International Standardization of Oxygen Reduction Systems for Fire Protection

Florence Daniault
Wagner Group GmbH, Langenhagen, Germany

Frank Siedler
Wagner Fire Safety Inc., Waltham, USA

Abstract

The technology of fire protection using a oxygen-reduced atmosphere to prevent fire from starting or propagating is quite new in comparison to a sprinkler system or even a gas extinguishing technique. This paper recalls the history of the development of new standards and regulations to cover this technology of oxygen-reduced atmospheres which started in Europe and has now, by demand from owners, reached North America.

This paper gives an overview about the design and installation guidelines available today all over the world, it also explains the main requirements and analyses the slight differences.

Regarding health and safety regulations the paper emphasizes the different positions of OSHA and the European insurances. It introduces the concept of risk classification corresponding to different operating ranges of oxygen concentrations and describes recommended protective measures.

Keywords: Fire protection, fire prevention, oxygen reduction, hypoxic air, standardization

Introduction

Fire protection using the oxygen reduction principle is an established technology, installed and in operation in more than 1000 projects and for more than 18 years, mainly in automated warehouses and server facilities all over the world. Peter Clauss has given an in-depth overview at SUPDET in 2014 [1]. The idea behind it is quite simple: reducing the oxygen concentration in a room will prevent fire from starting or propagating. However, oxygen reduction is achieved by complex technical systems that are providing a flux of nitrogen or nitrogen-enriched air into the protected areas [2].

Even after many years of experience many questions arise all over the place. Designers wonder how to determine the appropriate operating oxygen concentration level and the required nitrogen-enriched air volume flow inside the protected area. Manufacturers of oxygen reduction systems ask certification bodies how to get an approval. Certification authorities ask for standards that apply – either locally or globally. Owners of facilities inquire about the measures to allow access of people to protected rooms.

All this demonstrates the need for a full set of regulations and standards to cover design and installation as well as health and safety issues of oxygen reduction systems for fire protection in any part of the world.

Approval in the time before publication of any guideline

The Wagner Group company presented its first oxygen reduction system for fire prevention under the OxyReduct® trademark in 1998 on exhibitions and conferences in Germany (Security in Essen, Wagner Symposium) and started the operation of the first OxyReduct® fire prevention system in a server room in 1999.

How to get an approval for this brand new fire protection technique? At that time, of course, no standard or guideline was available. For cases like this, the German VdS referred to a specific procedure for the approval of new extinguishing techniques described in document VdS 2562. This includes tests of the extinguishing effectiveness as well as reliability tests of the components. Wagner went through this procedure and got its first approval from VdS in 2004. The experience gained from these test series was helpful to write the planning and installation guideline VdS 3527, first published in 2007 [3].

Another milestone was the first industrial installation in the US for the protection of the world's largest freezer warehouse in 2015, located in Richland, Washington State bringing oxygen reduction on an industrial scale to the US – although no local standard is on place. It has a capacity of 115.000 pallet stalls and a volume of approx. 1 Million m^3 / 38 Million ft^3. And now just north of the US border, Canada has its first installation at Dr. Oetker's new facility in London, Ontario.

Design and installation guidelines from VdS and EN to ISO and UL

Based on the VdS guideline from 2007 oxygen reduction made its way through Germany and got into other European countries (and beyond) within the last 10 years. Consequently, a European standard was to follow the German VdS guideline and today the prEN16750 is made the platform for international designs and for the New Work Item Proposal issued in September 2016 at ISO. The working Group ISO/TC 21/SC 8/WG 9 just started its work to develop an international draft standard on oxygen reduction systems.

Table 1 shows in chronological order how many national standards or technical guidelines about design, planning, installations and maintenance are now available to address relevant performance and safety requirements.

Table 1. World-wide overview of design and installation guidelines.

Country	Organization	Reference	Issue
DE **Germany**	VdS	VdS 3527 (01) VdS 3527 (02)	2007 2015
AT **Austria**	Fire brigades ASI	TRVB S 155 08 OENORM F 3073	2008 2010
CH **Switzerland**	SNV	SN 123456	2009
NL **The Netherlands**	KIWA	BRL-K21017	2009
UK	BSI	PAS 95	2011
Europe	CEN	FprEN 16750	2016
USA	UL	UL 67377 #1 UL 67377 #2	2016 Jan 2016 Aug

In countries without their own national guideline, especially in the Middle East or in the Asia Pacific region, either European or US guidelines are usually used.

The aim of the guidelines is to define rules for designing an effective installation that safely maintain the appropriate operating oxygen concentration even in case of a failure. They contain construction requirements for the generators, the pipe work, the control equipment and its power supply.

A key issue is to determine the operating oxygen concentration. Therefore, the guidelines include a list of known ignition threshold (e.g. 15.9 or 16.0 % O_2 for plastic material like ABS, PVC, PP, PE) as well as methods to ascertain ignition thresholds of unfamiliar materials. A safety margin (0.5 - 1.0 % O_2) and tolerances in the oxygen measurement have to be taken into account to calculate the operating concentration. The safety margin is arbitrary and varies between the different guidelines:

TRVB	0.5 % O_2
SN	0.5 % O_2 (with a fire alarm system or a sprinkler)
EN	0.75 % O_2
Kiwa, SN, VdS	1.0 % O_2

Figure 1 shows an example with an ignition threshold of 16.0 %, a safety margin of 1.0 % and measuring errors of 0.4 % which results in a maximum operating concentration of 14.6 % O_2.

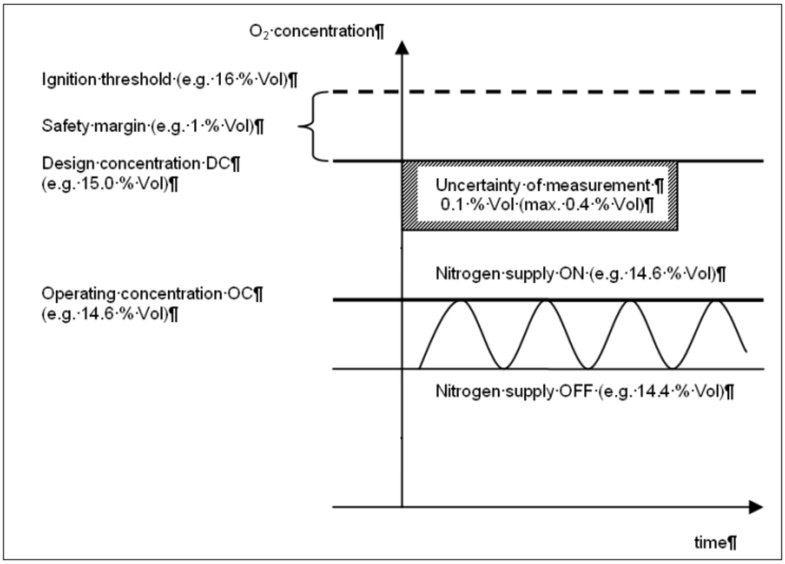

Fig. 1. Example of safety margins between ignition threshold and maximum operating concentration.

EN and VdS require a minimum number of oxygen sensors in each protected area to monitor and control the oxygen concentration. At least three oxygen sensors are required, even for small areas. The amount of sensors required depends on the volume of the protected area, as shown in Table 2.

Table 2. Number of oxygen sensors according to prEN 16750.

Volume in m³ from	to	Minimum amount of measuring zones	Minimum amount of oxygen sensors
> 0	500	1	3
> 500	4 000	4	4
> 4 000	10 000	6	6
> 10 000	25 000	8	8
> 25 000	50 000	10	10
> 50 000	100 000	12	12
> 100 000	200 000	14	14
> 200 000	300 000	16	16
> 300 000	400 000	18	18
> 400 000		Case by case evaluation	Case by case evaluation

If the oxygen concentration cannot be maintained within the control range, the control equipment shall signal this abnormal condition. For example, if a door to a protected room is left open for long time the oxygen level may increase far above the control range even if the generator don't stop producing oxygen reduced air. In this case, a fault shall be signalled (O_2 too high) to indicate a reduced fire protection. If it happens that the oxygen level falls far below the control range then a fault (O_2 too high) or even an evacuation alarm shall be signalled. Figure 2 illustrates the monitoring of the oxygen concentration with upper and lower thresholds above and below the control range for the example of an operating concentration in the range between 15.0 % and 15.2 % O_2. The fault thresholds are thereby displayed in yellow and the alarm threshold for evacuation in red.

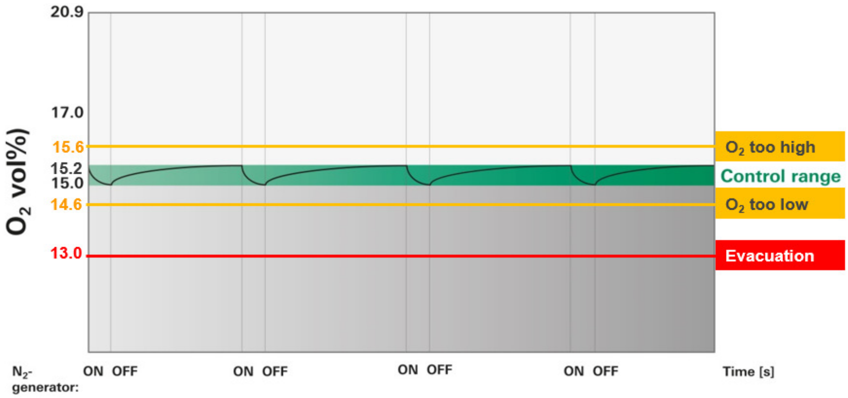

Fig. 2. Example of controlled oxygen level and monitoring of abnormal conditions.

UL has published the outline of investigation UL 67377 which refers to prEN 16750:2014 for the general design, installation and maintenance of the system. UL mentions especially prEN 16750 regarding the upper and lower thresholds to control the oxygen concentration. However, UL 67377 includes references to UL standards, e.g. UL 429 for valves or UL 508 for control equipment. In addition, UL 67377 introduces requirements on functional safety according to IEC 61508 series to the programmable logic controllers.

EN 16750 includes an annex on health and safety only for information and refers to national regulations for working in areas with lower oxygen concentration.

Health and safety regulations: OSHA versus European Insurances

Being in an oxygen-reduced atmosphere is comparable to being at a high altitude. The significant physiological factor is the oxygen partial pressure. From an occupational health perspective, real altitude (hypobaric hypoxia) and oxygen reduction (normobaric hypoxia) are considered comparable [4]. For example, going skiing at an altitude of 3000 m (9000ft) in the Rocky Mountains is comparable to an oxygen concentration of 14.3 % in an oxygen reduced protected area.

In the US, the Occupational Safety and Health Administration (OSHA) recognizes that, at higher altitudes, oxygen in air has a partial pressure that is less than the partial pressure of oxygen in air at sea level; accordingly, the Respiratory Protection Standard makes allowances for employees who work at altitude. However, OSHA made these allowances based on record evidence showing that such employees usually are acclimated to the reduced oxygen partial pressures.

However, OSHA still considers any atmosphere with an oxygen level below 19.5 % to be oxygen-deficient and dangerous to life or health. This is the reason why paragraphs (d)(2)(i)(A) and (d)(2)(i)(B) of the Respiratory Protection Standard require employers working under oxygen-deficient conditions to provide their employees with a self-contained breathing apparatus or an equivalent equipment.

On the other side, the Institute and Outpatient Clinic for Occupational and Environmental Medicine at the University in Munich [4] and the Medical Commission of the Union Internationale des Associations d'Alpinisme (UIAA MedCom) give recommendations on how to provide health and safety for employees in different kinds of low oxygen atmospheres [5]. European National Accident Insurances have compiled these recommendations for owners of facilities protected with oxygen-reduction systems in specific health and safety publications, as listed in Table 3. These European publications apply to working in environments with a reduced oxygen concentration down to 13.0 % without requiring any self-contained breathing apparatus.

Table 3. Overview of European health and safety publications.

Country	**Organization**	**Reference**	**Issue**
CH **Switzerland**	SUVA		2011
UK	BSI	PAS 95	2011
FR **France**	INRS	ED 6126	2012
DE **Germany**	DGUV	205-006 (BGI/GUV-I 5162)	2013

As a measure of precaution, no permanent work place should be located in oxygen-reduced areas and uninterrupted exposure should not last more than several hours. The above-mentioned publications therefore define risk classes and corresponding safety measures, as summarized in Table 4.

Table 4. Risk classes and corresponding safety measures in Europe.

Oxygen concentration c in vol% O2	Safety measures
17,0 ≤ c	Employee training UK: screening of personnel
15,0 ≤ c < 17,0	Employee instructions UK: screening of personnel CH, DE, FR: Occupational health examination CH, DE, FR: 30 min break after 4 h work inside CH, FR: max. 6 hours work inside
13,0 ≤ c < 15,0	Employee instructions UK: screening of personnel CH, DE, FR: Occupational health examination CH, DE, FR: 30 min break after 2 h work inside CH, FR: max. 6 hours work inside

The occupational health examination / screening of personnel focusses on cardiovascular and pulmonary afflictions. It starts with a simple questionnaire to determine heart and lung conditions.

In addition, technical and organization measures such as access control and signs indicating the oxygen-reduced atmosphere are recommended to protect the personnel. The access shall be restricted to authorized and instructed personnel. An audible alarm shall sound if the alarm threshold is reached to initiate the evacuation of the oxygen-reduced area. The Swiss SUVA requires a minimum safety level (SIL) of 3 for the safety functions of the measuring and control equipment.

First products standards

In analogy to conventional fire extinguishing systems where standards like the EN 12094 series define the requirements and test procedures for each system component, products standards are now available in Austria and Germany for the key components of an oxygen reduction system, as shown in Table 5.

Table 5. Products standards in Austria and Germany.

Country	Component	Reference	Issue
AT Austria	Oxygen reduction systems	OENORM F 3007	2009
	Control panels	OENORM F 3008	2010
DE Germany	Control equipment	VdS 3156 (01) VdS 3156 (02) draft	2012 2016
	Oxygen sensors	VdS 3404 draft	2016

Summary and outlook on future development

The required set of national and international standards and guidelines on oxygen reduction system for fire prevention, which guarantee a good quality level for performance and safety all over the world, has reached a respectable level of maturity even if some more work is still pending, especially at international level. The new ISO working group is facing the challenge to find an international consensus between European and US positions on designing and operating oxygen reduction systems.

References

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