

Europe - Germany

Fixed Firefighting Systems — Oxygen Reduction Systems

Active fire prevention vs. passive fire protection

CONTENT

- I) Basics of oxygen reduction
- II) Milestones in the development of oxygen reduction systems
- III) Application areas
 - i. Warehouses for
 - Frozen goods/Cold storage
 - Small-load carriers
 - Cellulose products
 - Lithium batteries
 - Hazardous materials
 - ii. Server rooms / EDP rooms
 - iii. Archives
- IV) System design criteria
- V) Fire tests with different materials
- VI) Existing standards in Europe
- VII) International approvals
- VIII) Health and safety
- IX) Experience derived from 700 installed systems
- X) References´
- XI) Legal Notices, Disclaimers and Warranties
- XII) Author

Fixed Fire Suppression Systems

Oxygen Reduction

- Active fire prevention

Foreword

This paper reflects the actual situation in Germany and Europe.

Assuming there are combustibles in an enclosed area and one is unable to completely rule out the possibility of all sources of ignition, it is usually assumed that there is the chance of a fire.

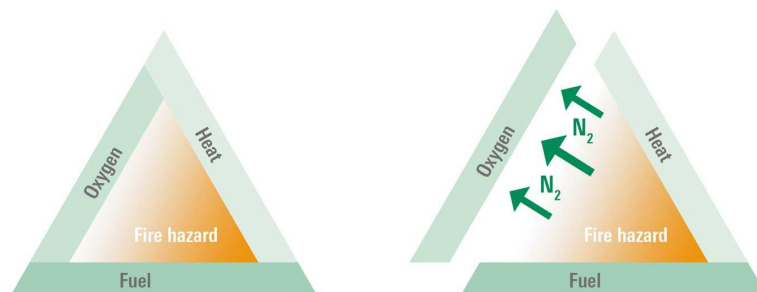
If life safety as well as monetary and non-monetary assets are stake, protective measures are usually pre-planned in order to minimize this risk. These steps might include simple hand-held extinguishers and automatic early fire detection along with all sorts of suppression systems. Most active mitigation measures are RE-active, only responding after a fire has already been detected.

Oxygen reduction takes a completely different – and PRO-active – approach.

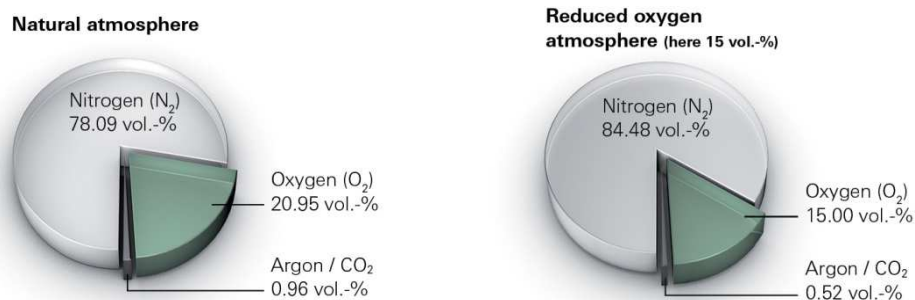
1) Basics Of Oxygen Reduction Systems

Principle

The basic principle of oxygen reduction systems such as the oxygen reduction fire prevention system is simple: combustion cannot take place if there isn't enough oxygen. If the oxygen content in the protected area is reduced, then flammability of the materials in that area is reduced. Where there is insufficient oxygen, fire can neither break out nor sustain itself.



The Earth's natural atmosphere is mainly comprised of 78.09 % nitrogen and 20.95 % oxygen by volume. By adding additional nitrogen into a defined space, the air's oxygen content can be reduced without causing any significant changes that would affect humans. Nature provides a further advantage for Oxygen reduction fire prevention systems (e.g. OxyReduct®): from the ambient air, nitrogen can be easily and economically produced onsite and fed into the protected areas in a controlled manner, in order to effectively reduce the relative level of oxygen.



Oxygen Reduction Systems Offer Active Fire Prevention

Under normal circumstances, a fire can break out at any time. Depending on the value of goods requiring protection, measures should be in place to minimize damage for such a scenario. Available methods range from simple hand-held extinguishers to automatic early fire detection and extinguishing systems. All previously existing approaches have one thing in common: they can only react AFTER a fire has already started. In contrast, Oxygen Reduction Systems operate continuously, preempting opportunities for fire to ever get started.

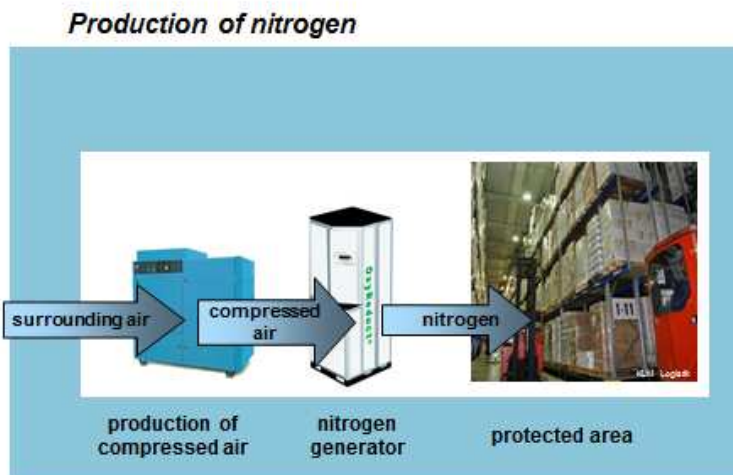
Advantages of Oxygen Reduction Systems

- Avoiding the initial outbreak or spread of fire.
- Significantly limiting damage from smoke, fire size and fire spread (if nevertheless occurring).
- The system operates and monitors itself 24/7. In the event of any deviation from normal operating parameters, the system provides trouble alerts, thereby assuring readiness when needed.
- Avoiding potential damage from common extinguishing agents that might be released pursuant to an incident.
- Requires minimal re-adjustment when fire risks change.
- Subject to few design limitations within the protected areas.
- Permits relatively unrestricted access by personnel into protected areas.
- Increases potential evacuation time in the event of any incident.

Nitrogen Production

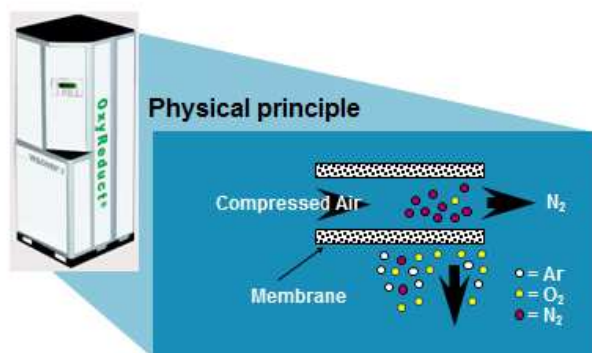
The main system components are:

- Nitrogen production (compressor & N₂-generator),
- N₂ distribution piping/network, and
- System controls and monitoring



Natural ambient air onsite is compressed by a standard industrial air compressor. This compressed air is cooled and filtered, then fed through a nitrogen generator in which the nitrogen and oxygen are separated by use of a selectively permeable membrane filtration system. This process produces 95 % pure N₂ for distribution/injection into the protected “thin air” environment. The separated O₂ is then vented to the outdoors.

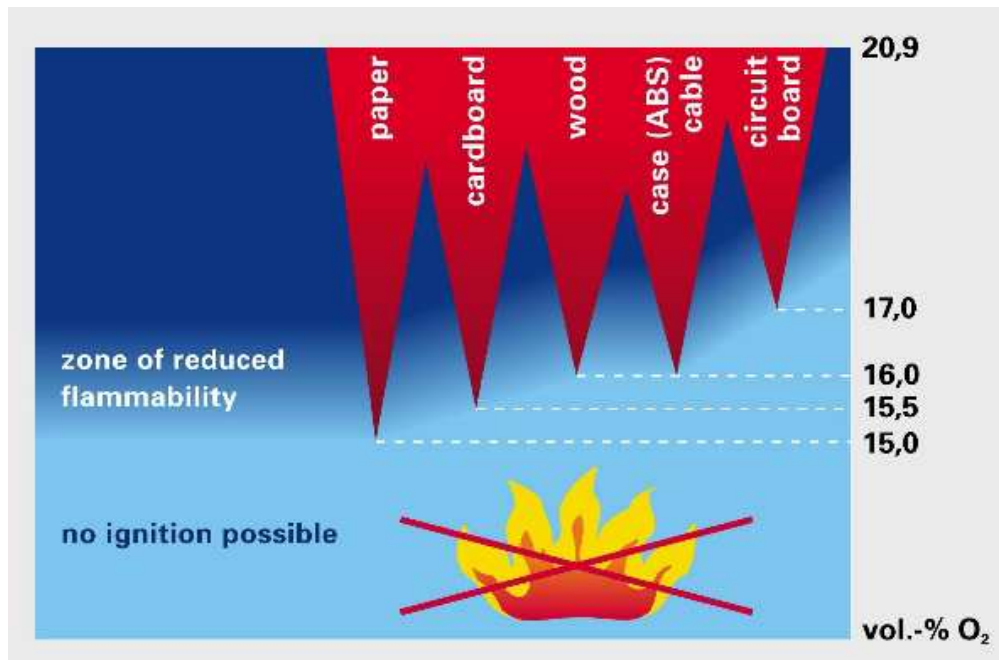
Producing Nitrogen



Determination of the Safe Oxygen Concentration Level

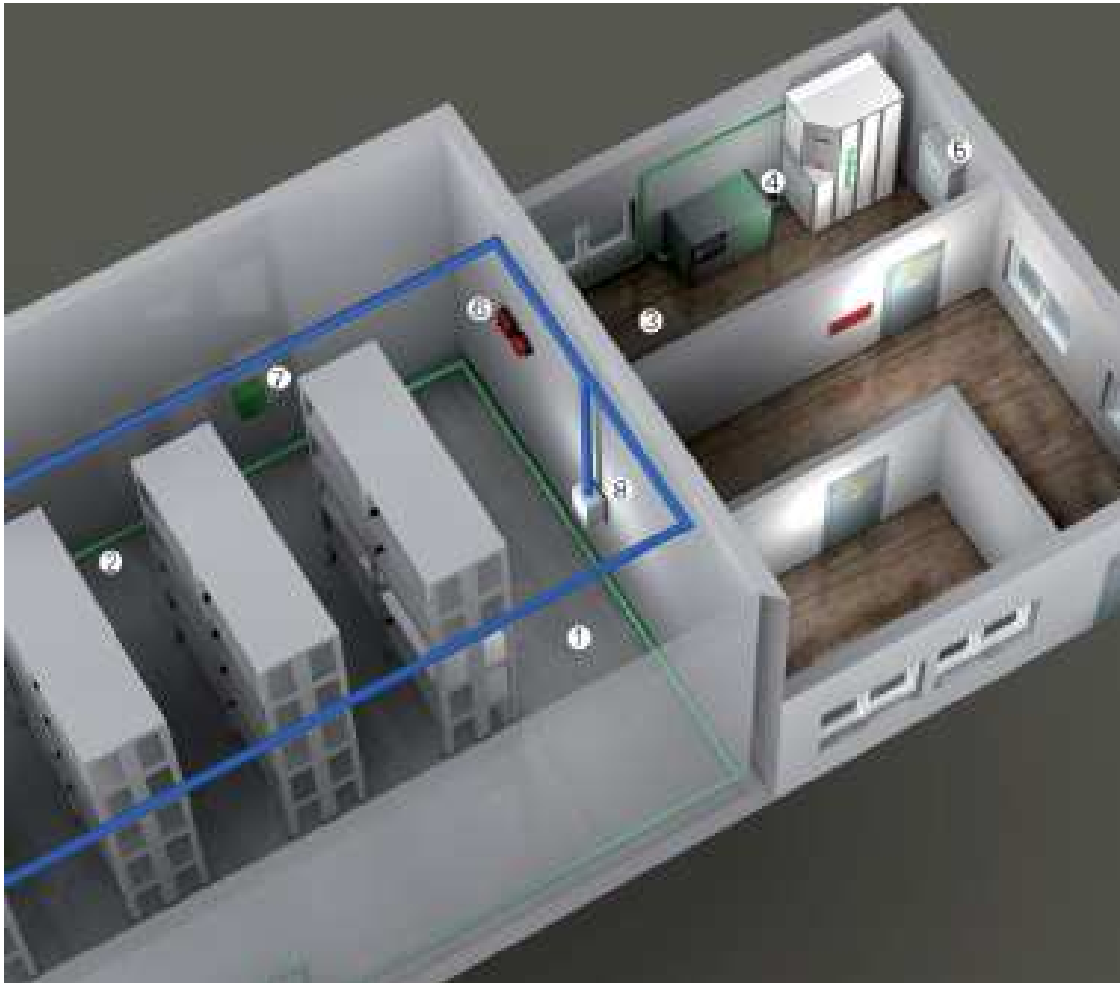
On a case by case basis the combustible materials in the area to be protected are identified. Then the oxygen concentration for these materials and an appropriate system configuration is determined that would prevent ignition or spread of a harmful fire. This determination can be done by employing an existing data base, or for unknown components and configurations, by conducting actual appropriate tests. Once these oxygen concentrations are known, the worst case scenario is selected, thus providing the lowest number to be employed. Since it is common practice in the safety industry to add a safety margin, the oxygen concentration is further reduced to account for unexpected situations.

This, together with the need to also consider possible measurement inaccuracies and other unpredictable operational needs, will result in a final determination of the recommended oxygen concentration, which will effectively be significantly lower than required by the tests, thus resulting in an even lower fire risk.



Controlling and Monitoring the Oxygen Concentration

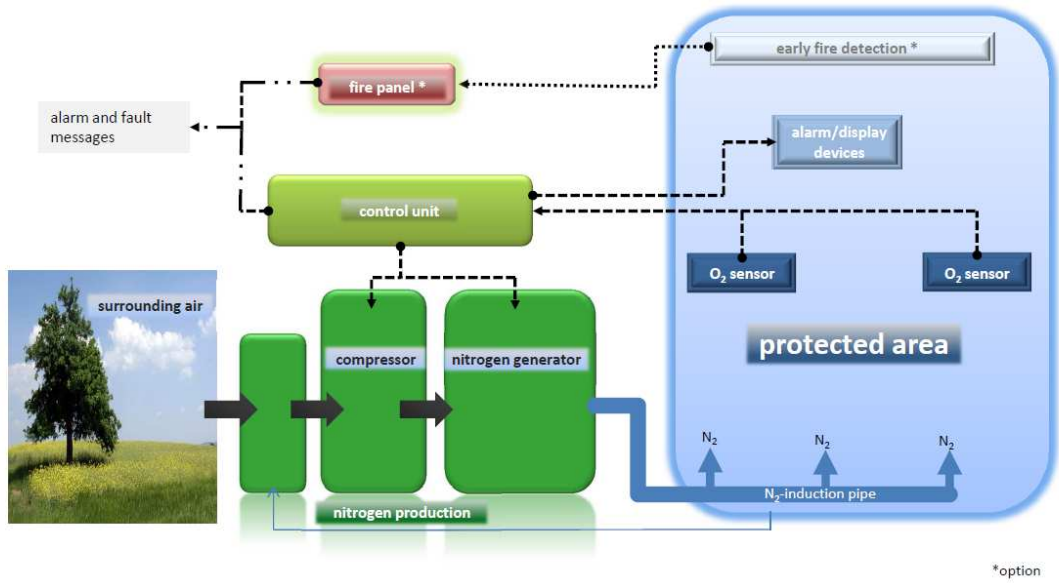
The oxygen-reduced air environment is consistently maintained and controlled by a dedicated control system that constantly monitors the concentration of O₂ in the protected area. Furthermore, it controls the N₂ generation as well as the injection of N₂ into the protected area. The OxyReduct® system is able to control O₂ concentration levels within a margin of ±0.2 %. If the concentration rises above the preset O₂ level, an alarm is triggered.



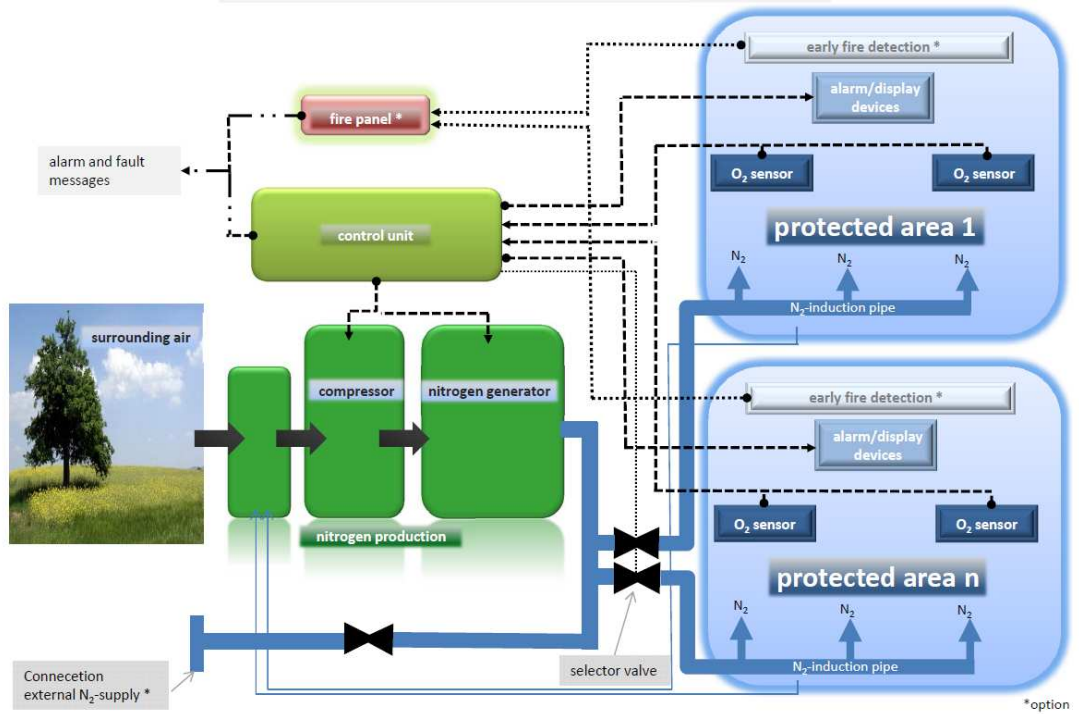
- | | |
|-------------------------|--|
| 1. Protected area | 5. Control panel |
| 2. Nitrogen input piece | 6. Alarm |
| 3. Operating room | 7. Oxygen sensor |
| 4. Nitrogen generation | 8. Air sampling smoke detection system |

General System Layout

System sketch for single zone system



System sketch for multi zone system



II) Milestones In The Development Of Oxygen Reduction Systems In Germany & Europe

1991	Halon prohibition ordinance in Germany
1993 - 1997	Approval of new extinguishing systems (Inergen, Nitrogen, Argon, Argonite, FM-200)
1997	Wagner started fire tests to identify flammability limits in oxygen-reduced atmospheres
October 1998	Presentation of OxyReduct® at the international trade show – “Security” – in Essen, Germany
September 1999	Installation of the first oxygen reduction system for a server room in Halle, Germany
December 2004	First approval for oxygen reduction systems in Germany by the VdS Testing Authority
June 2005	First VdS installer approval for oxygen reduction systems in Germany
January 2007	Publication of VdS guideline (VdS 3527) for inerting and oxygen reduction systems
November 2008	Publication of regulation TRVB S 155, Austria
June 2009	Publication of national standard ÖNORM F 3007, Austria
June 2009	Publication of national standard SN 123456, Switzerland
June 2011	Start of development of a CEN standard
November 2011	Publication of technical specification PAS 95, United Kingdom
October 2013	Request by CEN/TC 191/WG6 to initiate prEN inquiry WI 00191236 for oxygen reduction systems

III) Application Areas

Oxygen reduction fire prevention systems have proven their effectiveness many times. With more than 700 systems installed worldwide, OxyReduct® is on its way to becoming the industry standard for improved fire protection solutions. This innovative system is used for a wide variety of applications, protecting areas ranging in volume from 70 ft³ to 21,200,000 ft³ (2 to 600,000 m³) in size. Individual installations, precisely configured towards specific protection needs, can be designed in such a way that areas protected by oxygen reduction systems can also be accessed by personnel.

Warehouses

Frozen Goods / Cold Storage: System Advantages

- Even at the lowest temperatures, it is possible to create an atmosphere which provides secure fire prevention
- Avoidance of damage to warehouse goods by smoke, the effects of fire and by extinguishing agents
- The system can be adjusted if risk levels change
- Reduced risk of environmental damage thanks to active and preemptive fire prevention
- Secure fire protection for irreplaceable food and seasonal goods
- Assured availability of total warehouse capacity
- Easy adjustment of the system to accommodate changes in requirements



Small-Load Carriers

- Secure fire protection, despite flammable properties of plastic containers
- No loss of production or storage capacity
- No damage to warehouse goods as a result of smoke, effects of fire or extinguishing agents
- Easy adjustment of system parameters ensures flexibility to accommodate changes of occupancy and fire load



Cellulose Products

- Introduction of nitrogen generated on site reduces the oxygen concentration in the warehouse in a controlled manner to a level where the paper rolls can no longer burn
- Removal of the risk of a fire which might be brought in from outside via goods already containing smoldering elements that are entered into stock, since incipient fire traces can no longer spread



Lithium Batteries

- Ensuring risk-free transportation and disposal, especially of high power batteries, is extremely important
- The ideal solution for safe transportation of a damaged cell is a reduced oxygen atmosphere.
- Controlled introduction of nitrogen into a protected area reduces the oxygen level depending on the specific environmental conditions. This is highly effective, since in this reduced-oxygen environment fire cannot spread to neighboring cells
- Dangerous chain reactions which could rapidly lead to a major fire can be prevented. The oxygen reduction concept is ideal for processes where fire extinguishing using water would not be feasible, e.g. lithium battery aging process



Hazardous Materials

- Preventive fire protection for hazardous materials
- Easy system adjustment to accommodate changes in stored contents
- Reduction of environmental risks from fire or its consequences as a result of active fire prevention
- Cost-effective overall design thanks to optimization of construction parameters



Server Rooms / EDP Rooms

- Constant availability of IT infrastructure with reduced risk of downtime caused by fire
- The decisive advantage of this concept is that, in contrast with conventional fire protection solutions, it is not necessary to shut off power to the IT infrastructure. This ensures continued operation of protection while maintaining constant availability
- Secure fire protection for company and client data while maintaining full access to the protected areas
- System can be easily adjusted to changes of occupancy
- Self-monitoring system technology with continuous checking of function and the airtight integrity of the room
- No damage from fire, smoke or extinguishing agents in normal system installations



Archives

- Protection of irreplaceable documents and works of art
- Secure fire protection without loss of access to the protected area
- Innovative concept for areas with high fire loads
- Avoidance of damage to archived documents from smoke and normal extinguishing agents



IV) System Design Criteria

Planning an oxygen reduction systems (OxyReduct®) system involves several steps, each of which is based on the preceding one:

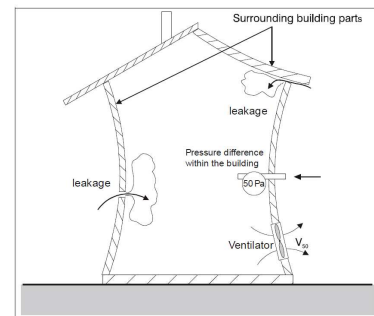
- Careful data acquisition
- Installation layout
- Early involvement of suppliers and authorities.

Dimensions of the system's components depend on the required nitrogen volume for the protected area, both in the case of single-zone installations (e.g., one protected room) and multi-zone installations (e.g., several rooms protected together). Nitrogen demand is time-dependent and defined as volume stream.

The necessary dimensions can be assessed with the use of "OxyCalc", the VdS-certified calculation program for OxyReduct® systems.

OxyCalc algorithms consider:

- Volume of the protected area
- Expected nitrogen loss
- Fresh air gain
- Rated concentration of the protection level
- Lowering times



For project planning of the OxyReduct® system, the following documentation is needed:

- True-to-scale location plan of the protected area and intended control room
- Intended use of the protected area, e.g. storage, archive, server room.
- Plans for ventilation of the protected area
- Data for existing or planned n50 value in the protected area

Location Data

Location data for a building have significant influence on the operational efficiency of the oxygen reduction system. Mainly they affect losses of the protected atmosphere out to and/or through the surrounding building. For this, it is necessary to collect the following data:

- Average yearly wind speed
- Altitude of the site
- Screening of any surrounding buildings

Data for the Protected Area

To calculate the required size of an oxygen reduction system, some information regarding the protected area is needed. The net volume - V - of the protected area determines the sizing of the oxygen reduction system. Depending on this volume, certain n50 values of the protected area have to be adhered to in order to maintain effective system operation.

Injection Points

The injection points (e.g. nozzles or outlet holes) must be arranged such that the required homogenous oxygen-reduced air concentration is established. This requires consideration of known leakage areas and their positions. The oxygen-reduced air flow can be applied directly into a compartment air system. This makes it possible to maintain the homogenous distribution of the oxygen-reduced air. In instances where a compartment air system is used to distribute oxygen-reduced air, it must be assured that the compartment air system is not failing to operate by providing, for example, power backup, redundant air conditioning, environmental monitoring or other means.

Monitoring the Oxygen Concentration

In an oxygen reduction system, the monitoring process is carried out by directly measuring the oxygen concentration in the protected area. The measurement must always be taken by at least two independent oxygen sensors per protected volume (see Table 1).

Volume in ft ³ (m ³)		Number of measuring sensors
from	to	minimum
> 0	17,657 (500)	2
> 17,657 (500)	141,258 (4,000)	4
> 141,258 (4,000)	353,146 (10,000)	6
> 353,146 (10,000)	882,866 (25,000)	8
> 882,866 (25,000)	1,765,733 (50,000)	10
> 1,765,733 (50,000)	3,531,466 (100,000)	12
> 3,531,466 (100,000)	7,062,933 (200,000)	14
> 7,062,933 (200,000)	10,594,400 (300,000)	16
> 10,594,400 (300,000)	14,125,866 (400,000)	18

Table 1: Minimum Number of Measuring Sensors

The oxygen sensors shall be evenly distributed throughout the protected volume (height and area). Every protected volume with a separate injection point shall be considered as an individual volume. False floors and ceiling voids must also be considered as individual volumes.

In the case of oxygen reduction systems, only oxygen measuring systems with proven suitability, measurement range and display range for this application shall be used.

The measuring points of the oxygen measurement shall be arranged such that the measured data provide information about whether the oxygen concentration in the entire protected volume is outside the specified range (warning and alarm threshold).

The measuring equipment shall read continuously the concentrations of each measuring sensor.

The measuring devices shall be suitable for use in the prevailing environmental conditions (temperature, water vapor, pollution, catalyst poisons etc.). The measurements of oxygen concentrations within the protected area are to be displayed constantly.

Alarms and Notifications

When alarm or warning thresholds are reached, notifications shall be issued according to the emergency plan and automatic protection functions or organizational measures must be initiated.

The control panel shall display the following visual and audible signals:

- a) Alarms triggered by reaching the lower alarm thresholds. In this case, the lowest value of all measuring points shall be taken as a basis;
- b) Warning triggered by reaching the upper warning threshold. In this case, the highest value of all measuring points shall be taken as a basis;
- c) System faults (collective fault);
- d) Shutdown of the oxygen reduction system (fault alarm);
- e) Faults at the measuring points for oxygen or auxiliary quantities and their monitored forms of transmission.

In the case of an alarm, appropriate audible and visual signals shall be provided in the protected area, in addition to indication at all designated access points of the protected area.

The average oxygen level must be displayed as an operational notification at the access points of the protected area and at the oxygen reduction monitoring equipment. This must be configured to operate even in the event of power failure or routine maintenance conditions.

Warning signs shall be applied at all entrances to the protected area to indicate the oxygen-reduced area, as well as cautions related to entry by unauthorized personnel.

Control Equipment

A control panel collects processes and, where applicable, transmits readings of oxygen or other measurements, alarms, fault indication on monitored equipment, changes of status and resource control. All wiring and other connections to safety-related components must be supervised so as to provide positive indication of broken wires, short circuits, and other wiring faults.

All equipment forming part of the control elements of the oxygen reduction system shall be configured such that safety to personnel is ensured at all times. This does not just apply to intended operational conditions, but also in the case of faults. Proof of effectiveness shall form part of the risk analysis.

Example for an OxyReduct[®] Calculation with OxyCalc[®]

- General project data
- Site data
- Yearly average wind speed
- Altitude of the protected area

- Number of protected areas
- Information regarding the protected area
 - Room data
 - Net volume
 - Air flow rate [n50]
 - Oxygen Levels
 - Fresh air supply by
 - Access
 - Charge
 - Fresh air supply by air conditioning

- Calculation
 - Reduction and Increase time
 - Maximum nitrogen requirement
 - Nitrogen production

V) Fire Tests With Different Materials

The combustible materials in a protected area must be identified and a safe oxygen concentration level determined for such materials. In the case of unknown components or configurations, this may require ignition threshold testing. This section describes the method for such testing of solid materials. These tests are in accordance with VdS and CEN specifications. The test compartment shall have a minimum volume of 3,531.47 ft³ (100 m³) and shall be equipped with an oxygen measuring system. Alternatively, volumes no less than 353.15 ft³ (10 m³) may be used, provided the oxygen concentration level, measured as the mean reading of the two lowermost oxygen sensors, is within a deviation of 0.1 % by volume during the test. The number of measuring points is dependent on the size of the compartment

but should not be any fewer than three measuring points, positioned within the test facility at heights of 0.1 H, height of testing specimen, 0.5 H and 0.9 H, with H being the ceiling height of the test compartment, at least 3.28 ft. (1 m) away from test specimen at the opposite side of the torch. The tests should be carried out at the highest temperature to be anticipated in the protected area.



The test shall be carried out as follows

- Test specimens shall be made from solid material. The individual test specimens shall not be smaller than 25 mm x 200 mm. The thickness may depend on the material concerned, but should not exceed 25 mm.
- The diameter of test specimens made of round material should be in a range of 10 mm to 25 mm.
- In the case of such materials where further combustion following ignition is highly dependent on the test structure, the most challenging arrangement should be selected. This includes materials such as paper, cardboard, and textiles. The tests for these materials shall be carried out in a vertical position with the specimens ignited from below.
- For each test, a test specimen shall be placed on the support or hung in a vertical position.
- Fix the oxyacetylene torch on the bracket such that the flame will hit a lateral side of the test specimen. Fix the flame nozzle at an angle of 90 ° towards the specimen, with the flame outlet

spaced 0.66 ft. (0.2 m) away from it and approximately 0.08 ft. (0.025 m) inwards from the edge of the specimen.

- Set the unobstructed length of the torch flame to 0.98 ft. (0.3 m).
- The specimen is set alight using a device that works independently of the surrounding atmosphere, e.g. an oxy-acetylene torch. The flame shall be in a temperature range of 1652 °F to 1832 °F (900 °C to 1000 °C), with little excess gas.
- The oxygen concentration in the test volume shall be reduced to the desired concentration. Flames shall be applied to the test specimen for a minimum of 3 min. The flame is then removed.

Test Criteria:

- If the test specimen continues to burn independently or spread of fire is observed on the test specimen for a period of 1 min after the test, it is considered to have failed the test. The test shall be halted and the oxygen concentration shall be reduced further.
- If the test specimen does not continue to burn independently after 1 min, it is considered to have passed the test. The test shall then be repeated twice with the same oxygen concentration and with a new test specimen. For every repeat test, the above criteria apply.
- If the test specimen does not continue to burn independently or ignite in three consecutive tests, it is considered to have passed the series of tests, and the oxygen concentration is set as the ignition threshold for this material. By determining the ignition threshold, the measuring tolerances shall be considered.



Ignition Thresholds

No.	Material	Ignition thresholds % by volume O ₂ (Reference temperature + 68 °F (+ 20 °C), unless specified)
Plastic as a packaging material and component part of products (e.g. casing)		
1	PE-HD (Casing, building material)	16.0
2	PP (Casing, building material)	16.0
3	PMMA	15.9
4	ABS	16.0
5	PVC (Cable)	16.9
6	1-5 lead to EDP risks	15.9
7	PE-LD (Packaging foil)	15.9
Cellulose in the form of packaging material and component part of products (e.g. books, files)		
8	Pine (pallet wood, untreated)	17.0
9	Corrugated cardboard (packaging paperboard, brown, untreated, unprinted)	15.0
10	Palletized cardboard (Packaging paperboard, brown, untreated, unprinted)	15.0
11	Paper (writing paper, 80 g/m ² , white, untreated)	14.1

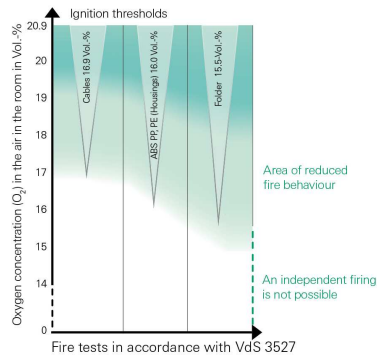
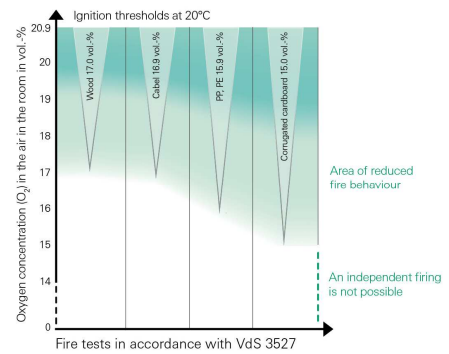
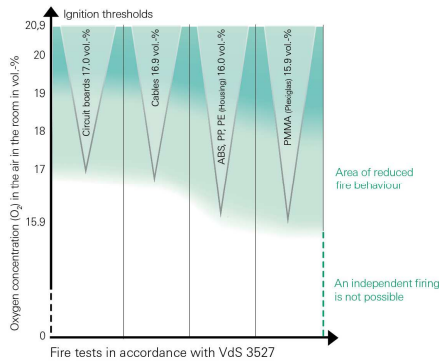
Table 2: Ignition Thresholds

NOTE Values obtained with mixtures of other gas components may differ from these figures.

NOTE The ignition threshold is related to the reference temperature. In case of different design temperatures the design concentration needs to be determined accordingly.

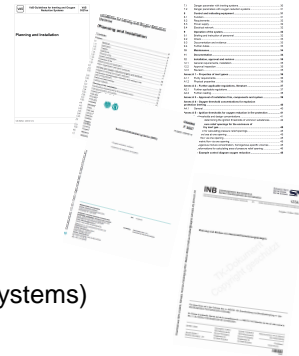
NOTE Source of data:

- VdS Schadenverhütung Test Report No. GLA 04042 for gas extinguishing systems. The data were determined using the method detailed in VdS 3527, A5.2 Letter b)
- VdS Schadenverhütung Test Report No. GLA 05071 for gas extinguishing systems. The data were determined using the method detailed in VdS 3527, A5.2 Letter b).
- VdS Schadenverhütung Test Report No. GLA 04009 for gas extinguishing systems. The data were determined using the method detailed in VdS 3527, A5.2 Letter b).



VI) Existing Standards in Europe

- Germany
 - VdS-Guidelines for Inerting and Oxygen Reduction Systems
 - VdS 3527en, Planning and Installation
 - New VdS guideline is in progress
- Switzerland
 - SN 123456 (Planning and Installation of Oxygen Reduction Systems)
- Austria
 - ÖNORM, F 3007, Oxygen Reduction Systems (SRS - Sauerstoff-Reduziersysteme)
- CEN
 - Resolution agreed at the CEN/TC 191 meeting on October 13, 2010 in Berlin to create new work item for 'Design of Oxygen Reduction Systems'
 - Task group started working process in 2011
 - Members of task group
 - Germany, Netherlands, UK, France, Denmark, Sweden, Norway, Spain, Italy, Switzerland, Austria, Finland
 - Approval for activation as a working item in October 2013
 - WI 00191236 for oxygen reduction systems
 - Request by CEN/TC 191/WG6 to initiate prEN inquiry
 - CEN/TC 191 will invite ISO/TC 21/SC 8 to participate (CEN lead).



VII) International Approvals

OxyReduct® certified fire protection was the first active fire prevention system to be approved by the VdS in Germany. This recognition by VdS Schadenverhütung GmbH is a confirmation of the system's high quality and reliability and is of central importance for both providers and users. Businesses equipped with VdS-approved

and monitored fire protection systems benefit from lower insurance premiums. In Germany and Austria, fire prevention systems are considered to be on the same safety level as gaseous extinguishing systems and are accepted by the VdS and by insurance companies as well as by local building authorities. Note, however, that there is not yet the same level of official recognition for these systems within the United States.



WAGNER – approvals (extract)

- VdS-certified systems, Germany
- VdS-certified installer, Germany
- POJTES, Russia
- CNBOP, Poland
- VB-Cert, Austria
- TSU, Slovakia,
- MSZT Cert, Hungary
- PAVUS, Czech Republic
- United Arab Emirates
- Kingdom of Saudi Arabia
- Bahrain
- Oman
-



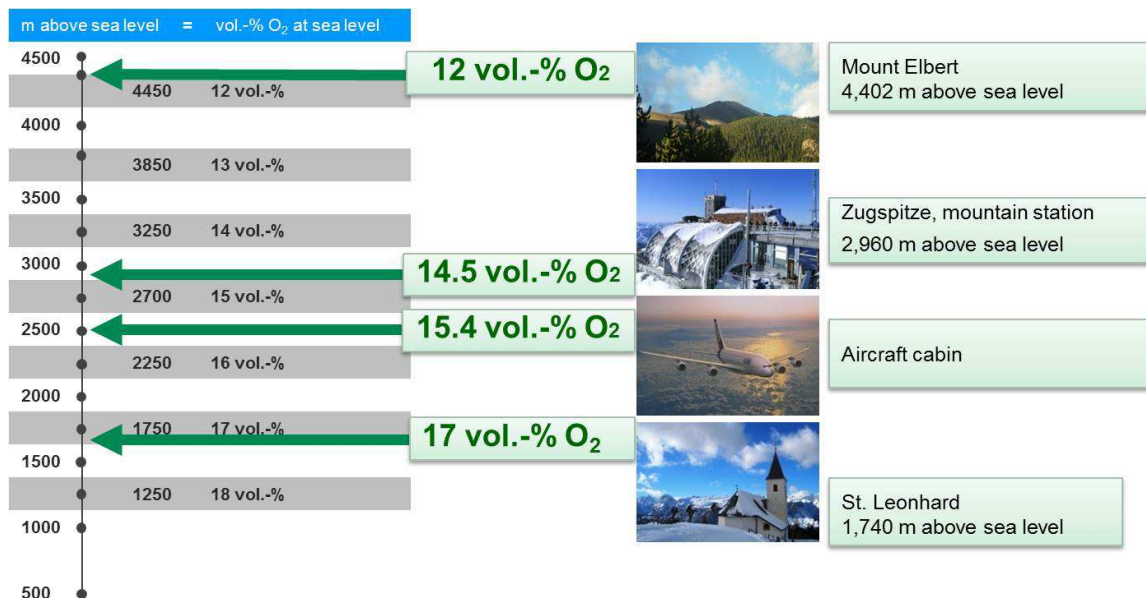
- Case by case (project) approvals

- Spain
- France
- Sweden
- Netherlands
- UK
- Turkey
- Estonia
- Switzerland
-



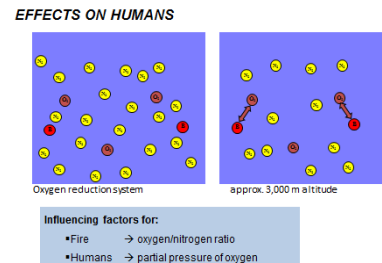
VIII) Health and safety

An important consideration in the design of oxygen reduction fire prevention systems is the maintenance of a safe working environment. It is important to users that down to 17 volume percent oxygen there is no restriction of access to work areas according to the rules and regulations now in place in Germany. (and elsewhere in Europe). It is possible therefore to comply with current safety regulations. Studies and investigations in the field of occupational medicine and by the German employer's liability insurance association have determined that persons in such environments suffer no significant deprivation of oxygen. Below the level of 17 volume percent oxygen, a preventive medical checkup for occupational health is required before entering these types of areas. This checkup is merely a precaution to avoid exposing persons with undiagnosed pre-existing conditions to unnecessarily stressful conditions. It has been determined that there is actually no acute health risk when working in areas with reduced oxygen levels. This type of fire prevention system is frequently used in the field of IT, where the oxygen level is kept between 15 and 17 volume percent, depending on the fire load of the materials present that are to be protected. This level of oxygen is equivalent to being at an altitude between 5,700 ft and 8,900 ft. (1,750 and 2,700 meters). Persons not acclimatized to high altitudes have been observed to enjoy largely unrestricted capacity for action up to altitudes of about 11,500 ft. (3,500 meters). The International Mountaineering and Climbing Federation (UIAA) has made a number of recommendations on this and other related criteria.

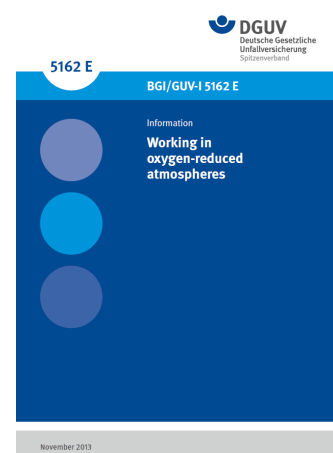


Principles of Occupational Health

Being in an oxygen-reduced atmosphere is comparable to being at high altitude. The significant physiological factor is the oxygen partial pressure (pO₂). From an occupational health perspective, real altitude (=hypobaric hypoxia) and oxygen reduction (=normobaric hypoxia) are considered comparable. When breathing air low in oxygen, depending on the selected oxygen concentration and the duration of stay, symptoms of acute altitude sickness can occur (headache, fatigue, nausea, loss of appetite, dizziness). For this reason, uninterrupted exposure should not last more than several hours. When exposed to breathing air with significantly reduced oxygen content (c < 11 vol.-%) for longer periods, this can lead to an increased frequency of errors in visual tasks and in logical thought as well as longer reaction times and reduced coordination. For physically demanding work, a loss of performance of ~10% per 2 % of O₂ reduction, starting from 17.4 vol.-%, must be taken into account in work scheduling. By reducing the oxygen content of the breathing air and the resulting lower oxygen partial pressure, employees with advanced heart and circulatory disorders, respiratory and pulmonary disorders or blood disorders may be at risk. The extent is determined by the severity of the disorder and the oxygen concentration. In extreme hypoxia (O₂ concentration < 13.0 vol.-%), all health protection measures must be defined on the basis of an individual risk assessment. For control reasons, the oxygen concentration can be stabilized at ± 0.2 vol.-%. This fluctuation range is physiologically irrelevant and can therefore be accepted from a personal safety perspective.



In Germany, the information sheet (BGI/GUV-I 5162 E; Information for Working in oxygen-reduced atmospheres) applies to areas in which the oxygen concentration of the atmosphere is reduced by way of technical measures for reasons of fire prevention. It describes the necessary protection measures in such areas.



[Download: www.publikationen.dguv.de/dguv/udt_dguv_main.aspx?FDOCUID=26158]

This information sheet is intended for employers/operators of oxygen-reduction fire prevention systems and aims to provide assistance and present the scope for the fulfillment of obligations with regard to compliance with the objective of employee safety and health protection at work. The objective and purpose of the information sheet is to describe the scope of action pursuant to the German Ordinance on workplaces in such a way that the workplace does not present risks to the health and safety of employees. It is hoped that this perspective, which based on careful medical evidence, will be adopted elsewhere in the world as well.



When determining the required occupational safety measures for the establishment and operation of workplaces in conformity with health and safety standards, a German, employer/operator must consider the principles of the German Occupational Health and Safety Act, which states that the state of the art, occupational health and hygiene as well as other sound ergonomic practices must be taken into account in the required measures.

Different oxygen concentrations may be applied depending on the ignition thresholds of the flammable substances present. These different concentrations also entail different risks for the persons in the protection area.

According to this risk, the oxygen-reduced areas can be divided into four risk classes:

Risk class 0	O ₂ concentration c $20.9 > c \geq 17.0$ vol.-%
Risk class 1	O ₂ concentration c $17.0 > c \geq 15.0$ vol.-%
Risk class 2	O ₂ concentration c $15.0 > c \geq 13.0$ vol.-%
Risk class 3	O ₂ concentration c $c < 13.0$ vol.-%

Table 3: Risk Classes

Risk Classes and Safety Measures

When working in rooms with reduced oxygen content, the measures from Table 4 must be applied

Risk class	Oxygen concentration c in vol.-% O ₂	Safety measures
Class 0	$20.9 > c \geq 17.0$	<ul style="list-style-type: none">▪ Employee training
Class 1	$17.0 > c \geq 15.0$	<ul style="list-style-type: none">▪ Occupational health examination pursuant to "Working in oxygen-reduced atmospheres"▪ Employee instructions▪ After 4 hours, a break of at least 30 minutes outside the oxygen-reduced area is required
Class 2	$15.0 > c \geq 13.0$	<ul style="list-style-type: none">▪ Occupational health examination "Working in oxygen-reduced atmospheres"▪ Employee instructions▪ After 2 hours, a break of at least 30 minutes outside the oxygen-reduced area is required
Class 3	$c < 13.0$	<ul style="list-style-type: none">▪ Not within the scope of this information sheet▪ Do not enter without specific additional measures

Table 4: Risk Classification of Hypoxia Exposure and Safety Measures

IX) Experience Derived From 700 Installed Systems

With more than 700 systems deployed, OxyReduct® is on its way to becoming the industry standard for effective fire protection. The great acceptance of the oxygen reduction fire prevention system shows that it is a fire protection solution with a particularly high safety factor. Its innovative, fully developed technology operates continuously to avoid the initial outbreak or spread of fire events.



Preventing fires is better than having to extinguish them after they break out

Fire prevention systems are becoming universally accepted worldwide. Data centers and warehouses are places where a company's very existence is at stake. Archives, museums and libraries face the ever-present threat that valuable, irreplaceable works of art could be lost forever. The fact is, fire could break out at virtually any time.

i. Cold Storage

There is a widespread misconception that fires cannot start in cold storage areas because of the low temperatures. In fact, the danger in these environments is particularly high because of the dry air and the highly flammable packaging materials present such as paper, cardboard and plastic wrapping.



Spark from a defective freezer unit may be all that is needed. Cold storage areas also present a particular challenge for fire protection because of the stored foodstuffs and the low temperatures. Use of chemical extinguishing gases or conventional water extinguishing systems can instantly contaminate the goods in storage, requiring all stock to be disposed of. The oxygen reduction fire prevention system provides effective fire protection in a cold storage environment. The fact that cold storage areas are very well sealed is highly beneficial for the efficiency of the system. Reduced oxygen levels can be maintained efficiently in most cold storage areas, which are by nature well insulated.

As in normal storage areas, the fire prevention system automatically monitors oxygen content, compensates for times when the areas are accessed during loading and unloading, and allows personnel to operate safely inside the protected area. All of this makes oxygen reduction systems the most effective solution for fire protection in cold storage areas.

ii. IT & EDP

Uninterrupted operation is a top priority in IT centers – even if a fire breaks out. Just a few minutes of downtime could do lasting damage to the reputation of an entire company – and jeopardize its existence. IT is rendered unavailable if a fire breaks out. In the event of a fire, conventional fire protection systems



require power to the entire IT infrastructure and air-conditioning systems to be interrupted in order to prevent fire reigniting following extinguishing. This situation can simply be avoided by using the most appropriate fire protection solution. The oxygen reduction active fire prevention system was developed to ensure uninterrupted availability of key resources. This means that there is no longer any need to disconnect the power from the IT infrastructure in the event of a fire. The system provides effective protection from the consequences of fire through controlled oxygen reduction by feeding nitrogen into IT rooms. Operations can continue without interruption and further damage to hardware components (such as damage caused by chemical extinguishing gases or the high sound pressure level which extinguishing processes often entail) will be avoided. Oxygen reduction systems are already been used successfully in the IT field for years.

iii. High-Bay-Storage

Automated high-bay warehouses carry a particularly high fire risk because of the wide range of electrical components they employ, including conveyor belts, storage and retrieval systems. With closely packed pallets and high narrow aisles, fire can spread easily, but extinguishing efforts are often hindered. In the



event of fire, even storage areas not immediately affected by the fire can be affected by smoke, soot and extinguishing water. Goods are often so badly damaged that they must be destroyed. Consequently, deliveries may be delayed and customer relationships can be negatively impacted. The optimum solution for fire protection, however, could be the simplest: ideally, preventing fires from ever igniting in the first place. Using oxygen reduction fire prevention systems protect appropriate storage areas effectively against the effects of fire. Damage can often be reduced to a minimum. The oxygen level of the storage area is continually monitored and maintained by the system, yet authorized personnel can still access the area. This solution is already providing reliable protection for many high-bay warehouses globally. OxyReduct® with VPSA (Vacuum Pressure Swing Adsorption) technology keeps operating costs extremely low and enables energy savings of as much as 50 % in comparison to previously used nitrogen recovery technologies.

iv. Archives And Museums

Sadly, the importance of a dependable fire prevention concept – especially in archives and museums – often only gets the attention it deserves after an historic library, rare collection or valuable work of art is destroyed.



Unique artefacts may be lost forever and no insurance

policy can replace them – the losses are bemoaned by proprietors and investors alike. And whatever wasn't destroyed by the fire itself is sure to be damaged by the enormous amounts of water which the firefighters used to put out the blaze – often so severely that the artefacts are difficult or impossible to restore.

Long-term, non-destructive fire prevention with oxygen reduction systems can preclude a loss scenario like this. The oxygen-reduced protective atmosphere provides a safe location for storing printed material, paintings and the whole range of artefacts. The nitrogen which is fed in has no detrimental effect on the exhibits. In addition, the protected areas remain accessible to personnel. Oxygen reduction fire prevention systems automatically compensate for leakages and nitrogen losses caused when people enter and exit the rooms.

v. Hazardous Chemical Storage

The risks that warehouse fires pose to personal safety and the environment can be devastating, regardless of what goods are being stored. Extremely flammable hazardous substances often have very low ignition thresholds, while the substances or their combustion residue can produce violent or toxic reactions. This



means that the risk to personnel and rescue teams is especially great due to potential for poisoning or explosions. Enormous clouds of smoke frequently form, which can also endanger occupants of neighboring buildings and other third parties within a wide radius if wind conditions are unfavorable. Many companies that work with chemicals and hazardous material now rely on active fire prevention using oxygen reduction systems to minimize not only losses for storage facility operators, but also risks of personal injury and environmental damage. One major advantage of the system is its exceptional flexibility. For instance, the level of protection can be set individually based on the type of goods being stored, with the additional option of providing more protection with a CO₂ extinguishing system for particularly high-risk zones, such as those containing highly explosive substances. This multi-level protection concept can suppress ignition sources and can significantly reduce the risks of fire.

X) References

Automated High-Bay Cold Storage Warehouse At EDNA International GmbH In Brehna, Germany

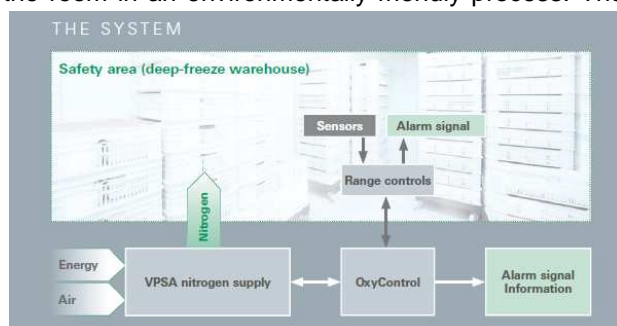
Customers from the Hotel, Restaurant, Catering and Bake – Off sectors have been relying on bakery products produced by EDNA International GmbH since 1987. With more than 1,000 different frozen products and 8,500 service articles, EDNA offers the largest complete range of frozen bakery products in Germany. The new high-bay cold storage warehouse at EDNA GmbH covers an area of around 75,350 ft² (7,000 m²) and boasts a volume of 4,590,900 ft³ (130,000 m³). It features an automated three-aisle tray store with 35,300 spaces and a mechanized four-aisle high-bay pallet warehouse with 9,600 storage spaces.



Up to 13,000 trading units per day can now be picked automatically on pallets at -11.2° F (-24 °C). This corresponds to around 400 order pallets and approx. 500 - 600 homogeneously loaded pallets directly from the production department.

In addition to the protection of staff, the stored goods and the high-bay warehouse itself, securing and maintaining logistics processes was given top priority when developing a suitable fire prevention concept for the high-bay cold storage warehouse of EDNA International GmbH in Brehna. In the event of a fire, the logistical processes within the warehouse and deliveries to customers should be disrupted as little as possible and extensive contamination or even destruction of warehouse goods by fire, soot or extinguishing water should be avoided under all circumstances. The ability to deliver should be preserved even in case of damage.

The core of the OxyReduct[®] fire prevention system is nitrogen generation. Using the highly energy-efficient VPSA (Vacuum Pressure Swing Adsorption) technology, it generates the nitrogen required to lower the oxygen level directly from the air in the room in an environmentally friendly process. The VPSA system is extremely robust, designed for continuous operation and therefore for a life span, and is particularly efficient. In comparison with the technologies used to harvest nitrogen in the past, this system achieves energy savings of around 50 %.



For the EDNA cold storage warehouse in Brehna, for example, two VPSA systems with a nitrogen output of approx. 16,951 ft³/h (480 m³/h) are interconnected.

The VPSA systems ensure a continuous protection level in the warehouse area and also compensate for the temporary rise in the oxygen concentration which occurs when doors are opened for the daily storage and removal of goods. The use of the OxyReduct® fire prevention system with VPSA offers the frozen bakery goods manufacturer EDNA International a double advantage: products and logistics processes are protected by active fire prevention and, at the same time, the new VPSA technology saves operating costs – without having to forego the high standard of safety. The concept of active fire prevention offers a high level of protection with its preventative approach and is suitable not only for protecting buildings but also stored goods and the logistics processes involved from the effects of a fire. The OxyReduct® fire prevention system can be used in all kinds of areas, even where conventional extinguishing systems reach their limits. The system is designed individually to reflect the actual conditions. The use of the VPSA technology also has an extremely positive effect on operating costs.



Largest Fully Automated High-Bay Cold Storage Warehouse In Germany

KLM Kühl- und Lagerhaus Münsterland GmbH based in Rheine has been supplying consumer markets with frozen foods and ice cream for more than 25 years. Its range includes products of renowned manufacturers like apetito and Coppenrath & Wiese, and licensed products like Landliebe, Mars and Snickers.



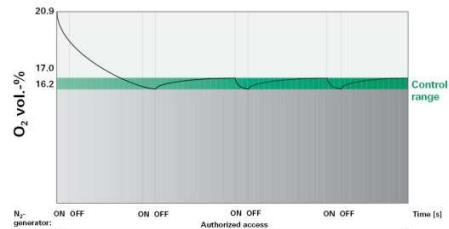
KLM, a subsidiary of the logistics service provider Newcold Advanced Cold Logistics, offers services including storage, consignment sale, packing and distribution as well as the import and export of frozen foods.

KLM decided to increase its storage capacities in order to expand its range of services for its customers. With an area of 91,870 ft² (8,535 m²) and a height of 125 ft. (38 m), the new high-bay cold storage warehouse offers a volume of around 13,419,573 ft³ (380,000 m³), which is enough space for 68,400 pallets. This makes it the largest fully automated high-bay cold storage warehouse in Germany at present, according to the builder Newcold Advanced Cold Logistics. As a result of this expansion to the existing warehouse in Rheine, KLM was able to increase its total capacity to 90,000 pallets.

The US\$ 56 million (€ 40 million) newly constructed facility is equipped with an automatic loading and unloading system that allows a truck to be fully loaded with 32 pallets in only two minutes. Also, a temperature-controlled and partly automated packing plant quickly configures mixed boxes. This means that it can process a good 5,000 pallets a day. KLM's customers have always relied on punctual and reliable delivery.



Ensuring the processes run smoothly was therefore of particular importance in the selection of the optimal fire protection solution for the new warehouse commissioned in May 2013. WAGNER's OxyReduct® active fire prevention system reduces the oxygen content in the high-bay cold storage warehouse to 16.2 vol.-% by way of controlled introduction of nitrogen. This oxygen-reduced protected atmosphere is extremely fire-retardant, which means the warehouse and the goods stored are effectively protected from the effects of a fire.



Using OxyReduct®, the oxygen concentration in the protected area in KLM's high-bay cold storage warehouse is reduced to approx. 16.2 vol% and constantly maintained at this level.

The reduction of the oxygen concentration to 16.2 vol.-% (normal breathing air contains 20.9 vol.-%) required in the protection concept was determined in collaboration with the independent testing institute VdS Schadenverhütung GmbH using fire tests at WAGNER laboratories. The fire protection solution was therefore tailored to KLM's requirements in the best possible way and has the maximum protective effect at the lowest possible cost.



The thick building envelopes in the cold storage warehouse provide ideal conditions for OxyReduct® VPSA: the fire prevention system ① reduces the oxygen level in the cold storage area by introducing nitrogen, meaning that a fire effectively cannot develop. The nitrogen is produced on-site using nitrogen generators with VPSA technology from the ambient air. The nitrogen is distributed by the warehouse ventilation system ②. This balances losses from the building envelope and the loading ducts ③. Sensors positioned at different heights monitor the oxygen concentration ④ and report this to the OxyControl control centre ⑤. Current values are displayed on a display next to the warehouse entrance. A light indicator over the door notifies the personnel of the reduced oxygen concentration in the warehouse area ⑥.

Legal Notices, Disclaimers and Warranties

GENERAL DISCLAIMERS

- The information contained in this document is for informational purposes only. Prior to the installation of any system, an evaluation of a prospective buyer's requirements must be performed in order to make an assessment of the appropriateness of any specific products for the buyer's intended use. Performance of the products described herein does not constitute a guaranty or warranty of fitness for a particular purpose. The performance of such products will vary depending upon a number of factors including the facility type, site, layout, environment and intended uses.
- The OxyReduct® system described in this document has not yet been approved for use in the United States. Any use of such products is subject to legal and/or regulatory approvals and/or permits from federal, state and local authorities, for which the seller and the buyer may share responsibility. No representation is made herein concerning the compliance of such products with federal, state and local laws and regulations.

LIMITED WARRANTY

- Wagner Group GmbH ("Wagner") warrants the OxyReduct® system components to be free from defects in materials and workmanship for a period of twelve (12) months from date of installation.
- This warranty does not apply where the system or any component has:
 - been subjected to abuse, misuse, neglect, negligence, accident, improper testing, improper installation, improper storage, improper handling, abnormal physical stress, abnormal environmental conditions or use contrary to instructions;
 - been reconstructed, repaired or altered by persons other than Wagner or its authorized representative(s); or
 - been used with any third-party system or product that has not been previously approved in writing by Wagner.

DISCLAIMER OF IMPLIED WARRANTIES

- Except as provided herein and in the terms and conditions of sale, Wagner assumes no liability whatsoever, and disclaims any express or implied warranty, relating to the sale and/or use of its products. This disclaimer includes liability or warranties regarding the products' fitness for a particular purpose, merchantability, or infringement of any patent, copyright, or other intellectual property right, whether express or implied by law, course of dealing, course of performance, usage of trade or otherwise.
- There are no other warranties, express or implied.

LIMITATION OF LIABILITY

- **No Liability for Consequential or Indirect Damages.** Neither Wagner nor its representatives shall be liable for consequential, indirect, incidental, special, exemplary, punitive or enhanced damages, lost profits or revenues or diminution in value arising out of or relating to the failure of any product to perform as intended, whether or not the possibility of such damages has been disclosed in advance or could have been reasonably foreseen, regardless of the legal or equitable theory upon which such claim is based, and notwithstanding the failure of any agreed or other remedy of its essential purpose.
- **Maximum Liability.** Wagner's liability under any warranty is limited to the repair or replacement of the defective product.
- **Assumption of Risk.** The buyer assumes the risk for the results obtained by the use of any products. No warranty is made regarding the general effectiveness, success or failure concerning the use of any products, regardless of any oral or written statements made, by way of technical advice or otherwise, related to the use of such products.

Author

Peter Clauss is a senior engineer with Wagner Group in Germany. For more than 23 years he has focused on the field of fire protection (Sales, Technical and Marketing). He previously worked for the KIDDE Group where he was responsible for approval and system integration of FM-200, Novec 1230 and Argonite fire protection systems in Germany, Austria and East Europe. He is an engineer and has been certified by VdS in Germany for planning and designing gaseous fire protection and oxygen reduction systems.

Peter Clauss is an active member of several standards committees (DIN, CEN and ISO), a number of German and European trade associations, as well as several other German and European working groups.

Contact information

Peter Clauss

WAGNER Group GmbH

Schleswigstr. 1 - 5

D-30853 Langenhagen, Germany

Telephone +49 (511) 9 73 83-210, Mobile +49 (172) 619 83 81

E-mail: peter.clauss@wagner.de, Internet: www.wagner.de