FIRE HAZARDS OF OXYGEN AND OXYGEN ENRICHED ATMOSPHERES

AIGA 005/04

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Acknowledgement

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1 Scope

This document explains the fire hazards resulting from handling oxygen and the relevant protective measures.

2 Purpose

This document consists of three parts.

Part I, the actual document, is intended for line managers and supervisors. It provides the background to the subject and a description of the fire and explosion hazards associated with oxygen and oxygen enriched atmospheres.

Part II, designated as Appendix B, is a summary of Part I suitable to be produced as a pamphlet to be handed over to operators or as overhead slides.

Part III, designated as Appendix C, lists some accidents which have taken place in recent years and which can be used as examples underlining the hazards of oxygen and oxygen enriched atmospheres.

It is recommended that the document be used as the basis for training programmes.

3 Definitions

Oxygen in the sense of this document includes not only pure oxygen but all air mixtures containing more than 21 % oxygen.

4 General Properties

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

4.1 Oxygen supports and accelerates combustion

Most materials burn fiercely in oxygen; the reaction could even be explosive.
As the oxygen concentration in air increases the potential fire risk increases.

4.2 Oxygen gives no warning

Oxygen is colourless, odourless and tasteless hence the presence of an oxygen enriched atmosphere cannot be detected by normal human senses. Oxygen also does not give any physiological effects which 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

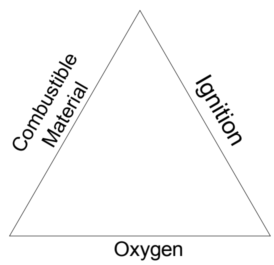
Being heavier than air, oxygen can accumulate in low lying areas such as pits, trenches or underground rooms. This is particularly relevant when liquid oxygen spills out. In that case the generated cold gaseous oxygen is three times heavier than air.

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 normal way of representing these conditions:



When one of the 3 elements is missing a fire cannot occur.

5.2 Oxygen

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

a) The more vigorously the combustion reaction or fire takes place;
b) the lower the ignition temperature and the ignition energy to get the combustion reaction started;
c) the higher the flame temperature and destructive capability of the flame.

Causes of oxygen fires can be categorised as follows:

d) oxygen enrichment of the atmosphere
e) improper use of oxygen

f) incorrect operation and maintenance of oxygen systems
g) use of materials incompatible with oxygen service

5.2.1 Oxygen enrichment of the atmosphere

Oxygen enrichment of the atmosphere can be the result of

a) Leaking pipe connections, flanges, etc. This can be particularly hazardous in areas where there is not sufficient ventilation causing the oxygen concentration to increase.
b) Breaking into systems under oxygen pressure.
A sudden release of oxygen under pressure can result in a relatively large jet of escaping oxygen. This may result in a torching fire.
c) Oxygen use in cutting and welding processes.
In processes such as cutting, gouging, scarfing and thermic 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. Effective ventilation and periodic analysis for oxygen content is recommended.
d) Oxygen use in metallurgical processes. Incorrect practice in the use of blowpipes can also lead to oxygen enrichment, especially in confined spaces. Therefore care should be taken:
to follow correct hose purging and lighting up procedures,
to avoid delay in lighting the blowpipe after opening the valves,
to close the valves of the blowpipe and of the gas supply when interrupting or finishing the work,
to select the correct nozzles and pressures to maintain oxygen hoses leak-tight and periodically inspected.
e) Desorption.
Oxygen can be released in appreciable quantities when cold materials which have absorbed oxygen such as absorbents (molecular sieve, silica gel, etc.) or insulation materials are warmed to room temperature.
f) 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. Nevertheless, atmospheric checks should be carried out to confirm this when approaching the vicinity of the vapour cloud.
g) Liquefaction of air.
When using cryogenic gases with boiling points lower than oxygen, e.g. 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 (approx –193 °C). This will also occur on pipework lagged with an open cell insulant. The liquid air so produced can contain up to 50 % oxygen and, if this liquid drips off and evaporates, the oxygen concentration in the last remaining portion can be over 80 %. Consequently, special precautions shall be taken with regard to the potential oxygen enriched insulation and to the vessel before starting repair work on any equipment.
h) Oxygen vents.
Particularly hazardous are areas where oxygen vents are located. A sudden release of oxygen can occur without warning. Note that the non-cryogenic production of oxygen or nitrogen might involve an occasional or continuous venting of oxygen.

5.2.2 Improper use of oxygen

Many serious accidents have been caused by the use of oxygen for applications for which it was not intended.

Examples of improper use of oxygen are:

a) Driving pneumatic tools
b) Inflating vehicle tires, rubber boats, etc.
c) Pressurising and purging systems
d) Replacing air or inert gas
e) Cooling or refreshing the air in confined spaces
f) A welder who intends to “cool” him/herself by blowing oxygen into his/her clothing
g) Dusting benches, machinery and clothing
h) Starting diesel engines

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

5.2.3 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

a) 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 next time it is used.
b) Rapidly opening valves. This can lead to ignitions caused by the heat generated by high velocity gas or adiabatic compression. Rapid opening of valves can result in momentarily high oxygen velocities, sufficient to project any debris being in the system through the system at sonic velocity causing frictional heat, sparks, etc. When the system is "dead ended" – as in the case with a pressure regulator connected to an oxygen cylinder – high heat can be generated through compression of the oxygen. Both these phenomena can cause a fire.
c) Opening a valve rapidly against a closed valve downstream in a system – this can lead to a similar situation as described above.
d) Start-up of oxygen compressor with oxygen should be performed according to the procedures described in the references No.5 and 6.

Examples of Incorrect maintenance

e) Working on pressurised systems.
f) Venting oxygen into confined spaces.
g) Allowing systems to become contaminated. Contamination by particulate matter, dust, sand, oils, greases or general atmospheric debris creates a potential fire hazard as highlighted above. Portable equipment is particularly susceptible to contamination and precautions shall be taken to prevent ingress of dirt, oil, etc.
h) Failure to completely remove cleaning solvents from components which are to be used in oxygen service. The solvent residues are not compatible with an oxygen enriched atmosphere.

5.2.4 Use of incorrect materials

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 combination of materials and their use in a particular manner.

Any modifications to a design must be properly authorised to prevent incompatible materials being used.

Substituting materials which look similar is extremely dangerous and many accidents are reported where the cause was incompatible replacement parts. Examples of this practice could be

a) Replacing o-rings and gaskets with similar looking items. There are hundreds of different types of elastomer and most are not compatible with oxygen.
b) Replacing a metal alloy with a similar type of alloy. The composition of particular alloys has a significant effect on its mechanical properties and oxygen compatibility. "Bronze", which covers a wide range of alloys, has several varieties which are compatible with oxygen and even more which are not; e.g. tin bronze is used in liquid oxygen pumps while aluminium bronze is considered hazardous.
c) Replacing 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.
d) Replacing parts/components with non-approved equipment is not allowed. The geometry of certain components is sometimes critical and approved manufacturer's parts shall always be used when maintaining oxygen equipment.
e) Replacing or installation of combustible material in filters e.g. plastics, paper, adhesives. Filters in oxygen systems are very sensitive to ignition due to presence of particles and complicated flow conditions. Therefore filters must be made of materials which demand very high ignition energy e.g. Monel.
f) Lubricants are generally not allowed in oxygen service except for special applications. Specialist expert advice shall always be obtained before applying such lubricants.

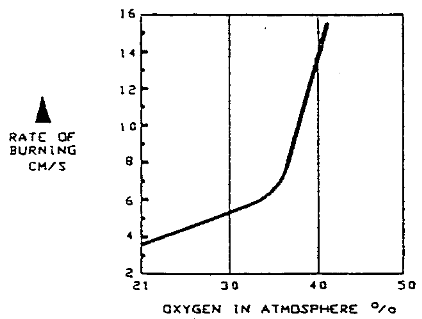
5.3 Combustible material

In oxygen enriched atmospheres

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

In enriched oxygen atmospheres the most common combustible material that directly affects 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 can be seen below, for a cotton clothing material exposed to fire in atmospheres containing increasing levels of oxygen (Ref. No. 8).



Similar curves, indicating the same kind of behaviour could be drawn for other materials – in particular for plastics and elastomers.

In pressurised oxygen systems

In principle all organic materials will burn in oxygen and so do most of the metals and metal alloys. Pressure affects the behaviour of materials, e.g. by reducing ignition temperatures and increasing combustion rates. It is for these reasons that pressurised oxygen systems are only allowed to be constructed from materials and equipment whose design has been approved for the relevant operating conditions.

Oil and grease are particularly hazardous in the presence of oxygen as they can ignite extremely easily and burn with explosive violence. In oxygen equipment, oil and grease ignition often causes a chain reaction, which finally results in metal burning or melting. In such cases the molten or burned metal residue is projected away from the equipment and may be followed by an oxygen release. This in turn can lead to fierce and rapidly spreading flames in any adjacent combustible material external to the equipment. Oil and grease shall never be used to lubricate equipment that will be in contact with oxygen.

5.4 Ignition sources

In oxygen enriched atmospheres

Ignition sources in oxygen enriched conditions could be:

a) open fires or naked flames (cigarettes, welding or other hot work, sparks from internal combustion engines, furnaces etc.)
b) electrical sparks
c) grinding or frictional sparks

In pressurised oxygen systems

In systems containing oxygen under pressure the sources of ignition are not as obvious as naked flames and hot surfaces.

The following ignition sources have been identified as having caused fires in oxygen systems:

d) heating by adiabatic compression
e) friction
f) mechanical impact
g) electrical sparks
h) high gas velocity with presence of particles
i) heating by turbulence

6 Prevention of fires in oxygen systems

6.1 Information/training

Any personnel using oxygen equipment should be aware of the hazards. The minimum information that is required is shown in IGC Doc 23/00 “Safety training of employees” (adopted as AIGA 009/04).

All personnel should also have read the safety data sheet and safety information provided by the gas supplier.

For a greater insight into the hazards of oxygen with materials the following information is recommended:
(Note: IGC documents are under EIGA)

a) "Oxygen Pipeline Systems" IGC Doc 13/02
b) "Prevention of hose failures in high pressure gas systems" IGC Doc 42/89
c) "Reciprocating compressors for oxygen service. Code of practice" IGC Doc. 10/81
d) "Code of practice for the design and operation of centrifugal liquid oxygen pumps" IGC Doc 11/82
e) "Centrifugal compressors for oxygen service" Code of practice" IGC Doc. 27/93
f) SAG Info 15/97: "Safety principles of high pressure oxygen systems".
g) Flammability and sensitivity of materials in oxygen-enriched atmospheres –American Society for Testing & Materials (ASTM) symposium series
h) Cleaning of equipment for oxygen service. IGC Doc. 33/97 (adopted as AIGA 012/04)

All maintenance and repair work shall be performed by experienced and fully trained personnel.

All persons who work in areas where oxygen enrichment can occur shall be given adequate instructions as to the risks involved. Special attention shall be drawn to the insidious nature of the risks due to the rapidity of their effects. Practical training shall be given in the means by which such risks can be minimised, stressing the importance of identifying sources of oxygen enrichment and their isolation.

6.2 Proper design

In oxygen systems only equipment that has been specifically designed for oxygen shall be used, e.g. do not use nitrogen regulators in oxygen service. The proper design of equipment intended for oxygen service takes into account materials to be used and their configuration in order to minimise any risk of ignition. The reasons for a particular design and choice of material are not always obvious and expert advice shall be sought before considering a change of materials.

Oxygen equipment shall never be lubricated with oil or grease. For special well-defined cases a few special lubricants may be available. Specialist advice from the supplier shall always be sought.

Oxygen systems shall be designed in such a way, that the flow velocity is as low as possible. If the velocity is doubled the energy of a particle in the gas stream will increase four times.

6.3 Prevention of oxygen enrichment

6.3.1 Leak testing

Newly assembled equipment for oxygen service shall be thoroughly leak checked using air or nitrogen e.g. by timed gas pressure drop test, leak detection test (e.g. with approved leak spray or diluted soap solution) or other suitable methods. Periodic retests are recommended.

6.3.2 Operation and practice

When the work period is over the main oxygen supply valve shall be closed to avoid possible oxygen leakage when the equipment is not being used.

Filters, where fitted, shall not be removed to obtain higher flows. Filters should be inspected at frequent intervals and all debris removed.

6.3.3 Ventilation

Rooms where there is a risk of oxygen enrichment of the atmosphere shall be well ventilated. Examples of such rooms are:

a) filling stations
b) rooms in which oxygen vessels or cylinders are stored, handled, maintained, etc.
c) rooms in which oxygen is used or analysed
d) rooms for medical treatment with oxygen in hospitals, home care, etc.

In many cases natural ventilation can be sufficient e.g. in halls or rooms provided with ventilation openings. The openings should have a flow area greater than 1/100 of the room's floor area, be diagonally opposite each other and shall ensure a free air circulation with no obstructions. Where natural ventilation is not possible a ventilation unit, with a capacity of approx. 6 air changes/hour shall be provided. Special consideration shall be given to the ventilation of underground rooms, vessels, pits, ducts and trenches. There shall be a safety warning to indicate if the ventilation unit fails.

6.3.4 Vessel entry/ blanking procedures

Prior to entry into any vessel which is connected to a gas source other than air, the vessel shall be emptied, disconnected from such a source by the removal of a section of pipe, by the use of a spectacle plate or by inserting blind flanges and the space shall be thoroughly ventilated so as to maintain a normal atmosphere. Piping lock-out devices need to be documented in the Hazardous Work Permit. Reliance on the closure of valves to prevent oxygen enrichment is not sufficient. Permission to enter such a space subsequent to completing the steps indicated above shall be given only after the issue of an entry permit certificate signed by a responsible person. An analysis of the vessel atmosphere shall always be requested as part of the work permit requirements.

6.3.5 Isolation equipment

When an oxygen pipeline enters a building, an isolation valve shall be provided outside the building in an accessible position for operation. This valve and location shall be clearly marked and identified. The purpose is to be able to operate the valve in a safe location in the event of an oxygen release in the building.

Disused oxygen lines should be dismantled or completely severed and blanked off from the supply system.

6.4 Oxygen cleanliness

One of the fundamental safety procedures in preventing oxygen fires is to ensure that all equipment is properly cleaned before it is put into oxygen service. There are several methods whereby oxygen equipment can be cleaned which are outside the scope of this document. The IGC Doc. 33/97 “Cleaning of Equipment for Oxygen Service” covers this subject in detail. (adopted as AIGA 012/04)

Oxygen equipment also must be free of solid particles. In order to remove particles new oxygen equipment before start-up shall be purged with oil free air or nitrogen

6.5 Control of hot work

Any hot work which has to be performed close to any oxygen equipment or in an area where oxygen enrichment could occur, shall be controlled by a written permission (hot work permit) which is part of the work permit system. Hot work includes operations such as welding, brazing, drilling, grinding, etc.

7 Methods of oxygen detection

The method selected must offer a high degree of reliability of operation and be sufficiently sensitive to ensure warning is provided before a hazardous concentration of oxygen is reached. The normal method is through the use of an approved atmospheric monitoring instrument to confirm the effectiveness of the isolation and purging procedures prior to entry into the area, and periodically during the course of the working to confirm that changes have not occurred.

A possible method of oxygen detection could be odorisation. The odorisation is occasionally used in shipyards, because there is a certain risk of oxygen enrichment while welding in small ship rooms. (For details see Ref.2). However, odorisation must only be viewed as a possible supplement to effective risk analysis, isolation, and atmospheric monitoring, and not as an alternative to them.

7.1 Measuring Instruments

Oxygen measuring instruments should be used as warning devices only, and should not be regarded as protection against the risks of oxygen enrichment. They should be seen as an addition to normal good practice of eliminating the causes of enrichment. Measuring instruments for the determination of the oxygen content indicate an increase as well as a decrease of the oxygen concentration in the ambient atmosphere and have, for example, a range from 0 to 40 % by volume of oxygen.

Various measuring techniques and methods are used giving visible and/or audible warning and they can be used for continuous or intermittent measurement.

7.2 Choice of the measuring method

When working in a room where the oxygen content can vary outside of 19.5 to 22.5%, continuous oxygen monitoring shall be used. When an abnormal condition is detected by the monitor, a flashing light visual alert in a colour locally recognised to represent danger and a horn audible alert shall be activated. The light and horn should be located so that they may be detected by personnel in the monitored area as well as at the points of ingress to the room. Signs should be posted at all points of ingress warning of the potential hazard.

7.3 Accuracy

The uncertainty of the measuring method should be such that when indicating 21 % the real value is between 19.5 % and 22.5 % oxygen in the air.

Instruments shall be calibrated before use and at regular intervals during use.

7.4 Utilisation of measuring instruments

The directions of the manufacturers for the use and maintenance of the measuring instruments shall be carefully observed.

The measuring instrument shall be located in the working area and as near as possible to the worker. In confined spaces, it is recommended that the worker is equipped with a personal monitor attached to his/her working clothes which will give an audible and/or visual alarm if the oxygen content of the atmosphere deviates from that of normal air. In areas with high noise levels, visual alarms are recommended.

8 Protection of personnel

8.1 Clothes

Many so-called "non-flammable" textile materials will burn fiercely in oxygen-enriched air.

Some synthetic materials can be fire-resistant to some extent, but can still melt and cause serious burns due to the adhesion of molten material to the skin. Synthetic materials are not recommended.

Using Flame retardant clothing can be useful, but washing can reduce the effectiveness of the treatment.

Whatever one wears, it is impossible to avoid danger from an oxygen fire solely by protective clothing. .

Clothing should be well fitting, yet easy to remove and free from oil and grease.

Persons who have been exposed to an oxygen-enriched atmosphere may not smoke or go near naked flames, hot spots or sparks until they have properly ventilated their clothes in a normal atmosphere. A ventilation period of 15 minutes minimum with movement of the arms and legs and with coats unbuttoned is recommended.

8.2 Analysis

Before persons enter a space which can be subject to oxygen enrichment, the atmosphere shall be analysed for oxygen by a reliable, accurate analyser (see section 7). Entrance is permissible only if the oxygen concentration is equal to that of normal air. All other concentrations, that is 23 % or more, are potentially dangerous. However, as a warning against local or temporary variation in concentration, it is recommended that anyone entering such a space should be issued with a personal continuous automatic oxygen analyser which sounds an audible alarm when the oxygen concentration in the atmosphere varies above 22.5% or below 19.5%.

8.3 Fire fighting equipment

The only effective way of dealing with oxygen-feed fires is to isolate the supply of oxygen. Under oxygen rich conditions, fire-fighting media could be water, dry chemical (powder) or carbon dioxide. The choice between these media needs to take into account the nature of the fire, e.g. electrical, etc. Burning clothing for example shall be extinguished by a large amount of water to remove as much heat to the skin as possible.

Fire fighting equipment should be properly maintained and operating personnel should know where it is located, how to operate it, and which equipment to use for which type of fire.

8.4 Smoking

All personnel shall be informed of the dangers of smoking when working with oxygen or in an area where oxygen enrichment can occur. Many burning accidents have been initiated by the lighting of a cigarette; it is therefore imperative to emphasise the danger of smoking in oxygen-enriched atmospheres or where oxygen enrichment can occur. In such areas smoking shall be forbidden.

8.5 First Aid

A person catching fire in an enriched oxygen atmosphere cannot be rescued by a person entering the area to pull them out, as the rescuer will almost certainly also catch fire. The victim shall be deluged with water from a shower, hose or series of fire buckets and go into fresh air as soon as possible.

9 Summary of recommendations

The more important points, which have to receive attention if accidents are to be avoided, are summarised below.

a) Ensure that people who are expected to work with oxygen, are properly trained and informed of the risks caused by an excess of oxygen.
b) Make sure that the proper equipment is used and that it is leak-tight and in good operational order.
c) Use only materials and equipment approved for use in oxygen. Never use replacement parts which have not been specifically approved.
d) Use suitable clean clothing, free from oil and easily combustible contaminants.
e) Never use oil or grease to lubricate oxygen equipment.
f) Check that all existing fire extinguishing equipment is in good condition and ready to be used.
g) When working in confined spaces where oxygen is normally used, isolate the equipment, provide good ventilation and use an oxygen analyser. Entry shall only be allowed by means of a permit issued by a trained responsible person
h) Smoking shall be strictly forbidden where there is any possible risk of oxygen enrichment.
i) A person catching fire in enriched oxygen atmospheres cannot be rescued by a person entering the area to pull them out, as the rescuer will almost certainly also catch fire.
j) People who have been exposed to oxygen enriched atmospheres shall not be allowed to approach open flames, burning cigarettes, etc., until after adequate ventilation of their clothing.
k) Make sure that all oxygen apparatus and equipment is properly identified.

Escape routes must be kept clear at all times.

References

[1]. Cleaning of equipment for oxygen service
EIGA: IGC Doc 33/97 (adopted as AIGA 012/04)

[2]. Odorisation of oxygen in combustion applications
EIGA: 911/03

[3]. Accident prevention in oxygen-rich and oxygen-deficient atmospheres
CGA Doc. P-14, 1992

[4]. The safe application of oxygen enriched atmospheres when packaging food
BCGA Doc. GN 5, 1998

[5]. The probability of fatality in oxygen enriched atmospheres due to spillage of liquid oxygen
BCGA Doc TR2, 1999

[6]. Reciprocating compressors for oxygen service
EIGA: IGC Doc. 10/81

[7]. Centrifugal compressors for oxygen service
EIGA: IGC Doc. 27/93

[8]. A method for estimating the offsite risks from bulk storage of liquefied oxygen
BCGA Report R 1, 1984

Properties of oxygen
Oxygen supports combustion

- Oxygen is essential to life, the normal concentration in the air we breathe is approximately 21 %. It is not flammable but supports combustion. Most materials burn fiercely sometimes explosively in oxygen. As the oxygen concentration in air increases, the potential fire risk increases. At concentrations above 23 % in air, the situation becomes dangerous due to the increased fire hazard.

Properties of oxygen
Oxygen gives no warning

- Because oxygen is colourless, odourless and tasteless, oxygen enrichment cannot be detected by the normal human senses.

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Properties of oxygen
Oxygen is heavier than air

- Being heavier than air, oxygen can accumulate in low lying areas such as pits or underground rooms, especially in cases of liquid spillage

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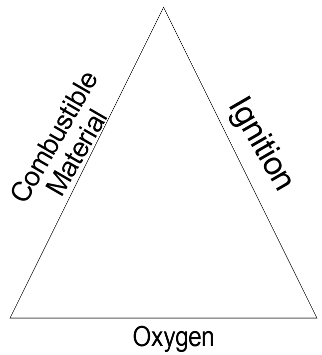
Necessary conditions for a fire

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 normal way of representing these conditions



When one of the 3 elements is missing a fire cannot occur.

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Causes of oxygen fires

- Oxygen Enrichment of the atmosphere
- Improper use of oxygen
- Incorrect operation and maintenance of oxygen systems
- Use of materials incompatible with oxygen service

Compatibility of materials

- Only certain materials are suitable for use in oxygen service.
- Most materials will burn in pure oxygen, even if they cannot be ignited in air.
- Oils, grease and materials contaminated with these substances are particularly hazardous in the presence of oxygen, as they can ignite extremely easily and burn with explosive violence.

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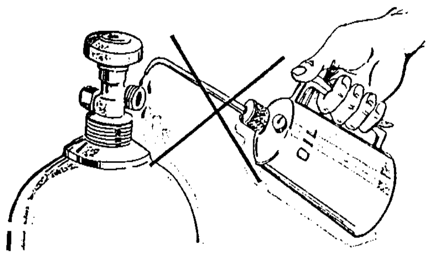
Never use oil or grease to lubricate oxygen equipment!

- Equipment contaminated with oil and grease shall be cleaned using approved cleaning agents/methods.



Check with your supervisor that any material/part or substance you intend to use is approved for oxygen service.

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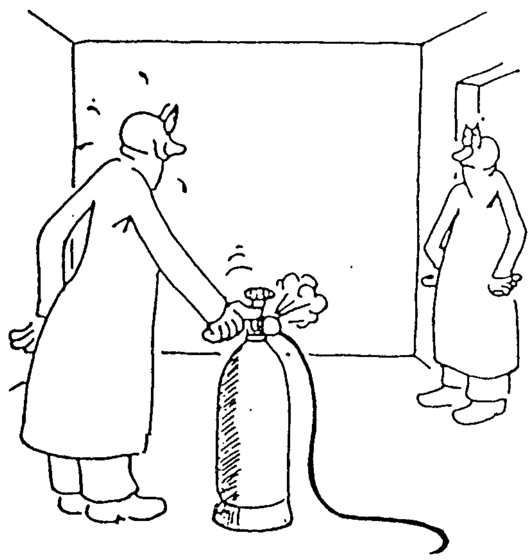
Leaking equipment is very dangerous

- It could lead to oxygen enrichment, i. e. increased fire hazard.
  Leaking connections, flanges, fittings are hazardous causing the oxygen concentration to increase especially where there is not sufficient ventilation. All equipment, newly assembled or after maintenance, has to be thoroughly leak tested before going into service.



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Liquid Oxygen spill

- A spill of liquid oxygen creates a dense cloud of oxygen enriched air as it evaporates.
- The clothing of personnel entering the cloud will become enriched with oxygen.
- When liquid oxygen impregnates the soil which contains organic material, e.g. wood, asphalt, etc., a dangerous situation exists, as the organic material is liable to explode when impacted.

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Do not use oxygen for applications for which it is not intended!

Do not use oxygen as a substitute for air, e. g. for:

- operating pneumatic tools
- inflating tyres
- starting diesel engines
- dusting benches, machinery or clothing

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In areas where oxygen enrichment can occur, do not smoke and do not use naked flames

If hot work (welding, flame cutting, soldering, grinding, etc.) has to be carried out, ensure that the atmosphere has been checked and confirmed as safe and obtain a Permit to Work.

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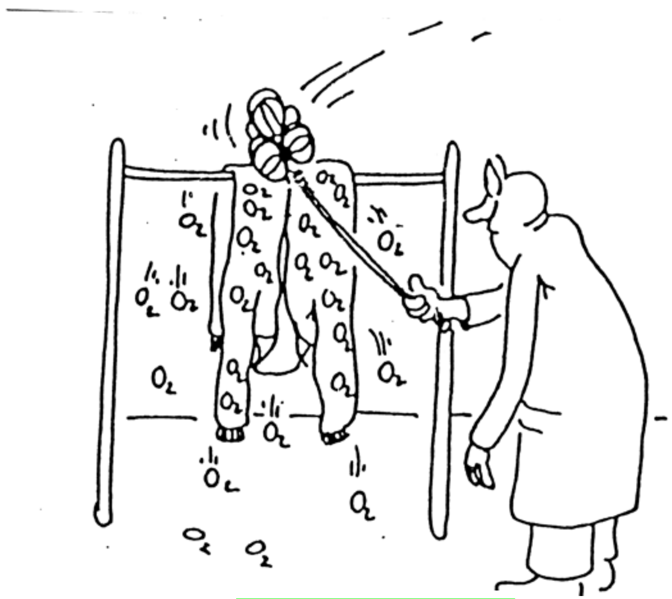
If you have been in an oxygen enriched atmosphere ventilate your clothing in the open air for at least 15 minutes before smoking or going near a source of ignition.



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Examples of oxygen enrichment accidents.

Had the recommendations of this Document been followed none of the following would have occurred

1. A safety valve on a gaseous oxygen supply line was greased during repair. When the safety valve was later checked under oxygen pressure, the **grease** ignited and the operator was badly injured.

2. A worker wanted to check the pressure of oxygen cylinders. He used a pressure gauge filled with **glycerine**, not suitable for oxygen service. When opening the valve the pressure gauge exploded, resulting in nearly total blindness of the worker.

3. A fitter lost the Teflon gasket of his oxygen regulator. Arriving at the place where he had to do a repair, he made a **rubber gasket** from an inner car tire and connected the regulator to the cylinder valve outlet.
   When he opened the cylinder, due to the use of a non-oxygen compatible gasket, a flash occurred burning his upper arm and shoulder.

4. A worker was welding on the outside of an oxygen pipeline. Before starting the work the welder isolated the pipeline by closing the valve, purging the pipeline and checking the atmosphere. Suddenly the welder was engulfed in flames and subsequently died of his burns. The valve was later found to be **leaking** allowing oxygen to enter the isolated pipeline.

5. At a factory, a valve on an **oxygen feed line** which ran into the plant shop **was left open**. A man's clothing ignited when contacted by electric welding sparks. He ran out and rolled on the grass but was seriously burnt. Several others who assisted were slightly burnt.

6. A worker attempted to change a blowpipe by nipping the oxygen hose. **Escaping oxygen** caused fire resulting in serious burns to the worker.

7. Men were working on the roof of an oxygen factory near a main **oxygen vent** which was operating. One man began to smoke, his clothing ignited and he was burned to death.

8. A contractor employee had to grind away a piece of railing on a platform at the air separation column.
   A Work Permit had been issued and a pre-job discussion had been held. The ambient temperatures were low and while waiting for a colleague he leaned over and partially sat down on an oxygen vent warming himself on the escaping relatively warm oxygen leaking through the valve. The moment he started grinding, a spark set his **oxygen saturated clothing** alight, causing burns on his total body of 2nd and 3rd degree resulting in months of hospital treatment.

9. When using an oxygen lance in a steel foundry, an operator realised that the coupling between hose and lance was leaking, but did not mind because it provided some cooling on his stomach. A spark of hot metal was projected towards the operator and ignited the **oxygen saturated clothing** at his stomach, resulting in serious burns.

10. An air powered rotary drill was connected by means of an adapter to an oxygen line. After several hours, the air in the working compartment had become so **enriched with oxygen** that when one of the workers lit a cigarette it flared up, ignited clothing, resulting in four fatalities and five other men being injured

11. A welder was working in a tank car. After a while, he interrupted his work in order to renew the air in the tank by **introducing oxygen**. When he resumed his welding a spark ignited his clothing. The worker succumbed to fatal burns.

12. A steelworker attempted to repair his car which had a blockage in the fuel line. He **used oxygen to clear the blockage** and the fuel tank exploded killing one person.

13. There are several reports of men being set on fire due to walking into the gas cloud from an **oxygen spillage** while smoking.

14. A person who was wearing proper clothing was working in an **oxygen enriched atmosphere**. He went to a smoking area and immediately lit a cigarette, whereupon his clothing ignited.

15. Several incidents are reported of hospital patients who had their clothing and bedding set on fire due to **smoking or sparks while receiving oxygen treatment**.

16. Several instances have been reported of deaths in hyperbaric chambers due to **smoking or electrostatic sparking under enriched oxygen conditions.** In one case 10 people were killed when a fire broke out caused by a portable hand warmer being used.