



FIRE HAZARDS OF OXYGEN AND OXYGEN-ENRICHED ATMOSPHERES

Doc 04/18

Revision of Doc 04/09

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





FIRE HAZARDS OF OXYGEN AND OXYGEN-ENRICHED ATMOSPHERES

As part of a programme of harmonization of industry standards, the European Industrial Gases Association (EIGA) publication, EIGA Doc 04, *Fire hazards of oxygen and oxygen enriched atmospheres*, has been used as the basis of an internationally harmonized gas association's publication on this subject.

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.

Disclaimer

All technical publications of EIGA or under EIGA's name, including Codes of practice, Safety procedures and any other technical information contained in such publications were obtained from sources believed to be reliable and are based on technical information and experience currently available from members of EIGA and others at the date of their issuance.

While EIGA recommends reference to or use of its publications by its members, such reference to or use of EIGA's publications by its members or third parties are purely voluntary and not binding.

Therefore, EIGA or its members make no guarantee of the results and assume no liability or responsibility in connection with the reference to or use of information or suggestions contained in EIGA's publications.

EIGA has no control whatsoever as regards, performance or non performance, misinterpretation, proper or improper use of any information or suggestions contained in EIGA's publications by any person or entity (including EIGA members) and EIGA expressly disclaims any liability in connection thereto.

EIGA's publications are subject to periodic review and users are cautioned to obtain the latest edition.

Table of Contents

1	Introduction	1
2	Scope and purpose	1
3	Definitions	1
3.1	Publication terminology	1
3.2	Technical definitions	1
4	General properties	2
4.1	Oxygen supports and accelerates combustion	2
4.2	Oxygen gives no warning	2
4.3	Oxygen is heavier than air	2
5	Fire hazards with oxygen	2
5.1	Necessary conditions for a fire	2
5.2	Oxygen	3
5.3	Combustible material	6
5.4	Ignition sources	7
6	Prevention of fires in oxygen systems	8
6.1	Information/training	8
6.2	Design	8
6.3	Prevention of oxygen enrichment	9
6.4	Oxygen cleanliness	10
6.5	Control of hot work	10
7	Methods of oxygen detection	10
8	Protection of personnel	10
8.1	Clothes	10
8.2	Analysis	11
8.3	Firefighting equipment	11
8.4	Smoking	11
8.5	Emergency response and rescue	11
9	Summary of recommendations	11
10	References	12
11	Additional references	13
	APPENDIX A—Pamphlet for daily operations involving oxygen	14
	APPENDIX B—Examples of the hazards of oxygen and oxygen-enriched atmospheres	26
B1	Examples of oxygen enrichment incidents	26
B2	Examples of improper use of oxygen	27
B3	Examples of incorrect design of oxygen system	27
B4	Examples of incorrect operation and maintenance of oxygen equipment	28
B5	Examples of use of incorrect materials with oxygen service	29

Amendments from 04/09

Section	Change
	Editorial to align style with IHC Associations style manual
3	Definitions added
5.2.5	Use of incorrect materials section expanded
5.3.2	Additional information on cooling systems included.

7	New section added
8.1	<u>Clothing requirements amended</u>
8.5	<u>Emergency response and rescue section added</u>

Note: Technical changes from the previous edition are underlined

1 Introduction

This publication explains the fire hazards resulting from handling oxygen and the relevant protective measures that should be taken.

2 Scope and purpose

The intent of this publication is to provide personnel working with oxygen, or potentially in or near oxygen-enriched atmospheres, with a high level of awareness of the fire and explosion hazards associated with these conditions. Oxygen levels less than 19.5% constitute an oxygen-deficient atmosphere and may only be entered using special precautions. See CGA SB-2, *Oxygen-Deficient Atmospheres*, or EIGA Doc 44, *Hazards of inert gases and oxygen depletion* [1, 2].¹

Appendix A is a summary of the information in this publication suitable to be produced as a pamphlet to be handed to those involved in daily operations involving oxygen or used as a supplement to safety presentations.

Appendix B lists some incidents that have taken place in recent years that can be used as examples underlining the hazards of oxygen and oxygen-enriched atmospheres.

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 Oxygen-enriched atmosphere

Air and gas mixtures in which the oxygen concentration by volume exceeds 23.5% at sea level or whose partial pressure of oxygen exceeds 175 torr (mm Hg) [3].

¹ References are shown by bracketed numbers and are listed in order of appearance in the reference section.

3.2.2 Pressure

Bar shall indicate gauge pressure unless otherwise noted – i.e. “bar, abs” for absolute pressure and “bar, dif” for differential pressure.

4 General properties

Oxygen, which is essential to life, is not flammable in itself, but supports and accelerates combustion. The normal oxygen concentration in atmospheric air is approximately 21% by volume.

4.1 Oxygen supports and accelerates combustion

Most materials burn fiercely in oxygen; the reaction can even be explosive.

As the oxygen concentration in air increases, the potential fire risk increases and combustion is accelerated.

4.2 Oxygen gives no warning

Oxygen is colourless, odourless, and has no taste; hence, the presence of an oxygen-enriched atmosphere cannot be detected by normal human senses. Oxygen also does not give any obvious physiological effects that could alert personnel to the presence of oxygen enrichment.

Increasing the oxygen concentration of the air at atmospheric pressure does not constitute a significant health hazard.

4.3 Oxygen is heavier than air

Oxygen can accumulate in low lying areas such as pits, trenches, or underground rooms because it is heavier than air. This is particularly relevant when liquid oxygen is spilled. In this case, the generated cold gaseous oxygen is three times heavier than air.

5 Fire hazards with oxygen

5.1 Necessary conditions for a fire

In general, for a fire or explosion to occur three elements are required: combustible material, oxygen, and an ignition source.

The fire triangle is the usual way of representing these conditions as shown in Figure 1:

When one of the three elements is missing, a fire cannot occur.

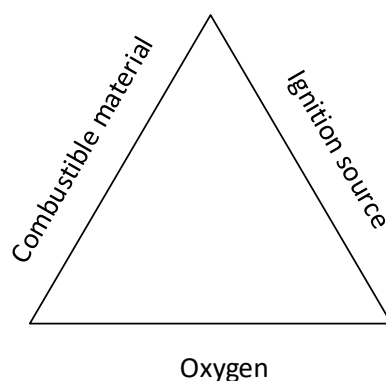


Figure 1 Fire triangle

5.2 Oxygen

Oxygen reacts with most materials. The higher the oxygen concentration and pressure in the atmosphere or in an oxygen system then:

- combustion reaction or fire will be more vigorous;
- ignition temperature and the ignition energy to promote the combustion reaction is much lower; and
- temperature of the flame is higher and consequently the destructive capability of the flame is greater.

Most causes of oxygen fires can be categorised as follows:

- oxygen enrichment of the atmosphere;
- improper use of oxygen;
- incorrect design of oxygen systems;
- incorrect operation and maintenance of oxygen systems; and
- use of materials incompatible with oxygen service.

Oxygen fires can be caused by one or more of the above conditions.

5.2.1 Oxygen enrichment of the atmosphere

Oxygen enrichment of the atmosphere can be the result of:

- Leaking pipe connections or flanges. This can be particularly hazardous in areas where there is not sufficient ventilation thus causing the oxygen concentration to increase;
- Opening of oxygen systems under pressure. A sudden release of oxygen under pressure can result in a relatively large jet of escaping oxygen. This can result in a jet flame and a projection of molten material;
- Oxygen used in cutting and welding processes. In processes such as cutting, gouging, scaring and thermal lancing, oxygen is used in quantities greater than necessary for the burning process. The unused oxygen remains in the atmosphere, and if ventilation is inadequate the air can become enriched with oxygen;
- Oxygen used in metallurgical processes. Incorrect practice when using blowpipes can lead to oxygen enrichment, especially in confined spaces;
- Desorption. Oxygen can be released in appreciable quantities when cold materials that have absorbed oxygen such as absorbents (molecular sieve, silica gel, etc.) or insulation materials are warmed to room temperature;
- Cryogenic liquid spill. A spill of liquid oxygen creates a dense cloud of oxygen-enriched air when evaporating. In an open space, hazardous oxygen concentration usually exists only within the visible cloud associated with the spill. The cold gas can collect in nearby low-lying spaces such as ditches or drains, which are not well ventilated; atmospheric checks should be carried out on any such nearby spaces after a spill;
- Liquefaction of air. When using cryogenic gases with boiling points lower than oxygen, for example, nitrogen, hydrogen and helium, oxygen enrichment can also occur. Ambient air will condense on uninsulated equipment where the temperature is lower than the liquefaction

temperature of air (approximately $-193\text{ }^{\circ}\text{C}$). This can also occur on pipework lagged with an open cell insulant. The liquid air can contain up to 50% oxygen and, if this liquid drips off and evaporates, the oxygen concentration in the remaining portion can be greater than 80%; or

- Oxygen vents. Areas near oxygen vents can be particularly hazardous. A sudden release of oxygen can occur without warning. The non-cryogenic production of oxygen or nitrogen can involve an occasional or continuous venting of oxygen. See EIGA Doc 154, *Safe Location of Oxygen and Inert Gas Vents* [4].

5.2.2 Improper use of oxygen

Serious incidents have been caused by the use of oxygen for applications for which it was not intended.

Examples of improper use of oxygen include:

- powering pneumatic tools;
- inflating vehicle tyres and rubber boats;
- pressurising and purging systems;
- replacing air or inert gas;
- cooling or refreshing the air in confined spaces;
- blowing oxygen inside clothing, for example, by a welder in an attempt to create a cooling breeze;
- removing dust from benches, machinery, and clothing;
- starting diesel engines;
- cleaning; or
- ventilating.

In each case, the fire and explosive risk is the same and results from exposing combustible materials such as flammable gases, flammable solids, rubbers, textiles, oils and greases to oxygen.

5.2.3 Design of oxygen systems

The correct design of oxygen installations is critical. Inadequate designs can and have led to serious incidents.

Examples of inadequate design include:

- Using rapidly opening (ball) valves. This can lead to ignition caused by the heat generated by high velocity gas or adiabatic compression (see the following);
- Allowing too high a gas velocity, which can cause ignition of incompatible materials in the system due to particle impact;
- Opening the main shut off valve in an oxygen supply pipeline without first equalising the pressure;
- High pressure gas flowing over sharp-edged orifices, rapid expansions, or rapid reductions;
- Poorly located vents that cause an accumulation of oxygen; and

- Using any components and lubricants that have not been approved for use with oxygen at the design conditions.

5.2.4 Incorrect operation and maintenance of oxygen equipment

Incorrect operation and maintenance of oxygen equipment is one of the most frequent causes of fires in oxygen systems.

Examples of incorrect operation include:

- Failing to reset pressure regulators to the closed position when the oxygen cylinder valve has been closed. This results in extremely high oxygen gas velocities when pressurising the regulator the next time it is used;
- Opening valves rapidly, which can result in momentarily high oxygen velocities, sufficient to project any debris present in the system through the system, at sonic velocity causing frictional heat or sparks;
- Opening a valve rapidly against a closed valve (or pressure regulator) downstream in a system can result in high heat being generated through adiabatic compression of the oxygen, causing a fire; and
- Starting an oxygen compressor erroneously with oxygen. This incorrect operation is only relevant to specific cases [5, 6].

Examples of incorrect maintenance include:

- Working on pressurised systems;
- Venting oxygen into restricted, enclosed, or confined spaces;
- Allowing systems to become contaminated. Contamination by particulate matter, dust, sand, oils, greases, or general atmospheric debris creates a potential fire hazard. Portable equipment is particularly susceptible to contamination and precautions shall be taken to prevent ingress of dirt or oil; and
- Failing to completely remove cleaning solvents from components that are to be used in oxygen service. The solvent residues are not compatible with an oxygen-enriched atmosphere.

5.2.5 Use of incorrect materials

The design of oxygen equipment is very complex and the “why and how” is not always obvious. In essence, nearly all materials are combustible in oxygen. Safe equipment for oxygen service is achieved by careful selection of suitable materials or a combination of materials and their use in a particular manner.

Any modifications to a design shall be authorised to prevent incompatible materials being used

Many incidents are reported where the cause was incompatible replacement parts. In many of the incidents, components were used because they looked similar to the original. Substituting materials that merely look similar is extremely dangerous. Examples of this practice include:

- Replacing O-rings and gaskets with similar looking items. There are hundreds of different types of elastomers and most are not compatible with oxygen;
- Replacing a metal alloy with a similar type of alloy. The composition of a particular alloys has a significant effect on their mechanical properties and oxygen compatibility. Bronze, which covers a wide range of alloys, has several varieties that are compatible with oxygen and even more

which are not. For example, tin bronze is used in liquid oxygen pumps while aluminium bronze is considered hazardous;

- Replacing polytetrafluoroethylene (PTFE) tape with a similar white tape. Not all white tape is PTFE and not all brands of PTFE tape are safe for use in oxygen. See EIGA Doc 138, *PTFE Used as a Sealant for Cylinder/Valve Connections* [7];
- Replacing parts/components with non-approved equipment. The geometry of certain components is sometimes critical and approved manufacturer's parts shall always be used when maintaining oxygen equipment;
- Replacing or the installation of combustible material such as plastics, paper, or adhesives in filters. Filters in oxygen systems are very sensitive to ignition due to presence of particles and complicated flow conditions. Therefore, filters should be made of materials that demand very high ignition energy such as Monel®;
- Using lubricants that have not been approved for use with oxygen at the design conditions; or
- Using incorrect leak detection fluid. See EIGA Doc 78, *Leak Detection Fluids Cylinder Packages* [8].

Using hydrocarbon-based substances such as oils, grease, some soaps, lubricants, degreasers, and organic chemicals are particularly hazardous in oxygen-enriched atmospheres. They can react violently with oxygen causing fire or explosion. In general, hydrocarbon-based oil and grease shall never be used to lubricate equipment that will be in contact with oxygen or oxygen-enriched air. Special lubricants such as approved perfluorocarbon lubricants are available for use in oxygen-enriched atmospheres. Oxygen pressure gauges shall not be tested or calibrated in contact with oil.

5.3 Combustible material

5.3.1 In oxygen-enriched atmospheres

Materials that do not burn in air, including fire-resistant materials, can burn vigorously in oxygen-enriched air or pure oxygen.

In oxygen-enriched atmospheres, a common combustible material that most directly affects the safety of personnel is clothing. All clothing materials will burn fiercely in an oxygen-enriched atmosphere. The same applies to plastics and elastomers.

An example of this increased reactivity is shown in Figure 2, for cotton overall material exposed to fire in atmospheres containing increasing levels of oxygen [5].

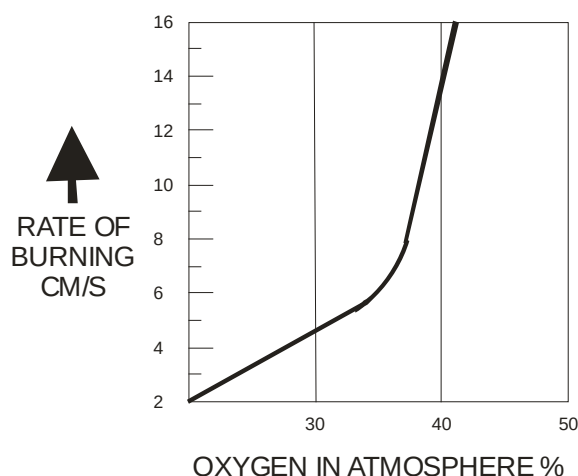


Figure 2 Reactivity for fire exposed cotton in increasing oxygen levels