Refer Section 4.
- Understand the hazards of each of these gases; Refer to Section 5.
- Determine how the gas(es) may enter the workplace, the potential quantity of gas and in what concentrations; Refer to Section 6.
- Determine which workplaces are at risk; Refer to Section 7.
- Identify who could be at risk; Refer to Section 8.
- Evaluate the level of risk and acceptability; Refer to Section 9.
- Ensure you have appropriate control measures; Refer to Section 10.
- Prepare for and understand how to deal with emergency situations if they arise; Refer to Section 11.
- Carry out re-assessment on a regular basis, including when a change occurs to the workplace, gas usage or storage.



Further information on risk assessment can be obtained from:

- The Health and Safety Executive (HSE), who provide a wide range of guidance on carrying out risk assessments on their website: [www.hse.gov.uk/risk](http://www.hse.gov.uk/risk).
- BCGA TIS 35 (34).

Further information on the storage, handling and use of gases can be found on the BCGA website: [www.bcgaco.uk](http://www.bcgaco.uk)

#### 4. THE PRESENCE AND IDENTIFICATION OF GASES

Commercially supplied gases are typically provided to the user either in bulk and stored in a tank, or via a gas cylinder. Some gases may be present from leakage from other local sources or appear on site naturally (for example, from the atmosphere, through human / animal respiration, from percolation through the earth, etc.), refer to Section 6.

Commercial gas suppliers will ensure that each container they supply will correctly identify the product it contains. The Safety Data Sheet will provide detailed information. For specific safety information and / or advice contact your gas supplier.

On a gas cylinder the label identifies the contents and provides basic safety information on the hazard(s) associated with the product.

Gases are classified according to their hazardous properties. There are internationally recognised hazard pictograms used to identify each class, refer to Table 1 and Table 2.

Category	Hazard pictograms
Class 2 Division 2.1 Flammable	 
Class 2 Division 2.2 Non-flammable Non-toxic	
Class 2 Division 2.3 Toxic	 

**Table 1:** Class 2 - Gases – Primary hazards

Each gas has a primary hazard and may have a number of subsidiary hazards. These will be shown on the labels as additional pictograms.

Category	Hazard pictograms
Class 5.1 Oxidising substances	
Class 8 Corrosive substances	

**Table 2:** Class 2 - Gases – Subsidiary hazards

## 5. HAZARDS FROM GASES

### 5.1 General hazards

Each gas will have its own particular set of hazards based on its physical and chemical properties. Always refer to the product Safety Data Sheet for specific information. This sub-section covers the general hazards applicable to many.

- Asphyxia, refer to Section 5.1.1.
- Health effects, refer to Section 5.1.2.
- Density, refer to Section 5.13.

There are additional hazards associated with a cryogenic gas, refer to Section 5.1.4.

For information on oxygen enrichment refer to Section 5.3.4.

#### 5.1.1 Asphyxia

The normal concentration of oxygen in air is 20.9 %. Oxygen is the only gas that supports life. The release of any gas will displace the existing atmosphere in an enclosed workplace, which in turn will (other than for released air and oxygen) reduce the volume of oxygen available to breathe. If the oxygen concentration in the workplace atmosphere decreases there is an increased risk of asphyxiation. Refer to Table 3.

For further information refer to the European Industrial Gases Association (EIGA) Safety Leaflet 01 (22), *Asphyxiation – The hidden killer*.

<b>O<sub>2</sub> concentration</b> <b>Volume %</b>	<b>Effects and symptoms</b>
20.9	Normal level of oxygen in the atmosphere
19.5	Minimum safe level of oxygen
< 18	Potentially dangerous.
< 10	Risk of unconsciousness followed by brain damage or death due to asphyxia is greatly increased.
< 6	Immediate loss of consciousness occurs.
0	Inhalation of only 2 breaths causes immediate loss of consciousness and death within 2 minutes

**Table 3:** The effects of inhaling reduced concentrations of oxygen

### 5.1.2 Health effects

Health effects can occur where people are exposed to gases. The *Control of Substances Hazardous to Health (COSHH)* Regulations (6) require that exposure to any hazardous substance is managed. The HSE provide guidance on workplace exposure limits in HSE EH 40 (8), *Workplace exposure limits*. Not all gases and mixtures of gases are listed, however the effect of asphyxiation is covered within HSE EH 40 (8) as a special case.

Specific gases may have other health effects, as well as asphyxia, for example, cold burns, toxicity, corrosive, etc. Always refer to the gas Safety Data Sheet.

### 5.1.3 Density

Knowing the density of the gases relative to air will suggest where the gas may preferentially tend to accumulate. For example, a gas with a density greater than air will tend to fall and collect in the lower areas of the workplace, such as pits, tunnels, drains, conduits, etc.

The density of a gas varies along with its temperature such that gases superficially regarded as being lighter or heavier than air in specific (for example, ambient) conditions may in fact have this characteristic reversed when either warmer or colder than those specific conditions. As an example, cold gases may initially accumulate in low lying areas, even when at ambient conditions the gas is lighter than air.

### 5.1.4 Cryogenics

Cryogenic gases may have the following additional hazards:

- Extreme cold – hazard to people, such as cold burns, frostbite, hypothermia, lung damage, etc.

- Extreme cold – hazard to materials and structures, such as embrittlement, loss of integrity, modification of mechanical properties, etc.
- Liquefaction of air - this can occur when air comes into contact with surfaces which are at a temperature below the boiling point of an air gas, for example, oxygen (typically at *circa* -183 °C). This can happen when transferring liquid nitrogen (typically at *circa* -196 °C) through uninsulated pipes which may result in the unexpected production of liquid oxygen on the pipe outer surfaces, due to the preferential condensing of the oxygen from atmospheric air, therefore increasing the fire risk (through oxygen enrichment, refer to Section 5.3.4).
- High liquid to gas volume expansion ratio.
- The formation of vapour clouds. Creating poor visibility which may result in disorientation. Until the clouds disperse they may also extend the area where a hazardous atmosphere may exist.

## 5.2 Class 2, Division 2.1, Flammable

Flammable gases, when mixed with air or oxygen, can combust and may explode if they are ignited. Flammable gases react or combust with oxidising gases. The likelihood that a flammable gas will ignite is affected by its flammability range. Some common examples of the flammability ranges of specific gases in air are:

- Acetylene, 2 to 85 %
- Hydrogen, 4 to 75 %
- Methane, 5 to 15 %

Some common examples of ignition sources are:

- Electrical, for example, connections, switching, overheating or faults;
- Friction, sparks, etc.;
- Hot work;
- Smoking;
- Static electricity discharge;
- Welding.

NOTE: Some flammable gases, for example, hydrogen, may ignite on release for a variety of reasons, examples include: due to the friction of the gas movement over a surface, adiabatic compression, self-generated static electrical charge, etc. Pyrophoric gases may ignite on contact with air (spontaneous combustion). Fusible gases may cause

an ignition source to be conveyed from one location to another, in some cases hundreds of meters away.

The primary hazard from a flammable gas is the risk of fire and explosion, in addition flammable gases have the hazard of asphyxia and some have narcotic effects.

### **5.3 Class 2, Division 2.2, Non-flammable, Non-toxic**

Non-flammable, non-toxic gases includes gases which are generally referred to as inert, as they are not reactive, refer to Section 5.3.1. This division also includes gases which have oxidising properties, refer to Section 5.3.3.

#### **5.3.1 Inert gases**

Inert gases are non-oxidising, non-flammable and non-toxic but which may dilute or displace the oxygen normally present in the atmosphere. Examples of inert gases include:

- Argon.
- Carbon dioxide (which has other hazards, refer to Section 5.3.2).
- Helium.
- Nitrogen.

The primary hazard from inert gases is asphyxia, refer to Section 5.1.1.

#### **5.3.2 Carbon dioxide - additional hazards**

The normal concentration of carbon dioxide in the air is approximately 400 ppm (0.04 % by volume). If the concentration of the carbon dioxide in the ambient air is increased and is breathed, the pulmonary gas exchange in the lungs is compromised. In simple terms, as its concentration in the ambient air increases, lower quantities of carbon dioxide leave the blood stream and / or alveoli and therefore there is less room for oxygen. Without sufficient oxygen one cannot live. This effect is called intoxication.

NOTE: Global carbon dioxide levels appear to be slowly rising. 2016 saw average concentrations of carbon dioxide rise to 403.3 ppm, up from 400 ppm in 2015.

Carbon dioxide intoxication usually occurs independently of the effects of oxygen deficiency (i.e. asphyxiation, refer to Section 5.1.1) therefore the oxygen content in the air is not an effective indication of the danger of intoxication.

The effects of inhaling varying concentrations of carbon dioxide are given in Table 4, but it should be appreciated that the reactions of some individuals can be very different from those shown.

For additional information on the physiological hazards of carbon dioxide refer to EIGA Safety Information 24 (23) – *Carbon dioxide physiological hazards “not just an asphyxiant”*

<b>CO<sub>2</sub> concentration Volume %</b>	<b>Typical effects and symptoms</b>
0.04	Normal level of carbon dioxide in the atmosphere
0.5	Minimum safe level of carbon dioxide. Maximum allowed exposure over an 8 hour period *
1 – 1.5	Slight and unnoticeable increase in breathing rate. 1.5 = maximum allowed exposure in a 15 minute period *
3	Breathing becomes laboured, rate increases. Hearing ability reduced, headache experienced with increase in blood pressure and pulse rate.
4 - 5	Breathing laboured at a greater rate. Symptoms as above, with signs of intoxication becoming more evident with longer exposure and a slight choking feeling.
5 - 10	Characteristic pungent odour noticeable. Breathing very laboured, leading to physical exhaustion. Headache, visual disturbance, ringing in the ears, confusion probably leading to loss of consciousness within minutes.
10 - 100	In concentrations above 10 %, unconsciousness will occur in under one minute and unless prompt action is taken, further exposure to these high levels will eventually result in death.

\* Refer to HSE EH 40 (8)

**Table 4:** The typical effects of inhaling carbon dioxide

### 5.3.3 Oxidising gases

Oxidising gases will support the combustion process. Many substances which would otherwise not combust, are able to combust and burn fiercely in an atmosphere enriched with oxidising gases. Substances may ignite with a lower ignition energy than that required for ignition in a non-oxidant enriched atmosphere, or they may ignite at concentrations below their normal Lower Explosive Limit (LEL). Typical oxidising gases include:

- Nitrous oxide
- Oxygen

NOTE: Oxygen can be produced through biological action or chemical reactions, refer to Section 6.

The primary hazard from oxidising gases is the increased risk of combustion, coupled with an increased intensity of combustion, refer to Section 5.3.4. Oxygen is a reactive gas and may cause a chemical reaction.

#### **5.3.4 Oxygen enrichment**

Oxygen plays a vital part in combustion mechanisms. Oxygen is not in itself flammable, but increasing the oxygen content in an atmosphere will increase the ignitibility and combustion rate of materials and substances. The initiation, speed, intensity and extent of combustion will depend on:

- Oxygen concentration;
- Pressure;
- Temperature;
- Material type and quantity, as well as any local substances which could become involved in the combustion.

The normal concentration of oxygen in the air is 20.9 %. However, oxygen enrichment of the atmosphere, even by a few percent, considerably increases the risk of fire and also increases the rate of propagation and intensity of a fire or explosion. Concentrations of oxygen above 23.5 % should be avoided. Where it is unavoidable, specific precautions shall be implemented following a risk assessment.

In oxygen enriched air, ignition sources which would normally be regarded as harmless can cause fires, and materials which do not readily combust in air, including fire resistant materials, can and do burn vigorously. Any fire will drive the evaporation process, especially with vaporising liquefied gases, which may cause a sudden escalation of the fire.

Whilst it is not strictly an oxidiser, compressed air, by virtue of its pressure, volume and velocity, may have a similar effect to that of an oxidiser in increasing combustibility. Elevated levels of oxygen are, in effect, present in compressed air. For this reason, care should be taken where compressed air lines and services are present, as splits and leaks from these services can have a similar effect to the introduction of oxidisers. This should be considered in the fire risk assessment.

In a workplace environment where there is a reasonably foreseeable risk of oxygen enrichment the choice of materials used in its construction and the presence of certain types of furniture, tools, equipment, hazardous products etc. which will readily combust or be a cause of ignition, should be taken into account during the design and fitting out of that workspace and in the fire risk assessment(s).

#### **NOTES:**

1. Oil and greases and other hydrocarbons are particularly hazardous in the presence of an oxygen enriched atmosphere as they can ignite on contact with only minimum ignition energy and combust with explosive violence.

2. Oil and grease should never be used to lubricate oxygen or oxygen enriched-air equipment. Where absolutely necessary, special lubricants which are certified as compatible with oxygen (and / or other substances which may be present) shall be used.

Clothing, human skin and other fully or partially gas-permeable items can become saturated with oxygen. Ensure good practice is observed in relation to clothing ventilation (for example, when personnel move to areas where smoking is allowed), specification, personnel awareness, proximity to sources of ignition, etc.

For specific guidance on oxygen enrichment refer to:

- HSE INDG 459 (14), *Oxygen use in the workplace. Fire and explosion hazards.*
- EIGA Document 04 (18), *Fire hazards of oxygen and oxygen enriched atmospheres.*

#### **5.4 Class 2, Division 2.3, Toxic**

This division includes both toxic and corrosive gases. The primary hazard from these gases is the potential severe physiological adverse effect on health. In addition to a physiological hazard, these gases have a secondary hazard of asphyxia and may also have flammable or oxidising hazards.

##### **5.4.1 Toxic gases**

Toxic gases impact adversely with people to varying degrees, from a mild irritant, to a severe reaction, including death, dependent on the concentration and the susceptibility of the individual. Typical toxic gases include:

- Anhydrous ammonia (WEL - Long term exposure limit = 25 ppm).
- Carbon monoxide (WEL - Long term exposure limit = 30 ppm).
- Hydrogen sulphide (WEL - Long term exposure limit = 5 ppm).

##### **5.4.2 Corrosive gases**

Corrosive gases chemically attack and damage skin, eyes and mucous membranes on contact. Typical corrosive gases include:

- Chlorine.
- Hydrogen chloride.
- Sulphur dioxide.

The corrosive nature of these products may have implications for and create other (non-human) hazards, for example, mechanical considerations due to corrosion, material deterioration, etc. These hazards may in turn result in indirect health exposures, for example, due to loss of containment.

## 6. SOURCES OF GAS RELEASE

The workplace atmosphere may be modified through either normal use or from abnormal release of gases. Examples include:

Normal (expected) use of the gas.

- Process exhaust gas, for example, welding (shielding and purge gas venting), laboratory equipment, etc.
- Chilling and freezing (cryogenic liquids and dry ice) operations in open containers, for example, shrink fitting.
- Gas blanketing.
- The emptying or purging of a tank or vessel.
- The routine operation of pressure control devices.
- Combustion processes (for example, gas welding and cutting; localised / workplace heating / mobile heaters, etc.) 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. The twin effects of gas leakage and of oxygen consumption due to combustion may need to be considered in combination.

NOTE: The products of incomplete combustion, such as carbon monoxide, may accumulate and create a toxic atmosphere.

- The use of medical gases, for example, the use of medical oxygen by patients, with leakage from face masks etc.
- Cryotherapy and cryosurgery.
- Modified atmosphere packaging, for example, packaging of food and other consumable goods.
- Dry ice sublimation.
- The decanting of cryogenic liquids.
- Evaporation directly from open cryogenic liquid containers, for example, dewars and bio-store freezers.
- The coupling / uncoupling of hoses, etc.
- A managed low oxygen environment, refer to Section 6.1.

Abnormal (but foreseeable) release or generation of gas:

- Poor setting up of equipment. For example, using an excess of the fuel gas, shielding gas and / or oxygen when welding, flame cutting etc.
- Poor siting / location of exhausts or vents. For example, purging.

NOTE: Refer to EIGA Document 154 (21), *Safe location of oxygen and inert gas vents*.

- Leaks from joints, pipework, hoses, valves, damaged equipment, etc.
- Cryogenic liquid spillage. The release of cryogenic liquid product will lead to the formation of a very large volume of gas (for example, oxygen, ratio liquid to gas: 1: 860).
- Liquefied gas (non-cryogenic) spillage. The release of liquefied gas will lead to the formation of a large volume of gas (for example, propane, ratio liquid to gas: 1:400).
- Dry ice spillage (leading to an increased rate of sublimation).
- The non-routine operation of safety devices, such as bursting discs.
- Inadvertent or accidental release of gas.
- Malicious release of a gas.
- Chemical reaction, for example, combustion, corrosion.
- Biological action, for example, fermentation, decomposition.
- Naturally occurring gases, for example, radon.
- External sources of gas, for example, from neighbour sites, drainage systems.

### **6.1 Managed low-oxygen environments**

There are workplaces where the use of a controlled, low-oxygen maintained atmosphere is adopted. 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 combust 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 should be considered as a potentially significant physiological hazard for humans. Risk assessment, the use of control systems to provide a safe atmosphere as well as health assessment, surveillance and related controls are required to ensure that any people exposed to these atmospheres are safe.

For further information on controlled, low-oxygen maintained atmospheres refer to:

- BCGA TIS 30 (33), *Working in reduced oxygen atmospheres*.

- EIGA Safety Information Leaflet 29 (24), *Oxygen deficiency hazard associated with hypoxic fire suppression systems using nitrogen injection*.

## 6.2 Pressurised tanks

In addition to the gas released through the use point, gas may be released through the pressure safety devices fitted to the tank or its pressure system. In the case of storage tanks the relief devices should be piped away to a safe (i.e. external, good natural ventilation, non-hazardous) location, refer to BCGA CP 4 (25), *Industrial gas cylinder manifolds and distribution pipework (excluding acetylene)*. Where this is not feasible due consideration shall be given to gas that may vent from pressure safety devices.

NOTE: The evaporation rate will increase as the insulation efficiency deteriorates in a cryogenic tank, for example, through wear and tear. Take this into consideration in the risk assessment.

In addition to pressure relief valves, cryogenic tanks are normally fitted with bursting discs. When a bursting disc operates, all the positive gas pressure in the tank, as well as gas created from evaporation will be released. The volume of gas released and the duration will depend upon the quantity of liquid in the tank, the pressure and the orifice dimensions.

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

## 6.3 Non-pressurised cryogenic receptacles

Non-pressurised receptacles (open), such as bio-freezers, dewars and flasks, containing a cryogenic liquid will release gas directly through normal evaporation. During the filling of these receptacles approximately 10 % of the liquid transferred will evaporate.

For guidance on the safe storage, filling and the use of dewars and flasks refer to BCGA CP 30 (27), *The safe use of liquid nitrogen dewars up to 50 Litres*. BCGA TIS 27 (32), *Model risk assessment for the safe use of liquid nitrogen dewars*, provides a model risk assessment for the safe use of liquid nitrogen dewars.

NOTE: The evaporation rate will increase as the insulation efficiency deteriorates, for example, through wear and tear. Take this into consideration in the risk assessment.

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

## 7. WORKPLACES AT RISK

Any area where gases are introduced, either deliberately, unintentionally or from natural sources, may be affected by the hazards identified in this document. The following areas typically present an increased risk:

- Internal gas storage areas – due to the quantity of gas stored;
- Confined space – a restricted space with potential poor ventilation;

- Small enclosed areas – as it is a space of limited volume with potential poor ventilation;
- Below ground – due to inadequate ventilation and the collection of dense gases;
- An area adjoining a place of storage / use – unexpected release of gas into an ostensibly ‘safe’ area, including into air intakes and from exhausts;

NOTE: Refer to EIGA Document 154 (21).

- Poorly ventilated areas – where there is inadequate rate of air change;
- Gas product transfer areas – due to the release of a gas during transfer, coupling and uncoupling losses, etc.;
- Non-industrial environments – for example, domiciliary oxygen patients.

When a change occurs to the workplace, gas usage or storage there may be a change in the risk and possibly the hazard. The risk assessment will need to be reviewed and appropriate control measures put in place.

## **8. WHO IS AT RISK**

Any person who enters, or is present in, an area with an atmosphere containing gas mixtures different from ambient air is at risk. Non-respirable atmospheres may result from gases accumulating, whether deliberately, unintentionally or from natural sources. Examples include:

- Those directly using the gas(es);
- Those in the area where the gases are being used, or where an atmosphere is being modified, for example, through combustion or hot work;
- Those who may be indirectly at risk, such as neighbours and those ‘downwind’ of a gas release.

NOTE: Gas concentrations may have a different affect on animals than on humans.

## **9. EVALUATON OF RISK**

As part of any assessment, the likelihood of a change in the atmosphere taking place and the probability of harm to people shall be determined.

Carry out a preliminary assessment to establish if gases in the workplace present a hazardous atmosphere and a risk to people. Refer to Section 9.1.

The preliminary assessment should consider the following elements:

- the largest volume of gas that can leak into the workplace;
- the volume of the workplace;
- whether the resulting foreseeable gas concentration(s) exceed threshold levels, for some common gases refer to Table 5.

If the gas concentrations are in all foreseeable circumstances below the threshold level, and therefore confirmed as low risk, a more thorough risk assessment is not necessary. Record the assessment.

If the preliminary assessment indicates that the gas concentration could exceed the threshold levels then a detailed risk assessment shall be made. Refer to Section 9.2.

NOTE: Assessing the gas concentration in a workplace is only a single assessment of one potential hazard within the workplace and all other hazards should also be considered.

Reassessment of the risk should be carried out on a periodic basis or in the event of changes taking place in the workplace which have the potential to create a different atmosphere.

### 9.1 Preliminary risk assessment

Preliminary risk assessment criteria:

This preliminary risk assessment considers the worst case scenario, in which the entire content of a container(s) is released instantaneously into the workplace being assessed. The assessment will need to be carried out for every foreseeable scenario, for example, each type of gas present, and shall be conducted by person(s) competent to do so.

- (i) Identify the gas container(s) from which gas may foreseeably be released.

Where multiple gas containers are connected together, then the combined volume may need to be considered. You will need to understand the relationship between container sizes and the pressure at which the gas is stored inside them. For example, cylinders with gas at a high pressure can store a greater quantity of gas than cylinders of a similar size with the gas stored at a lower pressure.

- (ii) Determine the volume of gas in the identified container(s):

- Compressed gas cylinder.  
 $(\text{pressure \{bar\}} \times \text{water capacity \{litre\}}) / 1000 = m^3$ .
- Liquefied gas cylinder.  
 $\text{weight of product \{kg\}} \times \text{specific volume \{at ambient temperature } ^\circ\text{C}\} \{m^3/\text{kg}\} = m^3$
- Cryogenic liquid container.  
 $(\text{capacity of tank \{litre\}} \times \text{expansion ratio \{at ambient temperature } ^\circ\text{C}\}) / 1000 = m^3$

- (i) Determine the free air volume in the workplace.

For a regularly-shaped workplace measure the height, width and length (in metres), then multiply together to determine the volume (m<sup>3</sup>). From this volume deduct the volumes of any objects within the workplace, such as machines, furniture, stock, etc. (these objects reduce the volume of free air in the workplace). Allowance shall be made for maximum stocks held during worst case conditions since these extra stocks further reduce the free air volume in the workplace.

(iv) Calculation.

$$C = 100 \frac{V_o}{V_r}$$

Where:

$C$  = Percentage of gas concentration

$V_o$  = For the result to be the percentage concentration of gas  
The volume of gas, m<sup>3</sup>

= For the result to be the percentage of oxygen  
= 0.21 ( $V_r$  – Volume of gas in the cylinder)

$V_r$  = The volume of free air in the workplace, m<sup>3</sup>  
(volume of workplace less volume of solid objects)

NOTE: There are example calculations in Appendix 1.

(v) Table of limits.

For some common gases the limits are referenced in Table 5. In all cases it is recommended that reference is made to HSE EH 40 (8).

Gas	Limit	Comments
Oxygen	Min: 19.5 %	
	Max: 23.5 %	
Carbon dioxide	Max: 0.5 %	
Inert gases, for example, nitrogen		Use oxygen minimum level
Flammable gases	Max: 25 % of the LEL	
Toxic		Use WEL for specific gas

**Table 5:** Limits for some common gases

(vi) Evaluation

If the gas concentrations are within the limits in Table 5 then the workplace can be considered low risk and a more thorough risk assessment is not necessary.

Record the preliminary assessment.

The preliminary assessment should be reviewed on a periodic basis and whenever changes occur in the workplace.

If the preliminary assessment indicates that the gas concentrations exceed the limits in Table 5, or are finely balanced, or have an unacceptable risk, a detailed risk assessment is necessary. Refer to Section 9.2.

## **9.2 Detailed risk assessment**

The preliminary risk assessment (Section 9.1) considered an instantaneous release of the entire contents of a gas container into an enclosed workplace, however this is a worst-case scenario. There are many variables that can be taken into consideration to accurately establish the level of risk. A further risk assessment considering normal and abnormal scenarios should now be carried out by person(s) competent to do so, considering all applicable variables.

The following should be considered for all gases:

- Identify the specific gas(es) and its properties:
  - Variation in effect due to temperature, density, pressure, physical state, etc.
  - The resulting atmosphere in the event of a gas release, refer to the calculations in Section 9.3.
- Potential release points, including the release rate, duration, volume and likelihood of release:
  - Venting via safety relief devices;
  - Deliberate release, for example, venting;
  - Natural boil off from cryogenic liquids;
  - Dry ice sublimation;
  - Process exhaust, equipment and flues;
  - Unintended leakage, for example, spills, leaking joint(s), damage to pipework/equipment;
  - Inadvertent or incorrect operation of equipment;
  - Release during connection / disconnection of hoses and regulators.
- Transfer of released product into other spaces, for example, ventilation system, air intake, elevation (basement, top floors, etc.), gulleys and trenches.
- The free air volume of the space in which the atmosphere may be present.

- Ventilation – natural – forced – air changes per hour.
- Occupancy of the spaces where a release may take place:
  - Presence of vulnerable receptors and populations, access controls and restrictions, etc.

Other factors to consider for flammable gases include:

- Potential sources of ignition.

For flammable gases (and indeed all compressed gases) a DSEAR risk assessment will be necessary. Refer to BCGA GN 13 (31), *DSEAR Risk Assessment*.

Other factors to consider for oxidising gases include:

- Increased fire risk.
- Health risk from high oxygen concentrations.

Other factors to consider for intoxicating, toxic and corrosive gases include:

- Acute and chronic health effects.

For intoxicating, toxic and corrosive gases an assessment in accordance with the COSHH Regulations (6) will be necessary.

Once released, a gas will be free to move and its movement will be influenced by any ventilation conditions or systems and/or by the prevailing weather conditions. Be aware of the hazard not only from your own gas supplies, but also from those held by your neighbour(s).

A model risk assessment is available in BCGA TIS 35 (34).

### **9.3 Calculations for risk assessment**

The following calculation may be used to approximate the resulting atmosphere where the release rate, the workplace free air volume, ventilation and release duration is known. This method can be used to establish the hazard resulting from a gradual release of product (non-respirable gas) into the workplace, for example, 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.

This equation gives the approximate resulting oxygen percentage concentration ( $OC_t$ ) after time (t) and should be used to establish the asphyxiation and oxygen enrichment risk:

$$OC_t = 100 \left( 0.21 + \left( \left[ \frac{0.21 \times n}{\left( \frac{L}{Vr} \right) + n} \right] - 0.21 \right) (1 - e^{-t/m}) \right)$$

and for long periods (t tending to infinity):

$$OC_\infty = 100 \times \left( \frac{Vr \times 0.21 \times n}{L + (Vr \times n)} \right) \text{ approximately}$$

This equation gives the approximate resulting gas percentage concentration ( $GC_t$ ) after time (t) and should be used to establish the intoxicating ( $CO_2$ ), toxic or flammable risk:

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

and for long periods (t tending to infinity):

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

Where:

$OC_t$	=	Oxygen percentage concentration after defined time
$OC_\infty$	=	Oxygen percentage concentration after long periods (days)
$GC_t$	=	Gas percentage concentration after defined time
$GC_\infty$	=	Gas percentage concentration after long periods (days)
$L$	=	Gas release rate, $m^3/h$
$Vr$	=	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
$m$	=	$\frac{Vr \times n}{L + (Vr \times n)}$

A worked example of the above method is given in Appendix 1.

#### 9.4 Risk evaluation

Risk is a combination of the likelihood of harm occurring and the severity of that harm. Consideration should be given to:

- People
- Environment
- Property

A risk matrix can be used to help you work out the level of risk associated with a particular issue. They do this by categorising the likelihood of harm and the potential severity of the harm. This is then plotted in a matrix. The risk level determines which risks should be tackled in which order. However, it does require expertise and experience to judge the relative likelihood of harm accurately.

Advice on risk matrices is available on the HSE website.

<http://www.hse.gov.uk/risk/faq.htm#hierarchy>

Any risks which are determined to be unacceptable (i.e. are not managed to a level characterised as ‘*as low as reasonably practicable*’) will require risk further control measures. Refer to Section 10.

Carry out re-assessment on a regular basis, including when a change occurs to the workplace, gas usage or storage, and in any event, from time to time.

## 10. IDENTIFYING RISK CONTROL MEASURES

Risks should be reduced to the lowest reasonably practicable level by taking preventative measures, in order of priority of effectiveness. This is what is meant by a hierarchy of control. The list below sets out a recommended order to follow when planning to reduce risks. To reduce the risk it may be necessary to use more than one type of control measure. Carefully consider each of the headings in the order shown, do not simply jump to the easiest control measure to implement.

- (i) **Elimination.** Redesign the task or process so that the hazard is entirely removed or eliminated. Refer to Section 10.1.
- (ii) **Substitution.** Replace the material, substance or process with a less hazardous one. Refer to Section 10.2.
- (iii) **Engineering controls.** Use work equipment or other measures to control risks from gases. Give priority to measures which protect collectively over individual protection in line with *The Management of Health and Safety at Work Regulations* (4). Refer to Section 10.3.
- (iv) **Administrative controls.** Identify and implement robust and effective procedures to ensure safety. Refer to Section 10.4.
- (v) **Personal protective equipment.** Only to be considered after all the previous measures have been applied and found not to have controlled the risks to the lowest reasonably practicable level. Refer to Section 10.5.

Control measures are those that will reduce the probability of a hazard for example, a hazardous atmosphere due to a gas release. The location of the gas storage, the control of gas usage, together with adequate ventilation, are the key risk control measures. Control measures from the recommended hierarchy set out above are discussed in further detail as follows:

## 10.1 Elimination

Remove the possibility of a hazardous atmosphere being created within an internal area. Where possible gas should be prevented from entering the workplace unintentionally.

Examples are:

- Carry out operations that use gases outside in the open air.
- Carry out operations in discrete areas isolated from the general workplace where there is adequate natural ventilation.
- Store gas sources, such as cylinders and tanks, outside. Refer to the relevant documents:
  - BCGA CP 26 (26), *Bulk liquid carbon dioxide at users' premises.*
  - BCGA CP 36 (28), *Cryogenic liquid storage at users' premises.*
  - BCGA CP 44 (29), *The storage of gas cylinders.*
  - BCGA CP 46 (30), *The storage of cryogenic flammable fluids.*

## 10.2 Substitution

Consider the properties of the gases in use and the environment(s) in which they will be used or may enter. Use the most appropriate gas, with the least hazard, for any particular situation. Examples include:

- When carrying out leak testing, instead of a flammable gas (hydrogen) use a non-flammable gas (helium).

NOTE: This will help manage flammability risks, but you will still need to consider and appropriately manage other risks, such as asphyxiation.

- When welding and cutting in confined spaces, such as underground, use a lighter than air gas, such as acetylene, rather than a heavy gas such as LPG.

## 10.3 Engineering controls

Prior to selecting engineering controls, understand which gases you have, their properties, the duration of use, the quantities, their location and their application in the workplace. Engineering controls isolate gases from personnel, may provide early detection of an accumulation of gas or control the release of gases by methods such as enclosing or extracting.

Engineering controls may require specialist knowledge. Where this is the case the controls will be required to be designed, installed and maintained by competent people.

Attention is drawn to the fact that equipment alone does not provide absolute protection, since such equipment can malfunction, be poorly maintained, be operated by non-competent persons, be out of calibration, be poorly located or be ignored.

Types of engineering control include:

- **Workplace ventilation.** This can be achieved by increasing natural ventilation (for example, by the use of additional louvres), using a whole workplace forced air ventilation system or providing local exhaust ventilation systems.

For further information on workplace ventilation refer to Appendix 2.

- **Atmospheric monitoring equipment.** Atmospheric monitoring equipment may be used to monitor the atmosphere in a specific area and to warn of changes which could create a hazardous atmosphere. These may include fixed or portable detection devices or a combination of both, as determined by risk assessment.

Independent sensors may be required for individual gases. As an example, separate sensors are required to measure carbon dioxide enrichment and to measure oxygen depletion, and different sensors may be needed to measure each of these within a specific background.

For further information on atmospheric monitoring refer to Appendix 3.

- **Pipework.** Distribute gas in to the work area through pipework of suitable integrity, at the lowest possible pressure and at a restricted flow-rate suitable for the work task and suitable for the ventilation capability. Provide over-pressure and flow-limitation control accordingly. Refer to BCGA CP 4 (25).
- **Exhausts.** Ensure that the exhausts from machines and pressure relief valves, vents etc. are directed to a safe area. Refer to EIGA Document 154 (21) and BCGA CP 4 (25).
- **Exclusion.** Provide a dedicated area that separates personnel from places where the gas might adversely affect the atmosphere, for example, a fume cupboard, a safety cabinet or an isolated compartment, where the activity exclusively takes place.

#### 10.4 Administrative controls

Design and put in to place safe systems of work for normal and non-routine activities for both operation and maintenance. For example, through:

- the provision of suitable information, instruction, supervision and training to those who need it, with a demonstration and record of competence;
- increasing hazard awareness through safety signage and other audio-visual safety systems, in accordance with *The Health and Safety (Safety Signs and Signals) Regulations (2)*;
- reducing the time workers are exposed to hazards (for example, by job rotation);
- restricting access to areas of concern;

- the use of permit to work systems to control specific tasks;
- health surveillance;
- Implementation of emergency procedures, to manage and prevent hazardous situations from escalating.

Special considerations are required for access to, and work in, a confined space. Refer to Appendix 4.

There are additional considerations where cryogenic or liquefied gases are in use, refer to Appendix 5.

### **10.5 Personal protective equipment.**

The work activity risk assessment will determine the requirement for the use of hazard controls, including any requirements for personal protective equipment (PPE). PPE may only be considered as a control to achieve an acceptable level of residual risk after other levels of control have been addressed. Where PPE is required a PPE Assessment shall be carried out. PPE shall be provided as required by the *Personal Protective Equipment Regulations* (5). The PPE shall be selected for a particular task, person and location and shall be appropriate and chosen to effectively reduce the overall risk. Thus there are different PPE requirements for differing products, different tasks and for different personnel. Due regard is to be given to the requirements of the *COSHH Regulations* (6), any relevant equipment publications, manufacturers information and the product Safety Data Sheet.

HSE L25 (15), *Personal Protective Equipment at Work*, provides guidance on the *Personal Protective Equipment Regulations* (5). EIGA Document 136 (20), *Selection of personal protective equipment*, provides guidance for selecting and using PPE at work.

Examples of PPE include:

- Personal atmospheric monitors, worn by an individual;
- Breathing apparatus (for emergency activities or special short term cases);
- Flame retardant clothing (for flammable gases);
- Suitable clothing for specific environments, for example, insulative / thermal clothing for cold atmospheres, anti-static footwear for flammable-gas environments, etc.;
- Separate and / or specific PPE for different products, for example, when handling cryogenic liquids.

## **11. EMERGENCY SITUATIONS**

Prepare for and understand how to deal with emergency situations if they arise.

Wherever gases are in use or in storage, alongside normal and abnormal operating procedures, emergency procedures shall also be established and implemented. The emergency procedures should consider:

- Identifying an emergency situation;
- Raising the alarm;
- Immediate actions for employees;
- How to prevent escalation, for example, through options for safe isolation of the gases; use of automated or remote shutdown (or alternatively, a risk assessed decision made to 'walk away' from the hazardous atmosphere and equipment whilst the gas supply safely expends itself);
- Safe evacuation, to a safe point of assembly, and roll-call;
- Clarification of person in charge (covering all shift patterns and foreseeable circumstances);
- Rescue arrangements Refer to the note below
- Assessment of potential escalation – Who else may be affected? Ventilation of the workplace at various phases of the emergency. Secondary or collateral hazards due to the effect of the emergency or the foreseeable progress of an emergency situation. These may include, for example, the formation of unusual gas mixtures, fumes, vapours or atmospheres, machinery damage / malfunction resulting in secondary hazards, emergency cascade or domino effects, access or egress restrictions etc.;
- Communication (to workforce, management, neighbours, emergency services), including sharing of the emergency plans, or relevant parts thereof);
- When and how to call the emergency services. Consider if pre-contact with emergency services (especially the Fire and Rescue Service) might be suitable and beneficial;
- Assessment of situation leading to recovery procedures. When is it safe to return? Sampling of the atmosphere. Who is authorised to give the 'all clear'? etc.;
- Recovery;
- Incident investigation. Preservation of evidence;
- Lessons learned – Review risk assessment and control measures, including emergency plans;
- Testing of the procedures, including out-of-hours.

NOTE: Most deaths in confined spaces are of those who attempt rescue. It cannot be over-emphasized that ill-considered rescue attempts shall be avoided.

When working in or near areas where gases are in use or in a confined space, if a person suddenly collapses and no longer gives any sign of life, assume that the person may lack oxygen due to the presence of an asphyxiating atmosphere. Prevent colleagues rushing to their aid unless competent and equipped to do so, for example, with breathing apparatus.

**WARNING:** Do not enter a confined space without adequate preparation and risk assessment – the biggest risk is that you will become the second victim. **Get proper assistance and support, and work according to the confined space entry procedures and an emergency plan.**

## 12. REFERENCES

	<b>Document Number</b>	<b>Title</b>
1.	SI 1996 No. 192	The Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996.
2.	SI 1996 No. 341	The Health and Safety (Safety Signs and Signals) Regulations 1996.
3.	SI 1997 No. 1713	Confined Spaces Regulations 1997.
4.	SI 1999 No. 3242	The Management of Health and Safety at Work Regulations 1999.
5.	SI 2002 No. 1144	The Personal Protective Equipment Regulations 2002
6.	SI 2002 No. 2677	The Control of Substances Hazardous to Health Regulations 2002 (COSHH).
7.	SI 2002 No. 2776	The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR).
8.	HSE EH 40	Workplace exposure limits.
9.	HSE Research Report RR 973	Review of alarm settings for toxic gas and oxygen detectors.
10.	HSE HSG 37	An introduction to local exhaust ventilation.
11.	HSE HSG 54	Maintenance, examination and testing and testing of local exhaust ventilation.
12.	HSE HSG 250	Guidance on permit-to-work systems. A guide for the petroleum, chemical and allied industries.

	<b>Document Number</b>	<b>Title</b>
13.	HSE INDG 258	Confined spaces. A brief guide to working safely.
14.	HSE INDG 459	Oxygen use in the workplace. Fire and explosion hazards.
15.	HSE L25	Personal Protective Equipment at Work.
16.	HSE L101	Safe work in confined spaces. Confined Space Regulations 1997. Approved Code of Practice and guidance.
17.	HSE L138	Dangerous substances and explosive atmospheres. Dangerous substances and explosive atmospheres Regulations 2002. Approved Code of Practice and guidance.
18.	EIGA Document 04	Fire hazards of oxygen and oxygen enriched atmospheres.
19.	EIGA Document 40	Work permit systems.
20.	EIGA Document 136	Selection of personal protective equipment.
21.	EIGA Document 154	Safe location of oxygen and inert gas vents.
22.	EIGA Safety Leaflet 01	Asphyxiation – The hidden killer.
23.	EIGA Safety Information Sheet 24	Carbon dioxide physiological hazards “Not just an asphyxiant”.
24.	EIGA Safety Information Sheet 29	Oxygen deficiency hazard associated with hypoxic fire suppression systems using nitrogen injection.
25.	BCGA Code of Practice 4	Industrial gas cylinder manifolds and distribution pipe work (excluding acetylene).
26.	BCGA Code of Practice 26	Bulk liquid carbon dioxide at users’ premises.
27.	BCGA Code of Practice 30	The safe use of liquid nitrogen dewars up to 50 litres.
28.	BCGA Code of Practice 36	Cryogenic liquid storage at users’ premises.
29.	BCGA Code of Practice 44	The storage of gas cylinders.
30.	BCGA Code of Practice 46	The storage of cryogenic flammable fluids.
31.	BCGA Guidance Note 13	DSEAR Risk assessment.

	<b>Document Number</b>	<b>Title</b>
32.	BCGA Technical Information Sheet 27	Model risk assessment for the safe use of liquid nitrogen dewars.
33.	BCGA Technical Information Sheet 30	Working in reduced oxygen atmospheres.
34.	BCGA Technical Information Sheet 35	Model risk assessment for the management of the atmosphere in the workplace when using gases.
35.	CoGDEM	The CoGDEM guide to gas detection.

Further information can be obtained from:

UK Legislation [www.legislation.gov.uk](http://www.legislation.gov.uk)

Health and Safety Executive (HSE) [www.hse.gov.uk](http://www.hse.gov.uk)

European Industrial Gases Association (EIGA) [www.eiga.eu](http://www.eiga.eu)

British Compressed Gases Association (BCGA) [www.bcgaco.uk](http://www.bcgaco.uk)

The Council of Gas Detection and Environmental Monitoring (CoGDEM) [www.cogdem.org.uk](http://www.cogdem.org.uk)

### EXAMPLE CALCULATIONS

#### **Preliminary Assessment: Example for an asphyxiant gas**

Refer to Section 9.1.

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

$$C = 100 \frac{V_o}{V_r}$$

Where:

Water capacity = 50 litre

Pressure = 200 bar

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

$V_o = 0.21 (V_r - \text{Volume of gas in cylinder})$

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

$$V_o = 0.21 (75 - 10) = 13.65 \text{ m}^3$$

$$\text{Resulting oxygen concentration, } C = 100 \frac{V_o}{V_r} = 100 \times \frac{13.65}{75} = 18.2 \%$$

This oxygen concentration is below the minimum workplace concentration for normal working (refer to Section 5.1.1).

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 should be assessed but are unlikely to be required in this case.

**Preliminary Assessment: Example for a liquefied gas**

Refer to Section 9.1.

One 6.35 kg carbon dioxide cylinder being used in a workplace with a free air volume of 75 m<sup>3</sup>.

$$C = 100 \frac{V_o}{V_r}$$

Where:

$$\text{Weight} = 6.35 \text{ kg}$$

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

$$V_o = \text{Volume of gas in the cylinder} = \text{Weight (of product)} \times \text{Specific Volume (at 1.013 bar \& 15 }^\circ\text{C)} = 6.35 \times 0.5344 = 3.4 \text{ m}^3$$

$$\text{Resulting gas concentration, } C = 100 \frac{V_o}{V_r} = 100 \times \frac{3.4}{75} = 4.5 \%$$

HSE have defined a workplace exposure limit for carbon dioxide of 0.5 % averaged over 8 hours, with a maximum exposure of 1.5 % for short periods of 15 minutes (refer to Section 5.3.2). 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.

**Detailed Risk Assessment: Example**

Refer to Section 9.3

An inert gas is being used in a work place with a free air volume of 32 m<sup>3</sup>, the gas flow rate is 1.1 m<sup>3</sup>/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:

$$OC_t = 100 \left( 0.21 + \left( \left[ \frac{0.21 \times n}{\left( \frac{L}{Vr} \right) + n} \right] - 0.21 \right) \left( 1 - e^{-t/m} \right) \right)$$

Where:

OC<sub>t</sub> = Oxygen percentage concentration after defined time

L = 1.1 m<sup>3</sup>/h

Vr = 32 m<sup>3</sup>

n = 0.4 per hour

t = 2 hours

e = 2.72

m =  $\frac{Vr \times n}{L + (Vr \times n)} = \frac{32 \times 0.4}{1.1 + (32 \times 0.4)} = 0.92$

$$OC_t = 100 \left( 0.21 + \left( \left[ \frac{0.21 \times 0.4}{\left(\frac{1.1}{32}\right) + 0.4} \right] - 0.21 \right) \left( 1 - 2.72^{-2/0.92} \right) \right)$$

$$OC_t = 100 \left( 0.21 + \left( \left[ \frac{0.084}{0.434} \right] - 0.21 \right) (0.886) \right)$$

$$OC_t = 100 (0.21 + (-0.0165)(0.886))$$

$$OC_t = 100 (0.21 + (-0.0146))$$

$$OC_t = 100 (0.1954)$$

$$OC_t = 19.54 \%$$

The concentration of oxygen in the air is 19.54 %.

The oxygen concentration in the workplace has dropped to 19.54 %, which is just above the minimum recommended (19.5 %, refer to Section 5.1.1.) and above the potentially dangerous level (18 %). However it should be noted that if the activity continues for 5 hours the oxygen concentration will drop to 19.3 %. By increasing the ventilation air change ratio to 1 would maintain the oxygen level at approximately 20.3 %.

## **WORKPLACE VENTILATION**

Additional ventilation can be achieved by increasing natural ventilation, using a whole workplace forced air ventilation system or by providing local exhaust ventilation systems (LEV).

The HSE provide guidance on ventilation systems on their website and within HSG 37 (10), *An introduction to local exhaust ventilation*, and HSG 54 (11), *Maintenance, examination and testing and testing of local exhaust ventilation*.

Building size, ventilation capacity, system pressures etc. shall each be considered in specific cases. The following guidelines generally apply:

- Ventilation should be continuous or interlocked with the gas supply such that the ventilation system operates whenever gas is being supplied or when personnel are likely to access the hazardous area. Interlocks functionality should be checked routinely.
- If a forced air ventilation system is used, it should be connected to the atmospheric monitoring equipment system to allow automatic operation, refer to Appendix 3.

**NOTE:** Where there is a reliance on forced air ventilation to prevent a hazardous accumulation of gases the ventilation system shall be verified at least every 14 months, refer to the COSHH Regulations (6).

- The ventilation system design should ensure adequate airflow around the normal operating area to prevent a hazardous atmosphere.
- The ventilation system should be compatible with all the gases that are in use. For example, where a flammable gas is in use then the system may be within the scope of the *Dangerous Substances and Explosive Atmospheres Regulations (DSEAR)* (7) and the *Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations* (1). For additional information refer to HSE L138 (17), *DSEAR. Approved Code of Practice and guidance*.
- 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.

## **APPENDIX 2**

Sheet 2 of 2

- Ventilation exhaust lines should be clearly identified and piped to a safe, external, well-ventilated area. Lines should be periodically inspected to ensure they remain in a serviceable condition, for example, there is no unacceptable damage and they are not blocked, refer to BCGA CP 4 (25).

## **ATMOSPHERIC MONITORING EQUIPMENT**

Atmospheric monitoring equipment (often referred to as ‘gas detection equipment’) is used to monitor the atmosphere in a specific area and to warn of changes which could create a hazardous atmosphere. These may be fixed or portable devices or a combination of both.

The requirement for and location of atmospheric monitoring equipment shall be determined by risk assessment. The risk assessment should indicate the appropriate location(s) for the detector / monitor measurement head(s).

Separate gas sensors (and where necessary, systems) shall be provided for the different foreseeable atmospheric monitoring duties. For example, separate sensors are necessary for carbon dioxide enrichment and for oxygen deficiency.

In many circumstances fixed atmospheric monitoring equipment is preferable to personal mobile equipment. Fixed equipment has an improved ability to detect hazards before a person is exposed, whereas personal equipment generally confirms that the person is about to be or may already be exposed to the hazard (which may be too late). Fixed equipment also covers an area, rather than the spot location where an individual happens to be.

Atmospheric monitoring equipment shall be to a recognised national or international quality and performance standard.

Atmospheric monitoring equipment shall be installed, used and maintained in line with the manufacturer’s recommendations.

The atmospheric monitoring equipment status shall be checked for serviceability before entry to the protected area and during occupancy. Alarm warnings, for example, flashing lights, audible alarms, etc, shall be clearly visible and shall be duplicated / repeated both outside (i.e. at all access points) and inside the workspace. Appropriate, clear and legible warning signs shall be provided (for example, ‘*Do not enter unless monitoring system shows no fault/safe to enter condition*’, ‘*Evacuate the area in the event of gas alarm*’, etc.), located appropriately and, where of potential benefit, repeated in several locations.

Personnel competence development programmes shall include clear details of the atmospheric monitoring equipment and the actions to take to ensure safe entry to confined spaces, maintenance / checking of the system, verifying status, how to respond to alarms, etc.

Where forced air ventilation systems are used, they should interconnect with the atmospheric monitoring equipment to allow automatic operation, refer to Appendix 2. What ‘automatic operation’ precisely means will depend upon the details of the overall control system(s). An integrated control system should be provided, in line with the Risk Assessment. Whilst it is not possible to provide definitive advice that will apply to all installations and circumstances, the following points should be considered in relation to system control integration:

- Will the ventilation automatically trigger in the event of a gas detection alarm?

- Is there value in installing multi-stage alarms (different percentage concentration detection) to trigger corresponding multi-speed\_ventilation fans?
- What fan overrun time should be applied, before an alarm resets?
- What self-diagnostics should the system(s) include?
- Is auto detection of ventilation failure (flow switches, differential pressure switches, etc.) desirable for the system?
- Should the ventilation system operate even when personnel entry is not required, or for a specific period in advance of entry?
- Will the alarm activate in the event of gas detection or ventilation fault / failure?
- Can or should inter-locking of access doors be included in the system functionality, to prevent entry during an alarm?
- Can remote automatic shut-down of the dispense system be included, in the event of alarm?
- Is an uninterruptable power supply (UPS) desirable for whole or part of the system, for example, critical control functionality or lock-outs?
- Auto detection of ventilation failure (flow switches, differential pressure switches, motor overload or underload, etc.)?
- Should the system(s) be linked to the premises fire alarms, taking account of the desirability of disabling the ventilation fans in the event of fire?
- How will system outages be managed (for example, for planned maintenance)?
- Should you be using data-logging functions to regularly review for non-alarm gas events in case these show trends or the need for investigation or intervention?
- Should ancillary systems (for example, refrigeration fans) be incorporated into the ventilation system (for example, where they might enhance the ventilation, rather than just recirculate the confined space atmosphere)?

The gas detection / ventilation system(s) shall be subject to a formally planned and recorded maintenance programme that includes calibration, periodic functional and end-to-end testing, (often known as ‘bump testing’), alarm and interlock checks, lamp (bulb) checks for visual alarms or annunciators and the periodic replacement of critical or wearing components, etc.

For additional information on atmospheric monitoring refer to:

- HSE RR 973 (9), *Review of alarm settings for toxic gas and oxygen detectors*.
- The CoGDEM guide to gas detection (35)

## WORK IN CONFINED SPACES

Any workplace designated as a 'confined space' following Risk Assessment shall then be assessed against the requirements of the *Confined Spaces Regulations* (3) and be subject to specific control measures before entry. In most cases the assessment will include consideration of:

- the task(s);
- the working environment;
- working materials and tools;
- the suitability of those carrying out the task;
- arrangements for emergency situations.

Some confined spaces are fairly easy to identify, for example, 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, for example, tank bunds, dry ice containers, etc. Care should be taken not to lean into such spaces.

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

- Analysis of the space for oxygen, flammable or toxic gases.
- Purging of the space with air. In the specific case of flammable gases, an inert gas purge shall be used first to prevent any explosion risk and then a subsequent purge with air.
- The use of a Permit to Work system.

Information on Permit to Work systems can be obtained from HSE HSG 250 (12), *Guidance on permit-to-work systems. A guide for the petroleum, chemical and allied industries*, and EIGA Document 40 (19), *Work permit systems*.

- The isolation, disconnection, sealing and spading of pipework.

NOTE: Rendering pipework pressure gas-tight is significantly different from pipe 'spading'.

- The use of interlock control devices.
- The use of additional PPE, for example, breathing apparatus. Refer to Section 10.5.
- Emergency planning. Refer to Section 11.

Entry in to confined spaces is a legislated activity covered by the *Confined Spaces Regulations* (3). HSE provide further information on working in confined spaces within:

- HSE L101 (16), *Safe work in confined spaces. Confined Space Regulations 1997. Approved Code of Practice and guidance*.
- HSE INDG 258 (13), *Confined spaces. A brief guide to working safely*.

**CONSIDERATIONS FOR CRYOGENIC OR LIQUEFIED GASES**

Ensure the location and installation of gas supply equipment is in accordance with good engineering practice and in-line with the manufacturers' guidance and industry best practice, refer to Section 10.1.

**NOTE:** Should the storage of cryogenic or liquefied gas be in close proximity to the workplace, there is the potential for released gases to enter. For example, the storage is located too close to openable windows or doors in buildings, too close to breather bricks, too close to ventilation / HVAC equipment intakes, etc.). In such cases it is advised that the location of the storage area is reviewed against current best practice and, as necessary, adopted retrospectively.

If multiple liquid storage 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 tank or system at a time.

Storage tank fill couplings should be located in well-ventilated areas. Anti-tow away and/or break-away protection for flexible hoses may be fitted to prevent liquid spillage due to inadvertent movement of tank / delivery vehicle. The fitting of excess flow valves can also prevent excessive spillage.

The risk assessment shall consider the location of pipework for liquid lines. Vent pipework, liquid lock relief valves and equipment exhaust ports should be located in safe, freely ventilated places. Pipe-back relief valves may be considered as an alternative to liquid lock relief valves, as this will remove the need to pipe-away to a remote, safe area.

When moving liquid gas in 'open' containers such as dewars, the risk assessment shall take into account the potential hazards which may result from, for example, spillage, venting, etc.

When transporting storage tanks that are fitted with overpressure protection such as relief valves, bursting discs and specialist transport valves, consideration should be given to the possibility of these devices operating and creating a hazardous atmosphere whilst being transported. It should be appreciated that vehicle movement and vibration can increase the evaporation rate of the liquid compared to true static conditions. Movement can also promote premature and unintended venting due to jolting and vibration of, for example, relief device springs.



**British Compressed Gases Association**

[www.bcgga.co.uk](http://www.bcgga.co.uk)