Active Fire Prevention by Oxygen Reduction Systems

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Abstract

After more than 15 years, active fire prevention by Oxygen reduction systems has become an established technology for fire protection and is today widely used around the globe.

Keywords: Fire prevention, Oxygen reduction, Innovative technology, Preventive Apporach

Introduction

The innovation of this technology is defined by its preventive approach for fire protection which is so far unique in the fire protection industry.

All fire protection systems – detection and extinguishing ones – are reactive systems and starting to alarm or activating extinguishing systems after smoke and/or fire is present. Oxygen prevention systems however are following a preventive approach. By creating an atmosphere of lower Oxygen content than in the normal atmosphere, the start of a fire and thus also the production of smoke can be avoided. Therefore, Oxygen prevention systems are providing a higher level of safety compared to other fire protection systems.

There are applications where such a preventive approach is offering significant advantages to the customer since damage on sensitive goods can be reduced to a minimum which can be crucial for corporations in order to maintain operational business processes.

Today, typical applications for Oxygen reduction systems are:

- Automatic warehouses
- EDP rooms
- Archives

In the meantime, the logistics sector and the protection of automatic warehouses has become the most dominant field of application showing the strongest growth rate.

Oxygen reduction systems for such applications are then used when already low amounts of smoke are damaging high sensitive and valuable products and making them non-usable such as all kind of food stored below 0 °F, pharmaceutical products, textile, historic or exclusive cars or hazardous goods.

For EDP rooms, Oxygen reduction system can provide continuous operation of the facility in case of smoke detected on an early stage e.g. by overheating of electrical equipment. The lower Oxygen concentration is avoiding of any open fire starting and thus preventing the EDP room from significant damage and potential loss of operation.

Archives have become an interesting application recently since high valuable documents or paintings can be protected from any damage by smoke and fire. There are historical archives or museums on one hand and storage of high valuable goods from private persons (secured storage) on the other hand.

During the presentation at AUBE, different examples realized around the globe will be presented.

Despite the lower Oxygen concentration in the protected areas, it is still possible to access those areas for service and maintenance for a defined period of time. The limitations and the time which is allowed to enter those areas is subject of national law and therefore, different in most of the countries around the globe.

In Switzerland for example – one of the most strict countries regarding access to such areas – the SUVA (Swiss Health and Safety Organisation) is limiting the access to areas of Oxygen concentration lower than 17 Vol% to six hours a day and people entering such areas must undergo a medical examination on a regular basis. Above 17 Vol% such areas are considered as normal working space without any limitations.

Today, several technologies have been established to permanently reduce the Oxygen concentration in a protected area. As a common element all these technology are reducing Nitrogen to be introduced into to protected area lowering the Oxygen concentration.

Preventive Approach

Oxygen prevention systems are creating an environment avoiding any formation of fire and smoke and thus, not reacting on a fire after it has started.

Three conditions must meet together to make a fire possible which can be seen from the triangle of fire (see Fig. 1): Oxygen, combustible and heat.

With almost all kinds of burning material, ignition and burning ability is directly associated with the Oxygen concentration in the ambient air and does decrease when the Oxygen concentration is decreasing as well.

In an atmosphere which does have reduced Oxygen already, much more energy is needed to ignite a fire.

In case a fire is starting in an environment with lower Oxygen concentration, the fire development is very much slowed down compared to a fire of the same material in ambient conditions. Oxygen prevention technology is using these physical effects to provide fire prevention.

Fig. 1. Triangle of fire.

With the controlled addition of Nitrogen into a protected area, it is possible to create an atmosphere in which no fires can burn any more and even cannot ignite. The use of Nitrogen does have significant advantages:

- With 78 % by volume, Nitrogen is the main constituent of the ambient atmosphere.
- Nitrogen is a non-toxic natural gas as long as the remaining Oxygen concentration is above 8 % by volume.
- Nitrogen can be produced easily on site by using different technologies.
- Nitrogen is mixing perfectly in the protected area.
- Nitrogen does have excellent fire prevention capabilities which are well know from gaseous extinguishing systems using Nitrogen as an extinguishing agent.

Real fire tests show that e.g. almost all solid materials are not igniting anymore if the volumetric Oxygen concentration is less than 16 %. In other words, no fire can start and be maintained if the volumetric Oxygen concentration is reduced below such a concentration level (see Fig. 2).

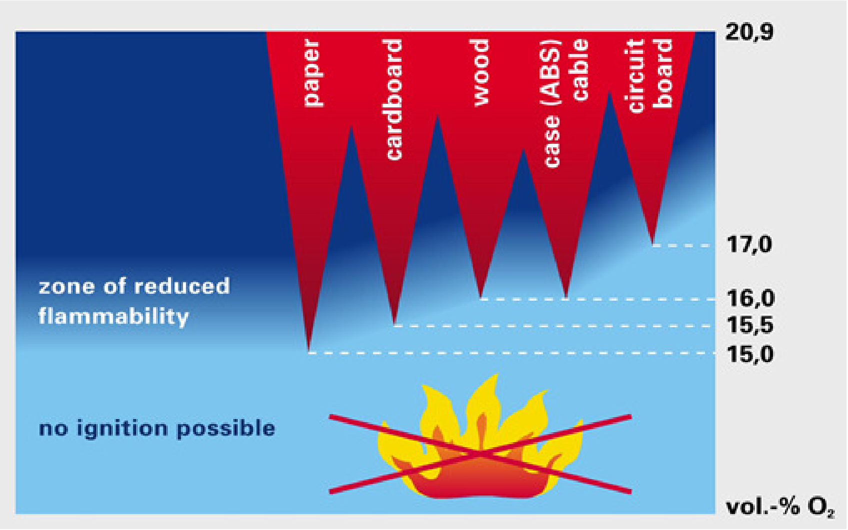

Fig. 2. Ignition limits for solid combustibles.

For flammable liquids however, the ignition limits are lower compared to solid materials which is easy to understand due to the flammable characteristics of such liquids. However, also for flammable liquids a fire is starting and developing much slower under reduced Oxygen concentration compared to normal environmental atmosphere.

Following most standards, the design concentration of a defined material must be lowered by 1 Vol% compared the ignition limit of this substance (safety margin). To assure full prevention from smoke and fire these standards further require that the Oxygen concentration is not exceeding the defined design concentration. Therefore the operational area of Oxygen prevention systems is normally set below the design concentration.

The Swiss standard SN123456 “Design and Installation of Oxygen Reduction Systems” allows to reduce the safety margin from 1 Vol% to 0,5 Vol% in case of additional safety measures taken such as the installation of an air sampling smoke detection, fire detection or sprinkler system.

For an archive of paper for example, the ignition limit is 15 Vol% and therefore, the design concentration is defined with 14 Vol% Oxygen. Operation of the system would be normally set in an area between 13,6 Vol% (IN) and 13,8 Vol% (OUT) Oxygen.

If there is a mix of different substances to be protected a risk analysis is undertaken to determine the critical substance to be used defining the design concentration. Normally, it is the substance showing the lowest ignition limit.

In case of very special materials, most standards are defining test procedures to measure the ignition limits of substances following a standardized approach as it is also laid down in the Swiss standard SN 123456. The technology behind the preventive approach assures that the Oxygen concentration is not exceeding the limits defined by the individual standards however there are different approaches for realizing the system technology.

Testing substances has also shown an effect of the temperature on the ignition limits. In case of lower ambient temperatures the ignition limit is moved to a higher value compared testing the same component at normal ambient temperatures. This effect is used when protecting automatic cold storage warehouses.

Functionality of an Oxygen Reduction System

The reduction of the volumetric Oxygen concentration is realized by controlled adding of Nitrogen which is produced by an air separation facility or by using Nitrogen from a storage tank of liquid Nitrogen equipped with an evaporator.

Since the use of liquid Nitrogen is normally more expensive, in most cases an air separation facility is realized. Today, different kinds of air separation technologies are seen for Oxygen reduction systems such as:

- Membranes
- PSA (Pressure Swing Adsorption)
- VPSA (Vacuum Pressure Swing Adsorption)

Membranes are acting like a filter system separating Oxygen and Nitrogen molecules. PSA technology is using active carbon to separate Oxygen and Nitrogen from each other. While the membranes are operating continuously, the PSA process is alternating since the process must be reversed when the active carbon is saturated.

The VPSA technology is also using active carbon for air separation however the operating pressure of 1-2 bars is much lower than compared to standard PSA technology operating in the range of 9-10 bars. Membranes are operating best at a pressure range of 13 bars which can be achieved with standard air compressors.

As it can be seen from above, the technology of Oxygen reduction systems is requiring compressed air in case of air separation realized on site which is leading to operating costs due to the energy consumption of the air compressors. Air compressors however allow recuperating electrical energy by cooling with water and providing hot water contribution or even fully replacing a heating system on the customers facility which is improving the energy balance of such systems.

Normally, the purity of the air used to permanently reduce the Oxygen concentration is having a purity of between 95 and 97 Vol% and therefore, there is still an amount of fresh Oxygen introduced into the protected area providing a hygienically change of air.

There are other technologies using hypoxic air and then constantly introducing the same atmosphere (or containing a little bit lower Oxygen) to the protected area that is going to be maintained there.

The produced Nitrogen or hypoxic air is transported into the protected areas by using a pipe system with nozzles. The Oxygen concentration in the protected area is permanently monitored by using Oxygen sensors. The amount of sensors is depending on the size of the protected area and also from the standard that is going to be applied. Normally the standards are defining a minimum amount of sensors that must be installed.

Today, there are different kinds of technologies to be applied to measure the Oxygen concentration: punctual ones or sensors using the air sampling technology. All these technologies are accepted by the international standards as long as the Oxygen sensors are also fulfilling the technical performance standards defined to such sensors.

The system control unit shall be able to monitor all sensor values for securing a homogenous Oxygen concentration in the protected area and it shall also monitor sensor failures such as Oxygen sensors that are going to sleep.

For system operation, the mean value of all Oxygen sensors installed in the protected area is used. Normally, a control panel is operating the Nitrogen production unit according to the Oxygen concentration in the protected area (see Fig. 3).

By doing so, all natural and other leakages (e.g. of material handling in an automatic warehouse, inspection access to a protected area) are compensated and the Oxygen concentration is maintained permanently on the specified level to assure full fire prevention. For a large warehouse for example, 1/3 of the losses is from the structure itself while 2/3 of the losses are caused by the logistics handling operations.

As an option, an external supply of Nitrogen can be added to the system (e.g. liquid Nitrogen tank) which can be used as a back-up system in case of longer maintenance periods of the Oxygen prevention system or also as primary Nitrogen supply if the liquid Nitrogen storage is equipped with an evaporator.

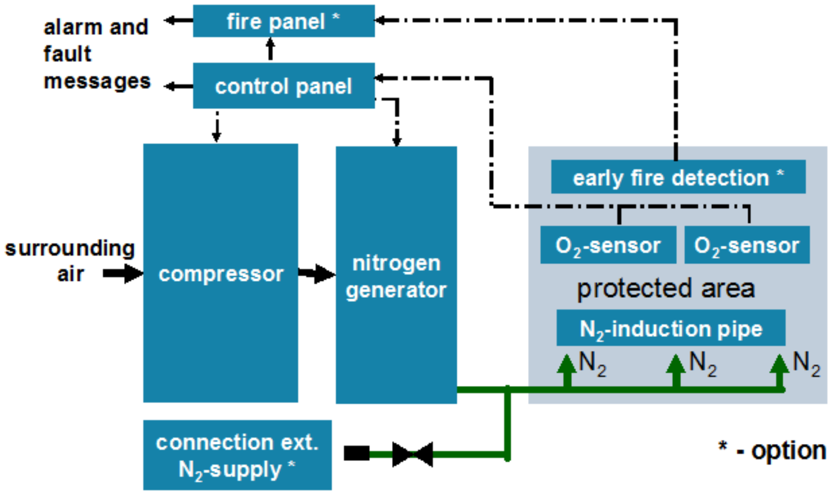

Fig. 3. Overview on single sector system.

As a further option, a quick release is possible by using Nitrogen stored in high pressure cylinders. Such an application allows reducing the Oxygen concentration in a protected area within 120 s to achieve a lower Oxygen level. The Oxygen reduction system is then designed to maintain the lower Oxygen level in the protected area. For such a system approach the use of a high sensitive air sampling smoke detection system combined to the Oxygen prevention system is mandatory. Such a process allows operating an archive normally at an Oxygen level of 17 Vol% which is then decreased in case of first smoke particles detected.

For maintaining the Oxygen concentration in the protected area the system control panel is defining an operational range of e.g. +/- 0,2 Vol% Oxygen, based on the mean level of all sensors. On the higher level, the supply of Nitrogen to the protected area is activated (ON) and on the lower level the supply of Nitrogen is stopped (OFF). Therefore, Oxygen reduction systems are supplying Nitrogen to the protected area between 6 to 15 hours a day, depending on the

- Tightness of the area
- Number of access to the area or number of logistic movements
- Size and characteristics of the openings
- Time period openings are really opened

Some standards such as the SN123456 require special alarming measures to avoid that the Oxygen concentration is reduced below 13 Vol%. Normally all standards are defining how many alarming devices must be installed such as digital Oxygen indicators in front of access doors, sounders, beacons or warning plates.

Access to protected area

In Europe and most countries over the globe the access to areas with reduced Oxygen concentrations for working, service or maintenance purposes is subject of national law. Therefore, standards for Oxygen reduction systems normally differ between the guidelines for design and installation and do refer to the national law accessing these areas such as the Swiss standard SN123456.

The Swiss standard for example is defining four concentration limits defining the time those areas can be accessed:

> 17 Vol%	unlimited access, free working space
> 15 – 17 Vol%	six hours a day, break for 30 min after four hours medical examination every second year
> 13 – 15 Vol%	six hours a day, break for 30 min after two hours medical examination every year
< 13 Vol%	access only with external Oxygen supply

Regarding the access to areas protected by Oxygen reduction systems in different countries a reference is made to the paper of Florence Daniault that is also presented during the AUBE conference 2017.

International Standards

Today, some countries in Europe and outside of Europe have already developed a standard for the Design and Installation of Oxygen reduction systems.

Currently, the drafted EN standard 16750 is in the final stage which has been developed on the basis of the Swiss Standard SN123456. Publishing of this standard will lead to an increase of installations of the Oxygen prevention technology in European countries waiting for an European basis to design and realize such systems.

In parallel, a ISO working group is now starting to prepare an ISO document under TC 121 SC 8. The document is using the draft of the EN 16750 standard as a working document.

Regarding the status of standardization of Oxygen reduction systems and the next developements a reference is made to the paper of Florence Daniault that is also presented during the AUBE conference 2017.