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Risk Control Services: Fire Prevention

Oxygen reduction atmosphere systems

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Standard recommendations based on recognized international standards and good practices are proposed. Moreover, very good NFPA (National Fire Protection Association) and FM Global Property Loss Prevention Data Sheets on these subjects exist. Since there is no need to reinvent the wheel, readers are referred to those references when relevant.

- NFPA free viewing at <http://www.nfpa.org/>
- FM Global Data Sheets free viewing and download available when registered at <http://www.fmglobal.com/>

Note that these materials are periodically revised and updated. Please monitor the above websites for updates and/or revisions.

Acknowledgement:

- FPO Fire Protection Engineer, main contributor

Technical Documents:

- FM Global data sheet 4-13 Oxygen Reduction Systems
- FM Global Research Technical Report January 2018 “Evaluation of Oxygen Reduction System (ORS) in Large -Scale Fire Tests”
- Wagner OxyReduct Active fire prevention system for deep freeze storage and cold storage warehouses
- Advantages and challenges with using hypoxic air venting as fire protection – by Martin Nilsson and Patrick van Hees - FIRE AND MATERIALS - Fire Mater. 2014; 38:559–575
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<http://onlinelibrary.wiley.com/doi/10.1002/fam.2197/epdf>
- OSHA (Occupational Safety & Health Administration)
https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATION&p_id=27004
https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATION&p_id=25743
13.16 Oxygen reduction atmosphere limitations

SCOPE

Oxygen reduction atmosphere systems are based on limiting the oxygen level (to around 13-16%), reportedly to avoid the possible occurrence of a fire in a given volume. **They are not fire protection systems**, they are fire prevention systems or fire limiting systems (i.e. they can prevent ignition or limit fire spread, depending on the fuel and oxygen concentration).

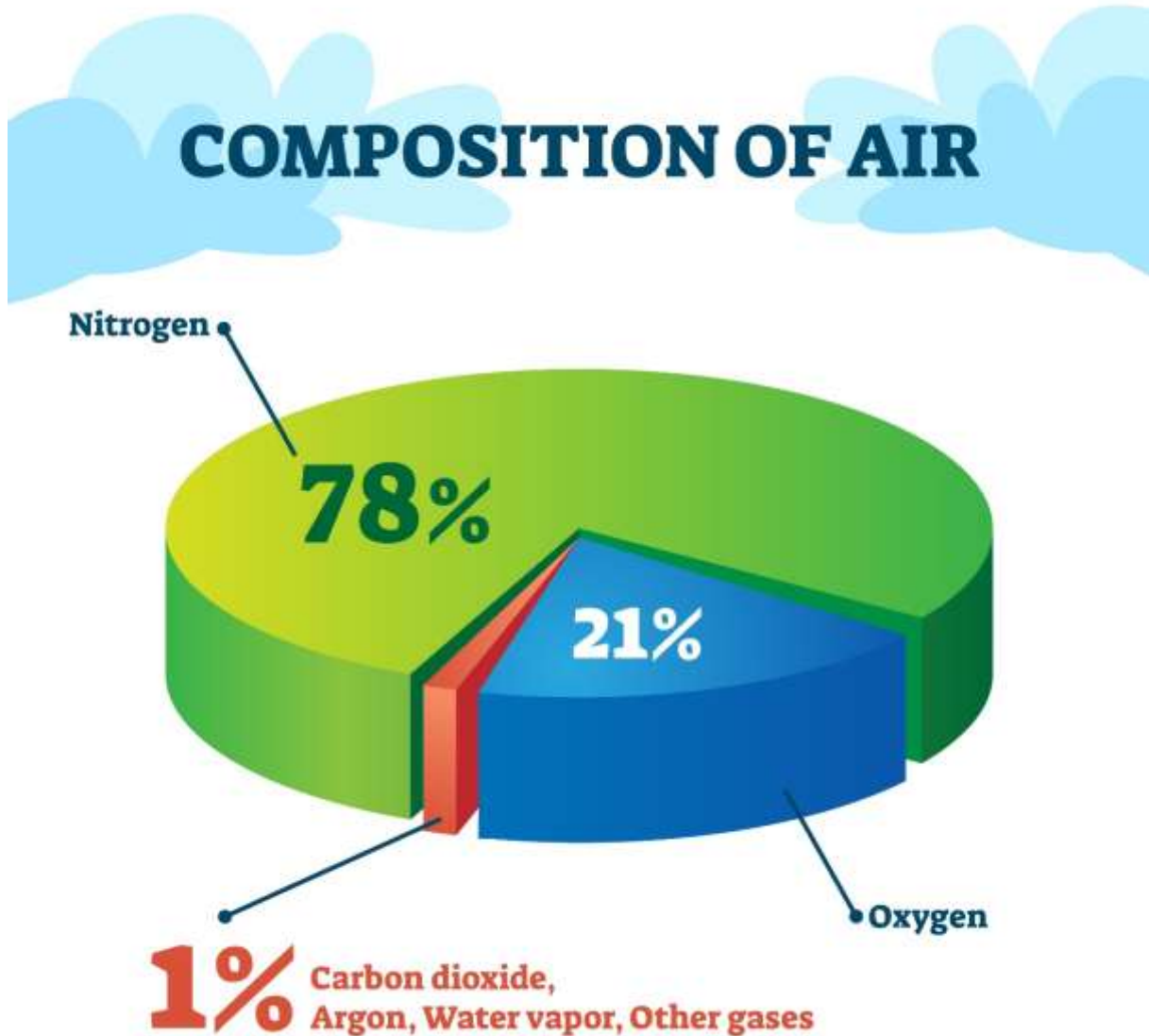


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1. The main components of an oxygen reduction system

- Nitrogen generation system (to continuously generate nitrogen in order to keep the oxygen level under a certain percentage).
Note that automatic sprinkler protection should be provided for the gas generation room and designed for the combustible load in the room.

- Electronic control device and alarms.
- Oxygen sensors (within the room that is “protected” by the system, as well as in the gas generator room).
In the gas generator room, oxygen sensors should be provided and set to alarm if oxygen levels drop below 19.5% or increase above 23.5%.
These values are meant to define an environment that can be accessed by a person without any special considerations or equipment.



Nitrogen is produced as required and stored temporarily, if necessary.

This may involve central nitrogen supply facilities. The storage quantities may be either liquid or gaseous.

Interlocks should be provided to shut down all operations within the building/room/equipment enclosure when smoke/fire or an oxygen concentration above set limits is detected:

- De-energize all electrical equipment except lighting within the building/room/equipment enclosure.
- Shut down all load/unload operations (if applicable)
- Close all exit/entrance doors.

2. We have the following comments/concerns regarding this type of protection

- Long-term energy costs for oxygen reduction systems are high because the system is normally in operation.
- Automatic sprinklers or fixed gas protection systems, on the other hand, present limited long-term costs (i.e. periodic inspection and maintenance).
- These systems should only be used in a space that is not normally occupied.
- An oxygen level of 15% is usually used because lower concentrations could pose serious health risks.
- At a 15% oxygen level, the risk of fire still exists, so a hypoxic air venting system cannot be seen as a substitute for an extinguishing system.
- To be seen as a substitute, the oxygen concentration needs to be lowered even further.
- There are possible medical limitations. In some countries, special medical tests to enter rooms with <17Vo% O₂ are requested. In some countries where this system has been provided, any person entering the room has to have a specific annual medical check, is not allowed to smoke 24 hours before accessing the room, and a fairly complex confined space entry permit has to be established.
- The most important parameters for determining possible health exposure are the oxygen concentration and duration of exposure. A limited exposure down to 13% oxygen concentration does normally not cause a health risk in healthy people. But disease, physical fitness, age and sex are important parameters that could increase possible exposure. Expected response to hypoxia varies widely between individuals, especially in people with pre-existing diseases. Physical activity may also increase the risk of becoming ill.
- Control of O₂ concentration: the reliability of the system is based on the low oxygen level. Therefore, the O₂ measurement should be as precise as possible and the release of nitrogen to compensate for that percentage should be done automatically. This means that a sufficient number of N₂ bottles must be available and ready to operate.
- An alternative to N₂ bottles would be to provide a N₂ generator, but this system requires some space to install and is normally not recommended for a volume of under 2,000 m³ (70,500 cu ft).
- A reduced oxygen environment results in higher production rates of soot and smoke.
- Room tightness: to avoid the need to provide nitrogen on a continuous basis (high cost) in order to keep the oxygen concentration low, the room should be as tight as possible (volume of air exchange should be lower than 5% per hour). This might be difficult during maintenance periods (people going in and out of the room) and

probably during operational periods (the room's air conditioning system should be on a closed circuit for air renewal).

- Frequency of people entering the room: each time the door is opened, the oxygen concentration might increase, thus requiring additional nitrogen.
- Building access for repairs or maintenance needs to be determined.
- Sprinkler system shutdown is not something that is frequently needed unless work is required on the sprinkler system itself.
- Raising the oxygen levels for regular maintenance should not be a normal procedure. When the oxygen levels are increased above the oxygen design point, the system should be considered impaired.
- Fire service response needs to be clearly defined for such areas.
- Fire service personnel enter buildings to fight and extinguish fires, or at least confirm the lack of a fire.
- Allowing air into a building with an oxygen reduction system could initiate regrowth of the fire without any fire protection within the volume.
- Sites with building/room/equipment enclosures that have reduced oxygen environments need to work with their fire service to develop a fire response plan that maintains the oxygen design point in the volume.

So before such a system is installed, it is advisable to study carefully the cost of the installation as well as the maintenance cost and the ongoing cost of providing additional nitrogen.

An integrity test of the room should also be performed in advance, in order to estimate the final cost of the system and the number of nitrogen cylinders required for reliability (and the feasibility of the installation).

3. Conclusions

As indicated above, this solution may be fully adequate, but has to be carefully studied to ensure its reliability and cost-effectiveness.

Reliability is the key word because if the O₂ concentration is not as expected, it could either be ineffective (too high) or dangerous for people (too low).

An alternative to this type of protection is a gas extinguishing system (inert gas release upon smoke detection), possibly in addition to a pre-action sprinkler system (to limit the fire spread in the event that the inert gas protection system malfunctions).

For any installation of such systems, FM Global data sheet 4-13 (Oxygen Reduction Systems) should be strictly followed.

4. Health effects of oxygen reduction:

- OSHA (Occupational Safety & Health Administration) states in Paragraph (d)(2)(iii) of the Respiratory Protection Standard that any atmosphere with an oxygen level below 19.5% to be oxygen-deficient and immediately dangerous to life or health.

- To ensure that employees have a reliable source of air with an oxygen content of at least 19.5%, paragraphs (d)(2)(i)(A) and (d)(2)(i)(B) of the Respiratory Protection Standard require employers to provide employees working under oxygen-deficient conditions with a self-contained breathing apparatus or a combination full-facepiece pressure-demand supplied-air respirator with auxiliary self-contained air supply.



- In the preamble to the final Respiratory Protection Standard, OSHA discussed extensively its rationale for requiring that employees breathe air consisting of at least 19.5% oxygen.
- OSHA has serious concerns regarding the health and performance effects on employees who cycle through oxygen-deficient atmospheres on a daily basis (e.g. eight hours of exposure to an atmosphere containing 15% oxygen, followed by 16 hours of exposure to air at 20.9% oxygen) over years of employment. Acclimatization to oxygen-deficient environments takes approximately four weeks. Therefore, employees cycling between the oxygen reduction atmosphere and ambient atmosphere will not have an opportunity to acclimatize to the oxygen-deficient conditions. OSHA believes that failure to acclimatize to these conditions could have serious consequences for employees with existing medical conditions affecting the lungs, heart, kidneys and central nervous system.
- Under the Standard, oxygen reduction could be allowed in a workplace without the provision of respirators to employees if, for example, the system raised the oxygen level in the protected area to at least 19.5% prior to employees entering the area. This alternative would be practical only for protected areas that only require infrequent access by employees.
- People at greatest risk would be older employees and those with health conditions such as pulmonary disease, cardiovascular disease or anemia.

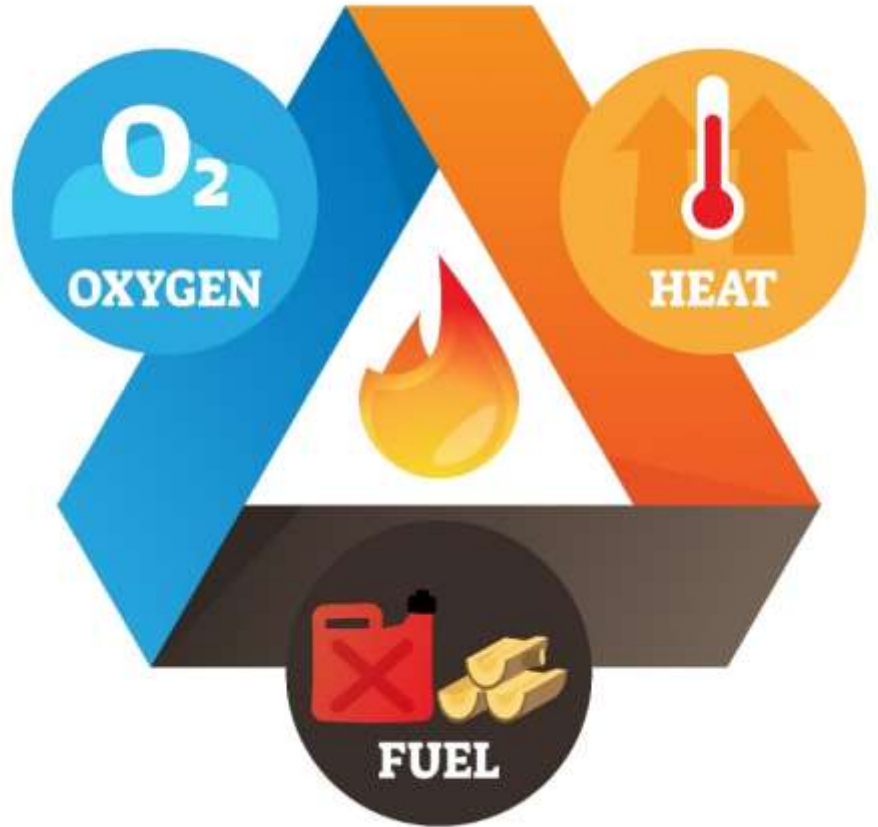
- Also, employees with lung disease and exertional demands greater than the resting level might experience greater hypoxemia.
- In addition to potential adverse health effects, hypoxemia might also affect neuropsychiatric function, resulting in safety issues such as increased risk of injury.

Health effects of oxygen concentration reduction:

- At concentrations of 16 to 19.5%, workers engaged in any form of exertion can rapidly become symptomatic as their tissues fail to obtain the oxygen necessary to function properly. Increased breathing rates, accelerated heartbeat and impaired thinking or co-ordination occur more quickly in an oxygen-deficient environment. Even a momentary loss of co-ordination may be devastating to a worker if it occurs while the worker is performing a potentially dangerous activity, such as climbing a ladder.



- Concentrations of 12 to 16% oxygen cause tachypnea (increased breathing rates), tachycardia (accelerated heartbeat) and impaired attention, thinking and co-ordination, even in people who are resting.
- At oxygen levels of 10 to 14%, faulty judgment, intermittent respiration and exhaustion can be expected even with minimal exertion.
- Breathing air containing 6 to 10% oxygen results in nausea, vomiting, lethargic movements and perhaps unconsciousness.
- Breathing air containing less than 6% oxygen produces convulsions, then apnea (cessation of breathing) followed by cardiac standstill. These symptoms occur immediately. Even if a worker survives the hypoxic insult, organs may show evidence of hypoxic damage, which may be irreversible.



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