HAZARDS OF OXYGEN-DEFICIENT ATMOSPHERES

Doc 44/18

Revision of Doc 44/09

EUROPEAN INDUSTRIAL GASES ASSOCIATION AISBL

AVENUE DES ARTS 3-5 • B – 1210 BRUSSELS
Tel: +32 2 217 70 98 • Fax: +32 2 219 85 14
E-mail: info@eiga.eu • Internet: www.eiga.eu

HAZARDS OF OXYGEN-DEFICIENT ATMOSPHERES

As part of a programme of harmonization of industry standards, the European Industrial Gases Association (EIGA) has issued EIGA Doc 44, *Hazards of oxygen-deficient atmospheres*, jointly produced by members of the International Harmonization Council.

This publication is intended as an international harmonized publication for the worldwide use and application by all members of Asia Industrial Gases Association (AIGA), Compressed Gas Association (CGA), European Industrial Gases Association, and the Japan Industrial and Medical Gases Association (JIMGA). Regional editions have the same technical content as the EIGA edition, however, there are editorial changes primarily in formatting, units used and spelling. Regional regulatory requirements are those that apply to Europe.

EUROPEAN INDUSTRIAL GASES ASSOCIATION AISBL
Avenue des Arts 3-5 B 1210 Brussels Tel +32 2 217 70 98 Fax +32 2 219 85 14
E-mail: info@eiga.eu Internet: www.eiga.eu

Table of Contents

1 Introduction

The industrial gas industry is very concerned about the incidents that industrial gas companies and users of inert gases continue to report each year, where the direct cause has been lack of oxygen resulting in asphyxiation.

There are two essential points to remember related to oxygen-deficiency incidents involving inert gases:

- Incidents resulting from oxygen deficiency due to inert gases happen unexpectedly and the reactions of personnel can be incorrect; and

- Incidents involving asphyxiating atmospheres are always serious, if not fatal.

2 Scope and purpose

This publication sets out the essential information necessary to prevent asphyxiation incidents involving inert gases.

It is not a detailed procedure for confined space entry but focuses on the considerations that are important when there is an actual or potential hazard from inert gases or oxygen deficiency.

The minimum safe oxygen concentration for entry into a space is 19.5% oxygen. There are applications with oxygen concentrations less than 19,5% where entry is permitted provided that further precautions are taken in accordance with proper risk assessment and national regulations.

This publication is intended for supervisors, line managers, direct workers and users wherever inert gases are produced, stored, used, or where oxygen depletion could otherwise occur.

Appendix A is a simplified summary of the main publication.

Appendix B lists some actual incidents that have taken place in recent years and may be used as examples to underline the potentially fatal hazards of inert gases.

Other hazards exist with oxygen-enriched atmospheres greater than 23.5% oxygen. When presented with an oxygen-enriched atmosphere, see EIGA Doc 04, *Fire Hazards of Oxygen and Oxygen Enriched Atmospheres*, for more information [1].

Although carbon dioxide is not an inert gas, most of the information in this publication is applicable as it too will cause oxygen depletion. This publication does not cover the specific hazards and physiological effects of carbon dioxide, see EIGA Safety Information 24, *Carbon Dioxide Physiological Hazards – "Not just an Asphyxiant!"* or CGA G-6, *Carbon Dioxide*, for more details about the additional hazards of carbon dioxide [2, 3].

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Anoxia

Abnormally low amount of oxygen in body tissues.

3.2.2 Asphyxiant

Material that reduces the amount of available oxygen either by simple dilution or by reaction.

3.2.3 Asphyxiation

Effect on the body of inadequate oxygen, usually resulting in loss of consciousness and/or death.

3.2.4 Confined space

Area not necessarily designed for people, that has limited or restricted means for entry or exit, and is not designed for continuous occupancy but which is large enough for workers to enter and perform certain jobs [4].

NOTE—Confined spaces include, but are not limited to, tanks, vessels, silos, storage bins, hoppers, vaults, pits, manholes, tunnels, equipment housings, ductwork, pipelines, etc.

3.2.5 Enclosure

Any type of architecture (for example, building, shed, bungalow) composed of five walls (one roof and four walls) allows workers to enter and perform certain jobs occasionally or permanently.

NOTE—An enclosure is also known as an enclosed space.

3.2.6 Flammable gas

Gas having a flammable range in air at 20 °C and a standard pressure of 101.3 kPa.

3.2.7 Inert gas

Gas that is not toxic, doesn’t support human breathing, and reacts scarcely or not at all with other substances.

3.2.8 Partially enclosed

Any type of architecture composed of three or four walls (including a roof) that allows workers to enter and perform certain jobs occasionally or permanently.

3.2.9 User

Individuals, companies, or other organisations that make use of the products sold by industrial gas companies.

NOTE—Users can be, but are not necessarily, customers.

4 General information about inert gases and oxygen depletion

In spite of the wealth of information available such as booklets, films, and audio-visual aids, there are still serious incidents resulting in asphyxiation caused by the improper use of inert gases or by oxygen depletion. It is therefore essential to draw attention to the hazards of inert gases and oxygen depletion.

4.1 Oxygen is essential for life

Oxygen is the only gas that supports life. The normal concentration of oxygen in the atmosphere is approximately 21%. The ability to concentrate, think, and make decisions is impaired when the oxygen concentration falls only slightly below atmospheric levels. These effects are not noticeable to the affected individual.

If the oxygen concentration in air decreases or if the concentration of any other gases increase, a situation is rapidly reached where the risks of asphyxiation are significant. For this reason, any depletion of oxygen below 19,5% shall be treated with concern.

An oxygen-deficient atmosphere can bring about unconsciousness without warning. In as little as one or two breaths, an individual's life can be endangered by low oxygen intake. Table 1 describes a quantitative evaluation of the health effects and symptoms that can be expected in humans who inhale air containing less than normal levels of oxygen.

4.2 Inert gases give no warning

It is essential to understand that with inert gases, asphyxia can occur with no warning.

Inert gases are odourless, colourless, and tasteless. They are undetectable and can therefore be a great deal more dangerous than toxic gases such as chlorine, ammonia, or hydrogen sulfide, which can be detected by their odour at very low concentrations.

The asphyxiating effect of inert gases occurs without any preliminary physiological sign that could alert the victim. Lack of oxygen can cause vertigo, headache or speech difficulties, but the victim is not capable of recognising these symptoms as asphyxiation. Asphyxiation leads rapidly to loss of consciousness—for very low oxygen concentrations this can occur within seconds.

Table 1—Effects at various oxygen breathing levels

Oxygen percent at sea level (atmospheric pressure = 760 mmHg)	Effects
20.9	Normal (below 19.5% is considered oxygen deficient)
19.5 – 10	Increased breathing rates; accelerated heartbeat; and impaired attention, thinking, and coordination
10 – 6	Nausea, vomiting, lethargic movements, and perhaps unconsciousness
<6	Convulsions, then cessation of breathing, followed by cardiac standstill (death). These symptoms can occur immediately.

NOTES

1 Adapted from Title 29 of the U.S. *Code of Federal Regulations*, Parts 1910 and 1926 [4].

2 These indications are for a healthy average person at rest. Factors such as individual health (being a smoker), degree of physical exertion, and high altitudes can affect these symptoms and the oxygen levels at which they occur.

3 A hazardous atmosphere oxygen concentration range as defined by OSHA is outside the range of 19,5% and 23,5% [4].

4 While the percentage of oxygen does not change with altitude, the partial pressure of the atmosphere decreases, which creates physiological effects similar to oxygen deficiency. These effects increase at higher altitudes. Working at altitudes above 2 438 m (8 000 ft) can have similar effects to working in a 15% oxygen atmosphere and working at altitudes of 4 267 m (14 000 ft) can have effects similar to a 12% oxygen atmosphere. Precautions such as supplemental oxygen and acclimatisation shall be taken when working at altitudes to protect the employees against the effects of altitude sickness and other physiological effects similar to those experienced with decreasing oxygen concentrations. Consult knowledgeable medical and safety professionals regarding the specific precautions to take when working at high altitudes.

WARNING: *Exposure to atmospheres containing less than 10% oxygen can rapidly overcome an individual and bring about unconsciousness without warning so the individual cannot help or protect themselves. Lack of sufficient oxygen can cause serious injury or death.*

4.3 Inert gases act quickly

In any incident when the supply of oxygen to the brain is affected, prompt emergency treatment is critical. Medical treatment such as resuscitation if given promptly can prevent irreversible brain damage or even death in some circumstances.

An emergency rescue procedure shall be planned in advance to avoid the possibility of the rescue team becoming victims also. Unplanned interventions resulting in the fatalities of would-be rescuers have occurred on multiple occasions.

Workers suddenly involved in emergency activities shall not allow emotions to override safe work procedures and training. Only qualified and trained personnel equipped with the necessary personal protective equipment (PPE) should attempt a rescue in accordance with the company's rescue procedures.

4.4 The ambiguity of inert gases

An inert gas is often thought to be a harmless gas. Individuals shall be aware of the ambiguity of the expression "inert gas," sometimes called "safety gas," when it is used to prevent fire or explosion. An inert gas can be applied as a safety gas, but it is not without its own risks (such as asphyxiation).

4.5 Awareness with regard to inert gases and oxygen depletion

Considering the hazards of inert gases, it is essential to provide all those who handle or use inert gases with the information and training necessary regarding safety instructions. This includes the means of prevention and procedures to be followed to avoid incidents, as well as planned rescue procedures to be implemented in the event of an incident.

5 Typical situations with inert gas and/or oxygen depletion hazards

Poorly ventilated areas, confined spaces, areas immediately outside confined spaces, enclosures, and low-grade areas can contain oxygen-deficient atmospheres. Work performed in confined spaces shall follow specific regulatory requirements.

NOTE Oxygen depletion can also be caused by the presence of any gas other than oxygen such as a flammable gas or a toxic gas.

5.1 Confined or enclosed spaces

An oxygen-deficient atmosphere can bring about unconsciousness without warning. In as little as one or two breaths, an individual's life can be endangered by low oxygen intake. Oxygen-deficient atmospheres are not limited to confined spaces, they also can exist outside of a confined space opening.

Examples of areas where oxygen-deficient atmospheres can exist include:

- storage tanks, vessels, reservoirs, the inside of coldboxes of liquefaction equipment, cold storage rooms, warehouses with fire suppressant atmospheres;
- outside confined space openings;
- analyser or instrument cabinets, small storage sheds, temporary/tented enclosures, or spaces where welding protective gas is used; and
- underground works and trenches/pits deeper than 1 m (3.28 ft).

5.2 Use of inert cryogenic liquids

The use of inert cryogenic liquids such as nitrogen or helium is accompanied by two primary hazards:

- They are very cold (–196 °C [–320.8 °F] for nitrogen and –269 °C [–452.2 °F] for helium) and can cause cold burns on contact with the skin; and
- Once vaporised, both products will generate a large volume of cold inert gas (for example, 1 litre of liquid nitrogen yields 0.65 m^3 gaseous product) that will displace ambient air, causing oxygen deficiency, and could accumulate in low points.

In processes where cryogenic liquids are handled and vaporisation takes place, care shall be taken to avoid situations where personnel are exposed to oxygen deficiency.

Examples of such spaces include:

- internal rooms of a building where cryogenic liquid cylinders/dewars are filled and/or stored;
- outdoor or enclosed storage tank areas where nitrogen is dispensed;
- laboratory rooms;
- elevators (lifts) used for transport of dewars;
- rooms where liquid nitrogen food freezers are operated;
- rooms where magnetic resonance imaging (MRI) scanners or other liquid helium-cooled equipment is used;
- rooms in which cryogenic deflashing equipment is operated;

- ASU control rooms;

- rooms where nitrogen is used as an instrument gas (see CGA P-78, *Guideline for the Safe Use of Instrument Air Systems Backed Up by Gases Other than Air*) [5]; and

- cryotherapy rooms.

Due to the extremely low temperature of liquid helium and liquid nitrogen, a secondary hazard can exist when the product is flowing through hoses or pipes. The components of air can liquefy on the outside of the hose or pipe, possibly leading to pooling of liquid that contains levels of enriched oxygen, see EIGA Doc 04 [1].

5.3 Areas near where inert gases are vented or can collect

The risk of asphyxiation can occur outdoors in the vicinity of:

- gas leaks;

- vent exhausts;

- safety valve and rupture disk outlets;

- openings of machines in which liquid nitrogen is used for freezing;

- blind flanges when they are removed;

- near manways/access to vessels or purged enclosures (for example, ASU coldboxes, electrical enclosures);

- near openings to confined spaces; and

- temporary access platforms by vent outlets in production sites.

Any cold gas or heavier-than-air gas will travel or flow—often unseen—and collect, even outdoors, in low spaces such as culverts, trenches, machine pits, basements, elevator (lift) shafts, and other low-lying areas.

Similarly, and just as dangerously, lighter-than-air gases such as helium will rise and collect in unventilated high points such as behind false ceilings or under a roof.

An assessment shall be carried out prior to installing access near any vent or opening to address the risk of an oxygen-deficient atmosphere.

5.4 Use of inert gas instead of air

5.4.1 Planned use

In many workplaces, compressed inert gas distribution networks are often used for process applications, safety, or instrumentation purposes (for example, inerting/purging of reactors or using nitrogen as a pressure source to operate pneumatic equipment or instruments).

Additionally, nitrogen is often used as either a backup to, or substitute for, an instrument air system. When used as a backup supply in case of an instrument air supply failure, it is common to find a nitrogen supply connected to an air supply by means of isolation valves. Most pneumatically operated instruments vent continuously, which means the vented nitrogen can accumulate in poorly ventilated control panels/cubicles or plant rooms. This can present a serious asphyxiation risk. When nitrogen is temporarily used to substitute for instrument air, it shall be carried out under strictly controlled conditions such as through a work permit. All relevant personnel shall be alerted of this change.

5.4.2 Improper use

When piped breathing systems are used, there is always the potential for employees or contractors who are insufficiently trained or not familiar with the systems to connect the breathing apparatus to a nitrogen system with fatal results. Such systems shall be clearly marked and ideally the breathing air system should have a dedicated connection type not used elsewhere on the premises.

5.5 Vessels containing adsorbents

Many adsorbents can adsorb nitrogen preferentially to oxygen. Over time, these adsorbents can release nitrogen, leading to an unsafe atmosphere. In such cases, even if the oxygen content is checked prior to entry in the vessel, the atmosphere can change over time.

6 Hazard mitigation and preventive measures

6.1 Training

Individuals who handle or use inert gases shall be informed of:

- safety measures that are required when using inert gases;
- hazards represented by the release of inert gases in to the working space and the potential for oxygen depletion; and
- procedures to be observed if an incident occurs.

This information and training should be systematically and periodically reviewed to ensure that it remains up-to-date and appropriate for the hazards identified.

6.2 Proper installation and operation

Equipment for the manufacture, distribution, or use of inert gas shall be installed, maintained, and used in accordance with all applicable regulations, the recommendations of the supplier, and industrial gas industry standards.

Newly assembled equipment for inert gas service shall undergo a proof test and be leak checked using suitable procedures.

Each inert gas pipeline entering a building should be provided with a readily accessible isolation valve outside the building. Ideally such valves should be remotely activated by push buttons or other safety-monitoring equipment.

Inert gas lines that are no longer required shall be physically disconnected from the supply system when not in use.

When not in use, all valves that isolate the inert gas line shall be closed to reduce the potential for leakage.

6.3 Identification and safeguarding of potentially hazardous areas

Potentially hazardous areas shall be identified or have their access restricted. Examples include:

- Warning signs displayed to inform of an actual or potential asphyxiation hazard. The warning sign should be associated with measures to prevent unauthorised entry to the areas. See Figure 1 for an example of a warning sign;
- Temporary or permanent barricades (for example, a physical lock on a vessel manway or barricades around temporary excavations); and

- Communication to site personnel to ensure awareness and understanding.

Figure 1—Example of a warning sign for asphyxiation hazard

6.4 Ventilation and atmospheric monitoring for inert gases and oxygen deficiency

There are a number of situations where the need for ventilation or atmospheric monitoring shall be assessed in order to avoid asphyxiation incidents from inert gases and/or oxygen depletion.

The occurrence of an oxygen-deficient atmosphere within an area depends upon the ventilation of the area, the volume of the space, and how much gas (flow rate or quantity) could be released. From this consideration, a risk assessment shall be carried out and suitable control measures implemented to reach the expected level of safety.

6.4.1 Ventilation and monitoring of enclosures

Examples of enclosures include rooms that contain inert gas piping with possible leaks such as compressor houses, control rooms (with control/analyser panels), and rooms where inert cryogenic liquid is used or stored (see 5.2).

Building/room size, ventilation capacity, and system pressures shall be determined for each specific case. The following control measures may be applied to ventilation system design:

- Continuous ventilation while the hazard exists. This can be achieved by interlocking the ventilation system with the process power supply;
- Adequate air flow around the normal operating areas;
- Minimum ventilation capacity of 6 air changes per hour;
- Use of devices to indicate incorrect system operation, such as:
    - warning lights
    - audible alarm
    - “streamers” on the fan or air vent
    - flow switches in the suction channels (monitoring should not rely only upon secondary controls such as “power on” to the fan motor); and
- Exhaust lines containing inert gases are clearly identified and piped away to a safe, well-ventilated area outside the building, away from fresh air intakes.

People working in or entering the area shall be aware of the action required in event of alarms from atmospheric monitors or loss of ventilation.

Consideration should also be given to the use of workplace atmospheric monitoring, for example, wearing a personal oxygen analyser or installing an analyser in the work area. The location of the monitor shall be based on an assessment of the areas described in 5.3.

6.4.2 Monitoring of partial enclosures

The following control measures can be applied for the monitoring of partial enclosures:

- Exhaust and purge lines containing inert gases are clearly identified and piped away to a safe area outside the building, away from fresh air intakes;
- Oxygen-deficient atmospheric monitoring (fixed or personal) and its location shall be determined by risk assessment; and
- People working in or entering the area shall be aware of the action required in event of alarms from atmospheric monitors.

6.4.3 Ventilation and monitoring prior to entry into confined spaces

As described in 5.1, confined spaces can include storage tanks, vessels, and other process equipment that:

- are not routinely entered;
- can contain inert gas or low concentration of oxygen; or
- have not been verified to contain atmospheric air.

The following shall apply to ensure a safe atmosphere prior to entry:

- Sources of inert gas shall be isolated from the space or enclosure by suitable methods such as blinds or double block and bleed, or by the disconnection of lines. There could be additional regulatory requirements to be followed for confined space entry;
- The storage tank, vessel, or enclosure shall be purged with air to remove the inert gas and replaced with air as follows:
    - It is necessary to have at least three complete air changes within the enclosure involved
    - Purging shall continue until analysis confirms that the quality of the storage tank atmosphere is safe for personnel entry. An analysis should be performed in the interior of the storage tank by taking a sample at several locations by probe or, if this is not possible, by a competent person using self-contained breathing apparatus (SCBA)
    - The purge system shall ensure turbulence for adequate mixing of air and inert gas to take place to avoid pockets of dense or light inert gases remaining or to avoid channelling of gases due to inadequate purging
    - Removal of argon or cold nitrogen from large vessels and deep pits can be difficult due to the relatively high density of the gas compared with air. In these cases, the gas should be exhausted from the bottom of the space
    - Ventilation shall never be carried out with pure oxygen, but with air; and
- Oxygen content of the atmosphere in the enclosure or storage tank shall be monitored continuously or repeated at regular intervals.

Consideration should also be given to the additional use of personal oxygen monitors.

When a safe atmosphere cannot be created and confirmed, then entry shall only be performed by qualified personnel provided with a positive pressure breathing air supply.

6.4.4 Ventilation and monitoring for entry into other spaces where inert gases can be present

Other spaces where inert gases can be present have the following characteristics:

- inert gas could accumulate from vents or by leakage; and
- inadequate ventilation.

Examples of these types of spaces are listed in 5.1 and 5.3.

In the majority of these cases, the presence of inert gases is not anticipated when entering such spaces. However, the one essential safeguard in all cases is to sample the atmosphere in the room, enclosure, trench, or pit for oxygen prior to any entry. Where appropriate, a continuous, fixed-point monitoring device should be used.

6.4.5 Purging requirements

The guidance for air changes described in 6.4.1 is valid when nitrogen is the inert gas involved because its density is very near to that of air and oxygen.

If the gas to be purged has a density that is very different from the density of air (such as helium, argon, or carbon dioxide), the ventilating air might not adequately mix and the purge might not be adequate. The preferred method of removal of very dense gases such as argon or cold nitrogen vapour is to remove the gas from the bottom of the space.

In the presence of toxic or flammable gases, an additional analysis of the gases present in the confined space shall be performed before entry of personnel. The measurement of only the oxygen content is not sufficient in these cases.

In the specific case of flammable gases, a nitrogen purge shall be used first to prevent any explosion risk and then subsequently purge with ventilating air.

6.5 Testing of oxygen content

Various types of oxygen analysers and detectors that are reliable and simple to operate are available. The selection of the type of apparatus depends on the nature of the work and the conditions in the area to be monitored. For example, the presence of dust as well as the temperature and humidity can affect an analyser's accuracy and response time.

Oxygen analysers and detectors are critical equipment and shall be maintained and calibrated in accordance with manufacturer's instructions. It is also important to ensure that fixed and portable analysers and detectors are positioned to measure a representative sample of the atmosphere.

Periodically confirm that the oxygen analyser/detector is operating in accordance with the manufacturer's instructions.

All oxygen analysers and detectors should be fitted with an alarm device to indicate possible defects, for example, low battery.

Testing the oxygen levels at various heights is required since some gases can accumulate at different levels due to their density. This testing shall also be performed at various locations in the area.

6.6 Work permit

For certain types of work, safety instructions and a specific work procedure shall be provided (see EIGA Doc 40, *Work Permit Systems*) [7]. Additional permits can be required for entry into a confined space.

A specific work procedure that provides detailed information shall be given to involved personnel before the start of work. This information should include documented risk assessments, procedures, and the training of personnel.

6.7 Lock-out and tag-out procedure

To ensure all sources of inert gas have been properly isolated, the implementation of a formal lock-out and tag-out procedure is required before working on any equipment, working in areas where an oxygen-deficient atmosphere can occur, or entry into a confined space.

6.8 Protection of personnel

Whenever practical, tasks in confined spaces with potentially hazardous atmospheres should be performed without entry. Personnel should only enter confined spaces if there is no practical alternative. The type of work to be performed, the layout of the premises, and the assessment of potential rescue scenarios shall determine the provision of additional protective measures. This additional protection should include organisational measures and/or safety equipment such as:

- fixed or personal oxygen-monitoring equipment;
- provision of an alarm system in case of an emergency;
- wearing of a supplied air breathing system (not cartridge masks, which are ineffective in cases of oxygen deficiency);
- wearing of other PPE such as safety boots, hard hat, goggles, or gloves, depending on the hazards of the location and task; and
- trained and equipped stand-by personnel.

Any entry into a confined space or enclosure with a potentially hazardous atmosphere shall be carefully controlled and have:

- Written procedure for the work to be undertaken with the space;
- Documented risk assessment for performing the work in this particular vessel;
- Formal lock-out and tag-out procedures;
- Assessment of potential scenarios where rescue could be required;
- A rescue plan to deal with any possible incident scenario related to entry in to the enclosure or vessel;
- Personnel wear a harness so they can be easily and rapidly taken out of a space in the case of an emergency. In practice, it is extremely difficult for one person to lift another person in the absence of a mechanical aid;
- Rescue personnel and equipment such as a hoist or SCBA available as required by the rescue plan;
- Trained and competent personnel in the roles of entrant, stand-by watch, rescue team (where required), and supervisor/permit issuer; and

- Work and confined space entry permits issued and signed before entry is allowed.

7 Rescue

Awareness training in the hazards of inert gases and oxygen-deficient atmospheres is of vital importance for individuals who could enter a space or who could discover an affected person in a space with potentially asphyxiant atmosphere, in order to prevent subsequent fatalities as a result of unplanned rescue attempts.

Training in rescue work is fundamental since quickly improvised rescue without the formality of a procedure often proves to be ineffective, if not catastrophic. In addition to training, there is a need to have rescue planning for each site. Rescue workers lacking foresight can become second or even third victims. This is one of the most common causes of multiple fatalities in cases involving asphyxiation.

7.1 Basic rules

If a person working in confined spaces or enclosures suddenly collapses and is no longer responsive, it shall be assumed that the person lacks oxygen due to the presence of an inert gas.

DANGER: *The rescuer must assume that their life is at risk entering the same area.*

A rescuer shall follow the rescue plan to prevent becoming another victim.

Rescues shall only be carried out by personnel who have been suitably trained and have the necessary equipment and support.

7.2 Rescue plan elements

The method of rescue shall be determined by the access to a particular space. If practical, a non-entry rescue is preferred. Considerations should be given to rescue plans for three different situations:

- rescue from normally accessible rooms and other enclosed or partially enclosed spaces;
- rescue from confined spaces; and
- rescue from pits, trenches, or excavations.

In each case, the development of a rescue plan should consider the following:

- how the alarm is raised;
- identification of possible rescue scenarios (not only for low-oxygen effects);
- any scenarios in the surrounding work place that could require immediate exit from the space (for example, site evacuation in the event of a fire);
- stand-by watch trained to keep visual and verbal contact with the entrant and to ensure the entrant exits the space if symptoms of oxygen deficiency are suspected or observed;
- any assistance that could be needed/given from outside the space to help the entrant escape from the space without further entry;
- re-checking/confirmation of atmosphere prior to rescue;
- manpower and equipment required to move an unconscious victim from the space;
- provision of first aid/medical treatment, for example, resuscitation and/or oxygen treatment inside the space if necessary;

- safe access by rescue and/or medical personnel if necessary; and

- how to make the space safe to prevent further injury after the rescue.

7.3 Equipment

A successful rescue might need some of the following equipment. The actual needs shall be determined as part of the rescue plan and made available and accessible during the work:

- Portable audible alarm devices (for example, personal horn, whistle, or klaxon) to alert nearby people that assistance is required;

- Telephone or radio at the work site so that an alarm can be raised in event of problems;

- Safety belt or harness connected to a line;

- Mechanical aid such as a pulley or hoist to extract the victim;

- A source of air to ventilate the confined space such as:

  - Compressed air hose connected to the plant compressed air network

  - Ventilation device;

- Additional oxygen monitors for the rescue team for re-checking the conditions inside the space;

- Positive pressure breathing air supply, for example, an externally fed breathing air system or SCBA;

  DANGER: *Cartridge masks for toxic gases are not suitable as they do not replenish missing oxygen.*

- Resuscitation kit supplied with oxygen for the victim; or

- Stretcher to carry an injured victim out of the space, away from the work place and/or to an ambulance.

Any equipment identified as necessary to carry out an emergency rescue from a confined space should be defined on the basis of a full risk assessment and the emergency plan developed from it. Where this equipment is not available, a rescue should not be undertaken.

7.4 Rescue training

When an emergency plan considers that a rescue is to be performed, it is recommended that there is an annual programme of training including practical rescue drills. It is also a good practice to consider a rescue exercise before the start of confined space work.

8 First aid

Where there is a potential hazard from inert gases/oxygen deficiency, consideration should be given to personnel who are formally qualified to give first aid and/or perform resuscitation. The simplest first aid treatment for someone suffering from the effects of oxygen deficiency is to bring the affected person into fresh air, as long as it safe to do so.

Refer to the safety data sheet (SDS) for the relevant gas for first aid measures.

In most countries, additional training is required for first aid providers to be qualified to provide oxygen as medical treatment for anoxia and other conditions.

9 References

Unless otherwise specified, the latest edition shall apply.

[1] EIGA Doc 04, *Fire Hazards of Oxygen and Oxygen Enriched Atmospheres*, European Industrial Gases Association. www.eiga.eu

NOTE—This publication is part of an international program for industry standards. The technical content of each regional document is identical, except for regional regulatory requirements. See the referenced document preface for a list of harmonized regional references.

[2] EIGA Safety Information, *Carbon Dioxide Physiological Hazards – "Not just an Asphyxiant"*," European Industrial Gases Association. www.eiga.eu

[3] CGA G-6, *Carbon Dioxide*, Compressed Gas Association, Inc. www.cganet.com

[4] *Code of Federal Regulations,* Title 29 (Labor), Government Printing Office. www.gpo.gov

[5] CGA P-78, *Guideline for the Safe Use of Instrument Air Systems Backed Up by Gases Other Than Air*, Compressed Gas Association, Inc. www.cganet.com

[6] EIGA Doc 40, *Work Permit Systems*, European Industrial Gases Association. www.eiga.eu

[7] EIGA Safety Newsletter NL 77, *Campaign against asphyxiation*, European Industrial Gases Association. www.eiga.eu

Appendix A—Summary for operators

A1 Why do we need oxygen?

OXYGEN IS ESSENTIAL FOR LIFE
WITHOUT ENOUGH OXYGEN, WE CANNOT LIVE

When the natural composition of air is changed, the human organism can be affected or even severely impaired.

If gases other than oxygen are added or mixed with breathing air, the oxygen concentration is reduced (diluted) and oxygen deficiency occurs.

If oxygen deficiency occurs due to the presence of an inert gas such as nitrogen, helium, argon, etc., a drop in physical/mental efficiency occurs without the person's knowledge; at approximately 6% oxygen concentration in air (instead of the normal 20.9% concentration), fainting occurs without any warning.

At less than a 6% concentration, there is a very high risk that death due to asphyxiation will occur within a few minutes, unless resuscitation is carried out immediately.

See EIGA Safety Newsletter NL 77, *Campaign against asphyxiation***,** for additional information [7].

A2 Examples of where oxygen deficiency can occur

The following are examples of where oxygen deficiency can occur:

- When liquefied gases such as liquid nitrogen, liquid argon, or liquid helium evaporate, one litre of liquid produces approximately 0.65 m^3 to 0.78 m^3 of gas. This enormous gas volume can quickly lead to oxygen deficiency unless there is adequate ventilation.

- When gases other than oxygen leak out of pipe work, cylinders, or vessels, oxygen deficiency shall always be expected. Checks should be made periodically for possible leaks. Spaces with limited or inadequate ventilation (for example, vessels) shall not be entered unless an air analysis has been performed, safe conditions are confirmed, and a work permit has been issued.

- When work is performed in the vicinity of ventilation openings, vent pipes, or vessel manways, personnel shall be prepared to encounter gases with low oxygen concentration or with no oxygen being discharged from these openings.

- Oxygen deficiency always happens when plant and vessels are purged with nitrogen or any other inert gas.

- In rooms where ventilation is used to prevent the build-up of gases if the ventilation system fails.

A3 Detection of oxygen deficiency

HUMAN SENSES CANNOT DETECT OXYGEN DEFICIENCY

Measuring instruments give an audible or visual alarm of oxygen concentration and can indicate the oxygen concentration in an area.

These instruments shall be tested in the open air before use.

If the presence of gases other than simple asphyxiants such as carbon dioxide, toxic, or flammable gases is possible, additional hazard-specific detection instruments shall be used.

A4 Breathing apparatus

Breathing apparatus shall be used in situations when oxygen deficiency is expected and cannot be remedied by adequate ventilation.

Cartridge gas masks necessary for use in the presence of toxic gases (such as ammonia, chlorine, etc.) are useless in oxygen-deficient atmospheres.

Recommended types of breathing apparatus are:
- SCBA using compressed air cylinders; or
- Full-face masks with respirator connected through a hose to a fresh air supply.

NOTE:
- When wearing these types of apparatus, particularly with air-filled cylinders, it can sometimes be difficult to enter manways;
- Periodic inspection of the correct functioning of the equipment shall be carried out in accordance with local regulations; and
- Users shall be trained and shall practice handling of the equipment regularly.

A5 Confined spaces, vessels, etc.

Any vessel or confined space where oxygen deficiency is expected and which is connected to a gas source shall be disconnected from such a source by:

- the removal of a section of pipe;
- inserting a blanking plate before and during the entry period; or
- isolation by double block and bleed.

Reliance on the closure of valves alone can be fatal.

A space or vessel should be thoroughly ventilated, and the oxygen content shall be measured periodically before and during entry period.

If the atmosphere in such a vessel or space is not breathable, entry shall be limited to a qualified person using breathing apparatus.

Permission to enter such a space shall be given **only after** the issue of an **entry permit** signed by a **responsible** person.

As long as a person is in a vessel or confined space, a watcher shall be present, stationed immediately outside of the confined space entrance, and a method to rescue the person shall be readily available. The responsibilities of the watcher shall be clearly defined.

The person inside the confined space shall wear a harness and rope to facilitate rescue. A hoist might be necessary to lift an incapacitated person.

A6 Emergency measures

In the event a person faints due to oxygen deficiency, the individual can be pulled out using the harness and rope. If entry is required, rescue personnel shall be equipped with breathing apparatus before entering the oxygen-deficient space without risk.

Remove victim to open air, administer first aid as needed, and follow emergency response procedures..

Appendix B—Incidents involving oxygen deficiency

The following incidents illustrate the importance of regularly notifying personnel as well as customers to the hazards of inert gases and oxygen deficiency:

- A worker was overcome by lack of oxygen after entering a large storage tank, which had been inerted with nitrogen. Two other workers, who went to aid the first without wearing breathing apparatus, were also overcome and all three died.
- On an ASU that was still in commissioning phase, three painters from a sub-subcontractor were working on a ladder to complete external painting works on nitrogen/water tower. To complete the painting of the top tower section, a wooden plank was put across the exhaust section to atmosphere. One painter climbed on the plank, surrounded by the nitrogen stream, and fell off inside the tower. The two other painters rushed from the ladder to the plank to rescue their co-worker. Both collapsed into the tower as well. The three painters died before they could be rescued.
- A nitrogen tank at a pressure swing adsorption plant was to be inspected by the competent body. The inspector entered the tank and lost consciousness immediately. Two people participating in the inspection pulled the inspector out without entering the tank. The inspector recovered.
- Never attempt to rescue someone who might have been asphyxiated unless you have been trained for rescue and have the required personal protective equipment.
- A worker from a contractor company had to weld inside a vessel. The vessel had been under a nitrogen blanket, but was ventilated with air before work started. The welder was asked to wear a fresh air breathing mask; unfortunately, the hose was connected to a nitrogen line and the welder died from asphyxiation.
- An air compressor that provided instrument air to an acetylene plant and for breathing air failed. A back-up nitrogen supply from a liquid cylinder was connected to the piping system to replace the function of the air compressor. An operator, who used a full respiratory face mask to load calcium carbide into the hopper, died after inhaling nitrogen.
- Always use certified breathing air for supplied air respirators. Always check that supplied breathing air is the correct composition before use, even if labelled as “air”. Never assume that “instrument air” is safe to breath.
- Welding work with an argon mixture was performed inside a road tanker. During lunch, the welding torch was left inside the tank and, as the valve was not properly closed, argon leaked out. The welder lost consciousness when re-entering the tank, but was rescued in time.
- A liquid carbon dioxide tank should have been purged with air but the purge was mistakenly connected to nitrogen. For unknown reasons, a contract employee used a ladder to enter the tank and was asphyxiated. That morning, employees had been told not to enter the tank before the atmosphere was officially checked.
- An experienced site employee wanted to include photographs in a report concerning production issues related to problems with leaks in the argon condenser. In the control room, the employee asked a contractor to assist with taking photographs of equipment in the coldbox. One hour later, the employees were found unconscious in a manhole access to the coldbox. Emergency authorities were called and declared that the victims had died.
- A customer was supplied with two low-temperature grinding machines that use liquid nitrogen, which were located in the same area in the factory. The customer installed a joint nitrogen extraction system between the two machines. One machine was switched off for cleaning while the other machine was left running. One of the operators who had entered the unit for cleaning fell unconscious and died before help arrived. The linked extraction system had allowed exhausted nitrogen from the operating machine to flow into the unit to be cleaned.

- A worker was overcome upon entering a steel tank that had been shut up for several years. The atmosphere inside the tank was no longer capable of supporting life due to the removal of oxygen from the air by the rusting of steel.

- Always ensure the atmosphere inside a vessel or enclosure is safe to breath before entering, even if the atmosphere had been safe to breath previously. Periodically check the atmosphere while inside. Equipment that is connected to a gas source shall not be left inside vessels, enclosures or confined spaces during breaks, etc. Merely closing the valves is not a guarantee against an escape of gas. If any work with inert gas is carried out in vessels, atmospheric monitoring, adequate ventilation or the use of proper breathing apparatus shall be provided.

- A driver making a delivery connected a transfer hose to a customer-installed tank, which was located in a semi-basement. After the fill process was started, a customer's employee reported that a cloud of vapour was forming around the tank. The driver stopped the filling operation and went to the tank to investigate. On reaching the bottom of the stairs, the driver collapsed. Fortunately, one of the customer's staff noticed the situation and managed to put on a breathing apparatus and rescue the driver. The driver fully recovered.

- A driver was asphyxiated during commissioning of a nitrogen customer station. The customer station tank was located in a pit that was not recognized as a confined space. During the commissioning gas began venting from the wrong location. The driver went into the pit to correct the valving error and was asphyxiated.

- During a routine overhaul of an air separation plant, a maintenance technician had the task of changing the filter element on a liquid oxygen filter. The plant was shut down and a work permit was issued each day for each element of work. In spite of these precautions, the technician collapsed when inadvertently working on the filter after it had been purged with nitrogen. The fitter collapsed, apparently asphyxiated by nitrogen, and could not be revived.

- An experienced contractor was hired to purge a 0.5 m-diameter natural gas pipeline that was 10 km long with nitrogen before start-up. When one contractor employee and two customer employees entered the remotely located chamber, they were asphyxiated and later found dead in the chamber. Two blind flanges were leaking and the oxygen monitor was not used.

- Vessels aren't the only places where oxygen-deficient atmospheres can occur. Oxygen-deficient atmospheres can occur in enclosures, rooms and other areas where nitrogen or other non-oxygen gases can collect.

- The perlite in a storage tank under erection had to be emptied by a contractor company, familiar with this job. During this work, one of the workers fell down in the perlite, which was approximately 3 m deep, and was asphyxiated.

- Asphyxiation is the most common hazard vessel entry and confined spaces, but is not the only hazard. All hazards must be identified and addressed.