Controlled Environment Fire Prevention: Using Oxygen Reduction Technology in the U.S.

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CEBA Controlled Environment Building Association

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Background

At the 2011 Global Cold Chain Alliance Assembly of Committees, held in August 2011 in Washington, D.C. a subcommittee to the CEBA Construction/Codes Committee was formed to study a novel concept of reducing the concentration of oxygen within a controlled environment to a degree that life sustaining oxygen was lowered just enough to prevent fire from starting or spreading while continuing to support human life.

The concept of using oxygen reduction technology for fire prevention had already been successfully implemented in Europe since 1998. In fact, members of the CEBA had visited several sites in Europe utilizing the technology. They reported that while walking through the facilities, they felt fine, experienced no adverse effects during or after the visit in 2013. Many of the members wondered why this technology was not being used in the United States.

To help address their questions, the Construction/Codes Committee formed a subcommittee with the following mission:

1. Become informed on this alternative fire protection concept and learn how it works.
2. Determine the viability of utilizing the concept in the USA and identify the obstacles, if any, for implementation; and
3. Analyze the costs involved in comparison to the traditional fire sprinkler system generally required by building codes.

The subcommittee worked from 2011 to 2017 and whose members were:

- Josh Currie, Fisher Construction Group
- Scott Griffin, Griffco Design/Build, Inc.
- Daren Sealover, Graycor Construction
- Frank Siedler, Wagner Fire Safety, Inc.
- Fred Walker, Americold Logistics
- Donald Wiginton, Wiginton Fire Systems

A first draft of the committee's findings was produced and presented at the November 2011. The subcommittee developed a first draft white paper to capture their findings.

In November 2012 at the CEBA Conference & Expo in Orlando, our master committee decided to ask our European counterparts to look at our research and help us fulfill our mission properly. After receiving some invaluable input, the authors decided it best to re-write the white paper from scratch. The paper was rewritten and reviewed by the Construction/Codes Committee in late 2013.

Note: This white paper is not intended to be the "final word" on this subject. As processes and technologies change, CEBA and GCCA intend to revise this white paper as the industry evolves.

Acknowledgements

CEBA and GCCA would like to acknowledge and thank all the members, listed above, who served on the subcommittee and contributed to this whitepaper.

The associations would also like to thank René Barman with B-Built BV, a design/build firm based in the Netherlands and Gary Koltiar of Fire Pass Corporation of Germany for their review and input into the white paper with particular appreciation expressed to Frank Siedler of Wagner Group, GmbH and Peter Clauss, formerly with Wagner Group, GmbH for the time and energy they spent in clarifying our understanding of the science and how it is being implemented in Europe and developing internationally.

Health and Safety

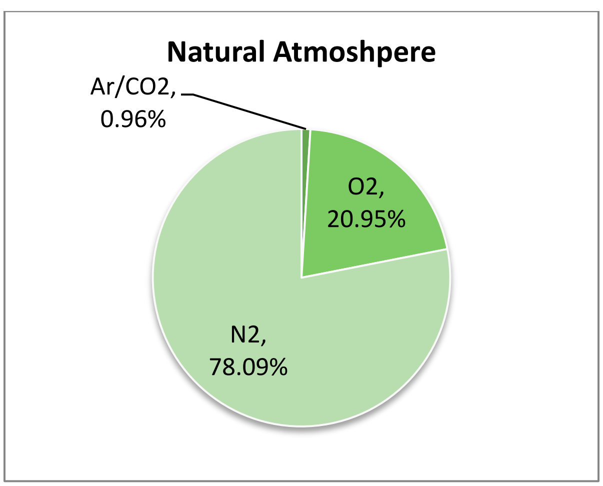
Those of us that have been at higher elevations have noticed that the air felt “thinner.”

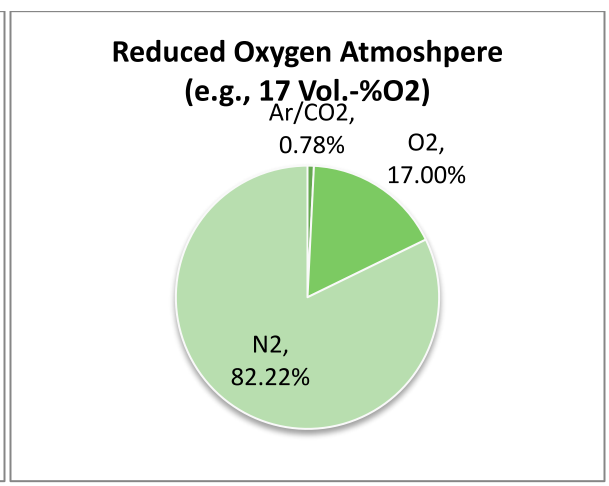
At sea level the oxygen content is about 21 Vol.- % and at 14,000 ft. it is still 21 Vol - %, but it ~~is~~ feels thinner to the human respiratory system and is equivalent to12 Vol.- % after factoring in the lower atmospheric pressure and the actual number of molecules available to breathe at 14,000 ft.

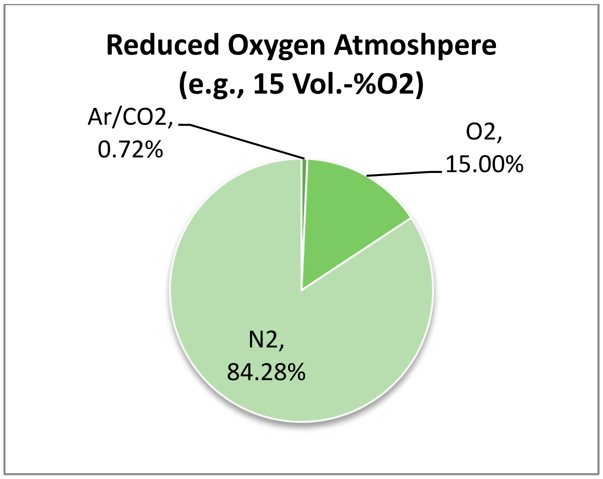
In normal surroundings, people do not use all the oxygen molecules they inhale with each breath. How much oxygen one needs depends on a variety of factors including their level of exertion, physical condition and time needed to acclimate. There are a multitude of people, all over the world, conditioned to high altitudes, who could run a race at the reduced oxygen levels. These people have higher hemoglobin concentrations in their blood and can extract oxygen more efficiently from the air they are breathing. Conversely, there are others that would be best suited to not subject themselves to a lowered oxygen environment.

Numerous long-term studies have been conducted in Europe, including by medical professionals the University of Munich in Germany and the Union International Des Association D’Alinisme of Switzerland. These studies indicated that limited exposure to lower oxygen environments can be safely managed without causing undue risk to healthy human beings, using reasonable prudence in safety. Science proves that a fire can certainly occur at the top of Pikes Peak where the percentage of oxygen is still 21% yet feels like and is equivalent to 12 % oxygen at or about sea level.

Oxygen atoms and Nitrogen atoms are naturally attracted to one another mixing and bonding naturally. In controlled environments where the oxygen percentage can be constantly measured and maintained by pumping in pure nitrogen, as needed, then “stirring it in”, to the space, by way of air movement created by the fans, the nitrogen percentage stays up and the oxygen percentage stays down. People can still breathe just as well as they can skiing in Aspen, but fire combustion cannot occur. It’s a phenomenon of physics and physiology working separately.







In contrast to OSHA regulations in the U.S., Europe's less restrictive regulations allow limited exposure for four hours at a time in environments with oxygen content between 15 Vol.- % and 17 Vol.- % and two hours at a time in environments with oxygen content between 13 Vol.- % to 15% Vol.- %, requiring a 30-minute rest break in between exposures, as well as physical examinations before entry along with repeat examinations every 2 years. If any difficulties are experienced, such as acute mountain sickness (AMS) the individual must leave the environment immediately.

Controlled Environment Fire Prevention Principles

Fire is a chemical reaction that requires three things to sustain itself - fuel, heat and oxygen.

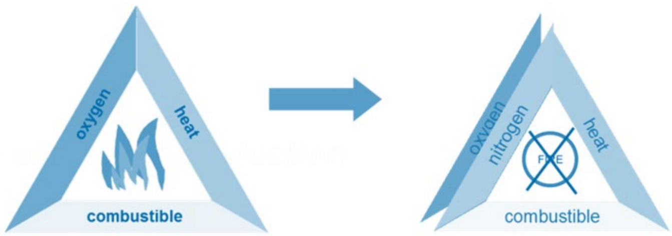
Oxygen is one of the fundamental components required for combustion (fire) to occur.

Too much O2 (rich environment) or too little O2 (lean environment) oxygen, and fire/combustion will not occur or sustain itself.

The pioneers of "thin air" fire prevention systems ~~claim they~~ can safely prevent unwanted fire from occurring or propagating all together within a controlled environment by breaking down the well known "fire triangle" by adding nitrogen to the space, thus ~~throug~~h reducing the concentration of oxygen in the controlled environment.

Depending on the combustibility of the fuels and the temperatures being maintained, life sustaining oxygen can be calibrated and maintained below its normal pressurized 21% oxygen by volume (Vol.-%) at sea level to lower percentages by volume, each having an equivalent molecule concentration, corresponding to various higher elevations.

This controlled environment fire prevention concept is basically just another form of air conditioning. Systems are not designed to make the air cooler. They are designed to make the air thinner (reducing oxygen) and in doing so, fire is prevented from starting or spreading. "Thin air" fire protection systems are quite different from all other forms of fire protection as it is proactive and constantly maintained to prevent the chemical reaction of "fire" to occur at all. Other fire protection systems such as fire sprinklers or gaseous agent systems are reactive in nature. However, what both forms of fire protection have in common, is their basic function of interrupting one or more of the three essential elements (fuel, heat and oxygen) of the chemical reaction known as fire.



To what degree the oxygen needs to be lowered to prevent fire depends on the other two legs of the "three legged" stool. The temperature the controlled environment will be maintained at and the combustibility and other characteristics of the products occupying the space must be considered. Since it is proactive in nature and not required to penetrate and extinguish a raging fire that has somehow broken out, the methods and heights for storing materials becomes irrelevant.

How it Works

The main system components are:

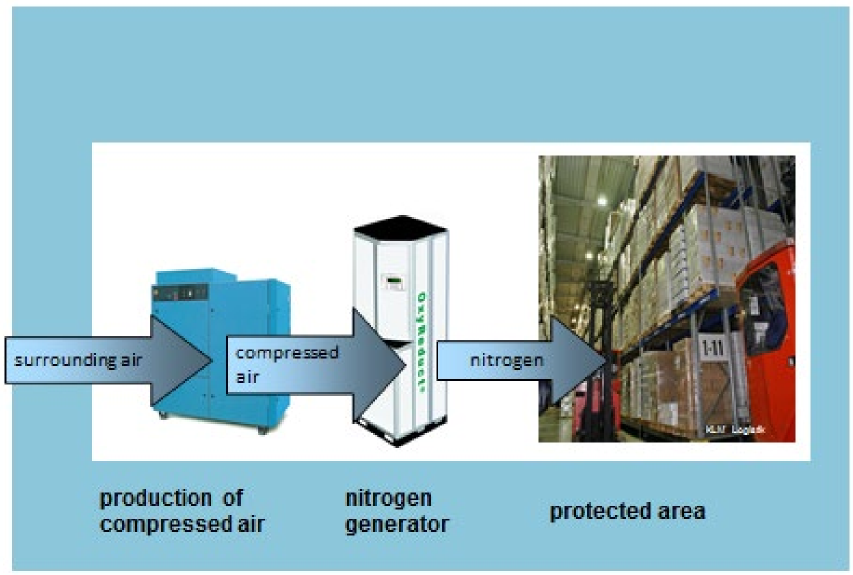
- Relatively airtight environment
- Nitrogen production generator,
- N_2 distribution piping/network, and
- System controls and monitoring

Air-Tight Environment

We must first begin with a controlled air-tight environment. A "thin air" fire prevention system is dependent on maintaining an air-tight environment and keeping the entire space at a constant oxygen concentration level. Emphasis on envelope tightness in order to meet the maximum allowed vapor exfiltration rate of 0.5GPM @ 1 pound per cubic foot starts at design and extends through pull down. It is imperative that the design addresses all possible point of exfiltration such as openings, penetrations as well as the overall envelope. In order to achieve this focus starts with the envelope to assure that all sub floor, wall and roof vapor barriers avoid all possibility of leakage. While these envelope measures are prescribed for most frozen warehouses openings are most often the highest source for infiltration / exfiltration resulting in general vapor and temperature loss, openings within a low oxygen environment, specifically those which have high traffic are designed with airlocks complete with high speed doors which not only have been tested to meet the required airtightness requirements, but are interlocked with the automation system so as sequence product movement in a manner which maintains vapor integrity. A critical part of the envelope which can be easily overlooked are all penetrations through said envelope all of which must be carefully thought out, detailed, located and installed in a manner that assures an airtight seal. Lastly, is performance of the required pre/post temperature pull down testing which can only be achieved by performance of a certified blower door test combined with a thermal scan. These tests provide the necessary verification that the envelope meets the requirements of the Low Oxygen system necessary for optimum system performance.

Oxygen Reduction through Nitrogen Production

Natural ambient air is compressed by a standard industrial air compressor. The compressed air is cooled, filtered, and fed to a nitrogen generator. In the nitrogen generator, the nitrogen and oxygen are separated by a filtration process. This results in almost ~~95%~~ pure N_2 for distribution/injection into the protected "thin air" environment. The separated O_2 is vented to the outdoors. There are various technologies to separate oxygen and nitrogen from the atmosphere. For small rooms membrane air separation seems to be the technology of choice and for large volumes VPSA (Vacuum Pressure Swing Adsorption) technology is currently used in recent installations.



Nitrogen Distribution

Nitrogen is distributed into the freezer warehouse, via the freezer evaporator fan ductwork and discharge grills. The N_2 is thoroughly mixed with the conditioned air and is diffused throughout the warehouse.

Key:

1. Protected area
2. Operating room with
   - Nitrogen generation
   - Control panel
3. Nitrogen pipe
4. Oxygen sensor
5. Air sampling smoke detection system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2
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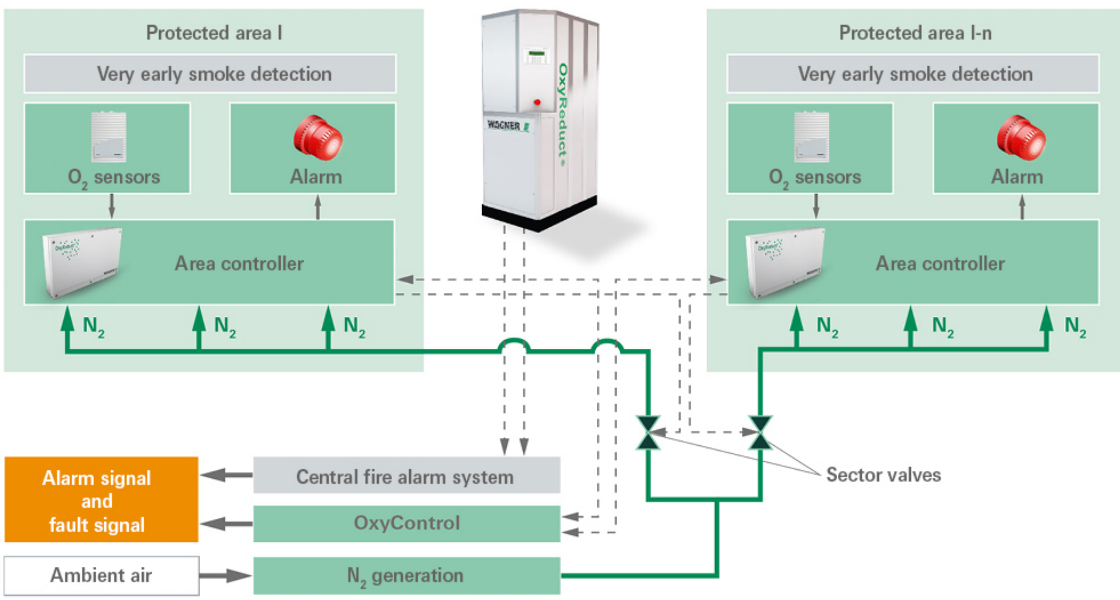
4
5

Controls and Monitoring

The oxygen reduced air is maintained through oxygen detectors/monitors distributed throughout the freezer. The system is controlled through a dedicated control system, that constantly monitors the concentration of O_2 in the protected area and generates and injects additional N_2 on as-needed basis. The system is able to control the O_2 concentrations levels within ±0.2%.

The reduced oxygen concentration is established during initial building/room commissioning and is continuously maintained during building use and occupancy. Thus, a fire-proof environment is always provided.

A general system layout of the proposed single zone system is illustrated as follows:



Aspiration Smoke Detection

Air sampling smoke detection systems (ASD) are active smoke detectors, which permanently take air samples through plastic pipes from the monitored areas and feed them to the integrated highly sensitive detector module for air analysis.

Even though the low oxygen level will protect the protected area(s) against fire or its propagation, the ASD systems will give alarm upon a beginning pyrolysis or smouldering in its early stage. This earliest possible fire detection brings significant time benefits, which enable counter measures to be taken. In addition the ASD system serves as a minimum back-up in case the low ox system is out of operation (e.g. maintenance services).

Installation Guidelines and Standards

There are several European companies involved in marketing and developing this means of fire prevention.

Currently, there is no guideline, standard or avenue for design, installation, or maintenance of Reduced Oxygen Fire Prevention Systems in the United States.

However, there are several different European guides available as listed below:

- VdS 3527 en, VdS guidelines for Inerting and Oxygen Reduction Systems (Germany)
- TRVB S 155 and ÖNORM F 3007 (Austria)
- SN 123456 (Switzerland)
- PAS 95 (United Kingdom, November 2011)
- EN 16750 (European Standard, 2017)

The European standard EN 16750 lays out most of the consideration related to design, installation, planning, maintenance. In addition, it recommends to current public safety precautions leaving it however to local organisations to release its own rules and guidelines (see section below OSHA).

Building Codes and Standards

Buildings constructed in the United States generally require adherence to one of the major model building codes, typically either the International Code Council (ICC), the International Building Code (IBC), the International Residential Code, the International Fire Code, the International Energy Conservation Code, the International Plumbing Code, the International Mechanical Code and others.

These codes call for fire protection to be provided at various hazard classifications and size thresholds that comply with the National Fire Protection Association standards.

Typically, the standard for public refrigerated warehouses is NFPA #13 Installation of Fire Sprinkler Systems.

Within the NFPA #13 standard, there is a statement which reads:

> "Nothing in this standard is intended to restrict new technologies or alternate arrangements, provided the level of safety prescribed by this standard is not lowered."

The Building Codes also allow for what is known as an Alternative Materials and Methods procedures. It can, and has been used, as a basis for substituting a reduced oxygen fire prevention system in lieu of fire sprinklers.

It's preferable if the owner/operator of the facility be personally invested in pursuing this process and has involved his insurance underwriter and provider to buy in to the AMM proposal, not only from a property and casualty perspective but also from a workman's compensation perspective.

Oxygen reduction fire prevention systems have been approved and in use, predominantly in Europe, for more than 20 years. Currently there are over 900 system installations in more than 25 countries.

Since September 2017 there is a EUROPEAN standard in place, the ISO Group is working on a global standard and NFPA has released a request for proposal to undertake a literature review on Low OX systems.

Other Design Considerations

When contemplating installing a reduced oxygen/ nitrogen enriched environment system there are several items to consider for the physical plant. These include the space to house the equipment, environmental conditions, pipe routing/distribution and backup power supply.

The equipment space requirement can be large depending on the warehouse volume served. The room needs to have an overhead door for maintenance and delivery of replacement media.

The process to generate nitrogen requires a substantial amount of air to strip the nitrogen from. The supply air must be tempered for the equipment to operate. Depending on the project location the supply air will need to be heated and potentially cooled as well.

When designing the facility, the routing of the nitrogen supply piping and discharge locations should be considered. The distribution of the nitrogen is best achieved with the evaporator fans for the refrigeration system serving the warehouse.

A backup generator should be provided to power the equipment in the event of the loss of primary electrical service.

OSHA

Currently, OSHA's Respiratory Protection Standard requires anyone entering a space that has an atmosphere less 19.5%, to utilize a full-face mask style self-contained breathing apparatus. OSHA has been reluctant to reconsider the Respiratory Protection Standard which in turn has created a barrier for widespread acceptance of "thin air fire protection" in the United States despite a proven personnel safety record in Europe and elsewhere. Thus, "thin air fire protection" in the United States has been primarily limited to un-manned, lights off, automated warehouses where access is limited to necessary maintenance activities where the use of a SCUBA pack is not substantially prohibitive

Insurance Underwriters

Each "early adopting" company should, most certainly speak and work with their risk management provider to make sure that are insurable and comfortable with the potential liabilities involved.

Practical Applications

Since it is essential to control the environment, Reduced Oxygen Fire Prevention Systems would present a challenge to the typical PRW warehouse which experiences excessive air infiltration caused by doors being regularly open and closed during operations. Some have overcome this challenge by going fully automated using airlocks and vestibules to keep the "thin air" from escaping.

Cost Considerations

A recent costing effort that utilized actual pricing for a facility of 150,000 SF and 22 MC, showed that the cost of an oxygen reduction system is approximately 60% of the cost of a traditional sprinkler type fire protection system. Further, as the volume of facility is increased, the cost savings of an oxygen reduction system increases. A comparison of the potential business loss costs due fire for a traditional sprinkler system vs. an oxygen reduction system shows that the potential business loss costs are avoided with an oxygen reduction system due the fact that fire ignition is not possible in a low oxygen atmosphere. This "cost savings" should be taken into consideration when evaluating the oxygen reduction system. Operational Energy Savings also can be realized with an oxygen reduction system because the increased integrity of the building envelope nearly eliminates infiltration and there is reduction of heat loads and electric loads in "dark" warehouse operation. Combination of these savings increase the viability of oxygen reduction systems as a cost-effective fire protection solution for the cold storage industry.

Operational Cost of the Oxygen Reduction System

While there are limited long term historical records, from an operational standpoint the cost to operate are proven to be slightly lower than that of a traditional double interlock pre-action system. While the low oxygen system has substantially larger compressors than the traditional fire sprinkler system, this allows the compressors to be controlled by Variable Frequency Drives (VFD's) reducing the electrical demand significantly.

In addition to the electrical operating cost of the compressors there will be energy costs associated with conditioning the supply air. The extent of the costs is dependent on the location of the project. Extremely colder or warmer climates will determine the ongoing energy costs.

The production of nitrogen requires a media that periodically is to be replaced. describe any ongoing servicing costs.

Conclusion

In Europe, Reduced Oxygen Fire Prevention Systems have already been enthusiastically accepted by users and public safety officials. In North America, (3) facilities have been completed and (2) are underway.

Resources

For more information, please consult the following resources.

Concerning STANDARDS

- EUSAS Journal No 5 April 2009 "Permanent Fire Prevention with Oxygen Reduction - Technology and Applications"
- Chiti, Stefano (November 9, 2011). "A Pilot Study on Hypoxic Air Performance at the Interface of Fire Prevention and Fire Suppression". *FIRESEAT 2011: The Science of Suppression*.
- "PAS 95:2011 Hypoxic air fire prevention systems. Specification". 2011. BSI.
- VdS Guidelines for Fire Prevention Systems, Oxygen Reduction Systems, Planning and Installation, VdS 3527en : 2015-05 (02). Germany
- European standard for “Fixed firefighting systems — Oxygen reduction systems — Design, installation, planning and maintenance”, EN 16750. 2017. Europe

Concerning OSHA:

- Torres, Katherine. "OSHA Rejects Fire Prevention Technology." *EHS Today Home Page*. EHS Today, 28 May 2008. Web. 25 Jan. 2013.

- Work in Hypoxic Conditions-Consensus Statement of the Medical Commission of the Union Internationale des Associations d’Alpinisme (UIAA MedCom)
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