

205-006

DGUV Information 205-006



Working in oxygen-reduced atmospheres

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About us Publisher:

German Social Accident
Insurance e.V. (DGUV)

Glinkastraße 40
10117 Berlin
Telefon: 030 13001-0 (central)
Fax: 030 13001-6132
E-Mail: info@dguv.de
Internet: www.dguv.de

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Preliminary remarks

Oxygen reduction is a fire prevention technology which is increasingly used in various areas, but mainly in information technology (IT and server rooms), warehouses (e. g. small-load carrier, hazardous material and deep freeze stores) as well as archives and museums. When operating fire prevention systems, the oxygen content of the air is reduced in the room, in accordance with the materials stored or the installations to be protected, in order to prevent the outbreak of fire. In order to avoid health hazards, protection measures must be undertaken as part of the risk assessment. These may be structural, technical, organisation and occupational health measures.

1 Scope of application

This information sheet 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.

This information sheet is intended for employers of oxygen-reduction fire prevention systems and aims to provide assistance and present the scope for the fulfilment 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 Section 3 (1) of the Arbeitsstättenverordnung (German Ordinance on workplaces) in such a way that the workplace does not present risks to the health and safety of employees.

When determining the required occupational safety measures for the establishment and operation of workplaces in conformity with health and safety standards, the employer must consider the principles of Section 4 of the Arbeitsschutzgesetz (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. These requirements are the object of this information sheet and are reported therein. In accordance with Section 2 (2) of the German Ordinance on workplaces¹ (ArbStättV), places of work are defined as workplace areas. In accordance to Section 2 (2) of the German Ordinance of workplaces are defined as parts of workplace areas, in which employees are working during their employment.

2 Description of the technology

The higher the oxygen content (O_2) of the air, the higher the risk of fire¹⁾. With a „normal“ O_2 proportion of approximately 21 vol. % most oxidisable substances become flammable (following the introduction of the corresponding ignition energy). If the O_2 proportion is reduced, the risk of fire is also reduced. The functional principle of the systems lies in reducing the oxygen content of the ambient air of the area to be protected. While keeping the same ambient pressure, the oxygen level of the ambient air is reduced by introducing nitrogen or nitrogen-enriched air. The areas concerned must therefore be closed off from the surrounding atmosphere. The nitrogen or the nitrogen-enriched air required is generated using various technical procedures and introduced into the area to be protected. O_2 sensors permanently monitor the pre-defined oxygen concentration. The oxygen concentration is maintained constant by a setting. Based on experience, this is done by a control hysteresis (see Figure 1) from $\pm 0,1$ bis $\pm 0,2$ vol. % oxygen. The oxygen monitoring system must be designed as a redundant system. The control is undertaken via no less than two oxygen sensors which are installed at different locations within the oxygen-reduced area.

¹⁾ **Risk of fire:** A risk of fire within the meaning of this TRGS 800 ist the possibility that the safety or health of workers, other persons or the environment will be adversely affected because of the development or spread of a fire and related consequences such as heat or smoke.

Description of the technology

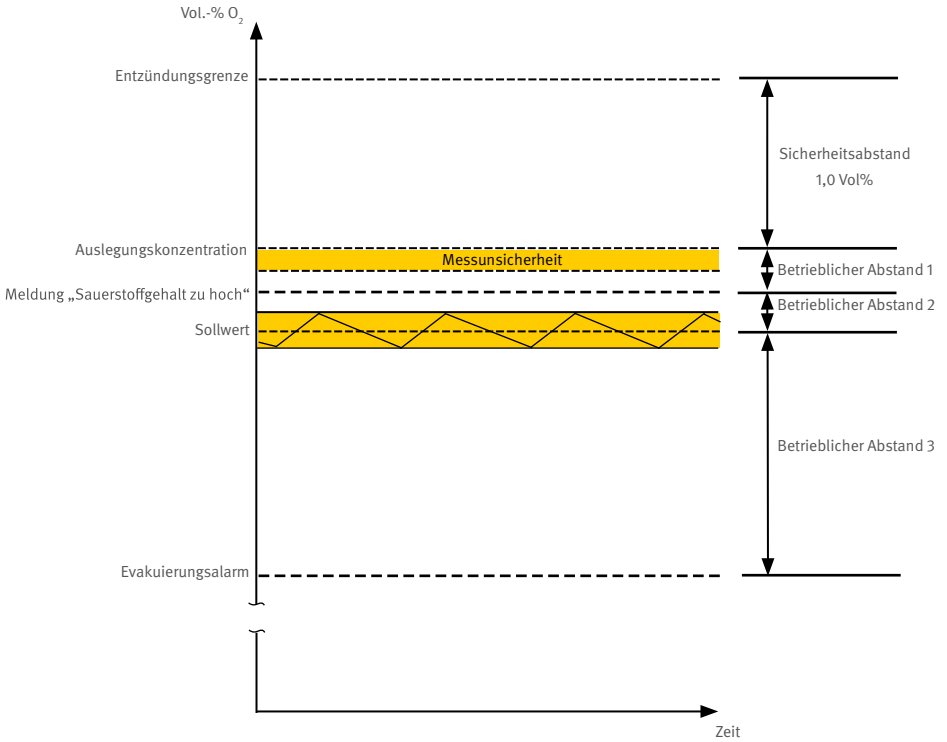


Fig. 1 Example control diagram for oxygen-reducing systems

- Ignition threshold:** The ignition threshold is the oxygen concentration whereby a flammable substance is no longer able to ignite under experimental conditions.
- Design concentration:** Ignition threshold minus a safety distance.
- Safety distance:** This distance considers the fact that the flammable substance can exist in the system under different temperatures and pressures than when determining the oxygen threshold concentration in the laboratory.
- Operational distance 1:** This distance takes account of spatial and temporal variations in the oxygen concentration resulting from operational factors, of the delay between triggering of protective measures, of the measurement error resulting from measurement technology factors and of the alarm delay of the measurement instrument monitoring the oxygen concentration.
- Operational distance 2:** This distance defines the reference value of a concentration regulator in order to prevent false alarms, with regard to the “Oxygen level too high“ message.
- Operational distance 3:** This distance defines the reference value of a concentration regulator in order to avoid false alarms, with regard to the lower alarm value (evacuation alarm).

3 Principles of occupational health

Being in an oxygen-reduced atmosphere is comparable to being at a high altitude. The significant physiological factor is the oxygen partial pressure (pO_2). 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 a 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 O_2 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. The Principles of Occupational Health Examinations 28 „Working in Oxygen-reduced Atmospheres“ published by the DGUV provide further information.

In extreme hypoxia (O_2 concentration $< 13,0$ vol. %, risk class 3) all health protection measures must be defined on the basis of an individual risk assessment. Self-contained breathing apparatus must be worn in such conditions (see also DGUV Principle G 26 „Respiratory Protection“).

For control reasons, the oxygen concentration can be stabilised at $\pm 0,2$ vol. %. This fluctuation range is physiologically irrelevant and can therefore be accepted from a personal safety perspective.

4 Risk classes

Different oxygen concentration 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 ≥ 17,0 vol.-%]
Risk class 1	[O ₂ concentration c 17,0 > c ≥ 15,0 vol.-%]
Risk class 2	[O ₂ concentration c 15,0 > c ≥ 13,0 vol.-%]
Risk class 3	[O ₂ concentration c c < 13,0 vol.-%]

5 Essential requirements

Planning and installation

When designing a space with an oxygen-reduced atmosphere, the local conditions (e. g. the altitude above sea level, weather and air pressure conditions), in addition to the chemical, biological or physical effects (such as cold), as well as the severity of the physical work to be performed and the psycho-mental burden must be taken into account. The structural, technical, organisational and occupational health measures must be documented in the risk assessment (the safety concept specific to each operation).

The protection measures to be taken are determined by the level of reduction of the oxygen content in the atmosphere. The measured oxygen concentration [in vol. %] applies for localities up to an altitude of $h = 700$ m above sea level. Above this limit, the influence of altitude above sea level must be considered. For occupational health risk classification, the real altitude and the equivalent altitude produced by the system must be added.

The lowest oxygen concentration that can occur in the room (alarm value for the minimum oxygen concentration = lowest control range minus $c = 0,1$ vol. %) is decisive in the determination of protection measures.

The residual oxygen content must be defined as high as possible, which means only as low as is absolutely necessary for fire protection reasons.

No permanent workstations may be established in oxygen-reduced areas.

6 Protection measures for all areas with oxygen-reduced atmospheres

Structural and technical measures

Signs indicating the oxygen-reduced atmosphere must be put up at all entrances and access must be reserved to authorised persons. The signs must correspond to workplace regulation „Safety and Health Signs at Work“ (ASR A 1.3) (see Figure. 2).

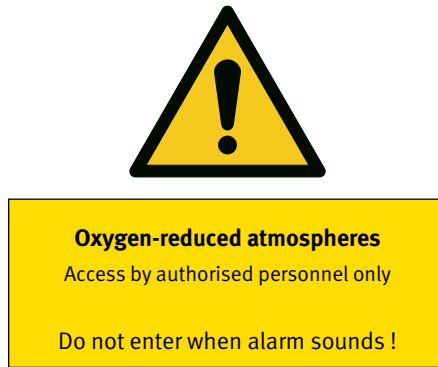


Fig. 2 Example sign at the entrance to an oxygen-reduced area

An alarm must sound if the oxygen concentration is too low.

The alarm must be heard from every location within the area with an oxygen-reduced atmosphere. This must be ensured by way of a redundant acoustic (e. g. by 2 electrical alarm systems) or an acoustic and visual alarm [see also DIN VDE 0833 Part 1]. If it has been ensured via the system that the oxygen concentration cannot fall below 13 vol. % ($c > 13 \text{ vol. } \%$) in all protection areas, a simple secure acoustic alarm will suffice [see also the Machinery Directive 2006/42/EC and/or DIN EN ISO 13849].

The alarm must be signalled by way of an illuminated panel at all entrances to the oxygen-reduced areas (see Figure 3). Visual alarms must be prominently signalled by way of uninterrupted illumination.

The alarm may only be switched off if it has been ensured that unauthorised persons can no longer access the oxygen-reduced areas by way of the illuminated panels at the entrances to the areas at risk or by closing off entrances.



Fig. 3
Example sign at the entrance to an oxygen-reduced area in case of an emergency - illuminated panel

The measurement system must be designed in such a way that a loss of function or a measurement error can in no event lead to the minimum oxygen threshold not being detected.

A fault in the measurement and control system must be detected and signalled in good time.

The measurement systems must be calibrated and maintained regularly by the manufacturer or by trained persons in accordance with the manufacturer's instructions and their work instructions. Calibration and maintenance must be documented.

The introduction of nitrogen into the room must be able to be switched off manually from a secure location at all times.

It must be ensured that there is a homogeneous oxygen concentration throughout the oxygen-reduced area.

The spreading of the oxygen-reduced atmosphere to other areas not intended for this (e.g. through wall openings, cable ducts, floor drainages, leaking doors, conveyor belts, etc.) must be prevented.

7 Organisational measures

The employer must put up operating instructions for oxygen-reduction systems, which take into account the operating manual supplied by the manufacturer, and which must in particular contain all the required safety instructions.

The employer must define which persons are authorised to enter the oxygen-reduced areas in writing. These employees must be informed and instructed on the risks, protection measures and rules of conduct prior to taking up their duties and prior to the first time they enter rooms with oxygen-reduced atmospheres, and at regular intervals thereafter. The instructions must be documented.

The training can form a part of the general health and safety instructions.

For rooms with oxygen-reduced atmospheres, it must be ensured that only authorised and instructed employees can enter the rooms (access concept).

The length of stay in areas with oxygen-reduced atmospheres must be kept as short as possible.

The oxygen concentration in the oxygen-reduced area must be measured and logged at least every 10 minutes. The results must be archived for at least one year.

The employer of rooms with oxygen-reduced atmospheres must ensure that the organisational, personnel and, if required, occupational health measures are complied with by the employees of third party companies.

In the event of rescue measures, the rescue forces must be informed of the existence of an oxygen-reduced atmosphere before their intervention begins. This must be marked on the fire brigade plan.

It must be possible to contact persons outside the rooms with oxygen-reduced atmospheres (e. g. call connection, telephone, radio ...).

If the alarm sounds, the room must be left immediately.

Employees experiencing discomfort must immediately leave the area with an oxygen-reduced atmosphere. If the discomfort subsides within no more than 30 minutes, the oxygen-reduced area can once again be entered. Otherwise, or if the symptoms re-occur, a doctor must be consulted before the oxygen-reduced area is accessed again.

Risk classes and safety measures

When working in rooms with a reduced oxygen content, the measures from Table 1 must be applied.

Table 1 Risk classification of hypoxia exposure and safety measures

Risk class	Oxygen concentration c in vol. % O_2	Safety measures
Class 0	$20,9 > c \geq 17,0$	Employee training
Class 1	$17,0 > c \geq 15,0$	Occupational health examination pursuant to G 28 “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	$15,0 > c \geq 13,0$	Occupational health examination pursuant to G 28 “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	$c < 13,0$	Not within the scope of this information sheet Do not enter without specific additional measures

8 Inspections

Inspection obligation

The employer must have the oxygen-reduction system inspected by qualified persons (see Betriebs-sicherheitsverordnung (German Ordinance on Industrial Safety and Health)).

The employer must have the oxygen-reduction system immediately inspected by qualified persons if unusual events have taken place which may have harmful effects on safety. If defects are discovered that constitute a danger to persons, the oxygen-reduction system must be taken out of operation. Fire protection must then be ensured by way of suitable alternative measures.

If defects are discovered, the employer of the oxygen-reduction system must ensure that the defects signalled are remedied.

Inspections

Acceptance test

The employer must subject the oxygen-reduction system to an acceptance test by the manufacturer/installer or by a qualified person after installation or after any significant modification to the system. This test must take place prior to commissioning.

Regular inspections

The employer must have the proper function of oxygen-reduction systems tested by a qualified person at least once per year. Special operational circumstances may make it necessary to carry out more frequent inspections.

Record of inspections

The results of the inspections must be recorded in an inspection report. The records of the acceptance tests must be kept throughout the operating time of the oxygen-reduction system. The records of the regular inspections must be kept for at least 4 years. These may be stored on computer data carriers. The documents must be presented to the competent supervisory authorities upon request.

9 Occupational health examinations

Persons accessing oxygen-reduced areas of

risk class 1 [O_2 concentration c $17,0 > c \geq 15,0$ vol. %]

and/or of

risk class 2 [O_2 concentration c $15,0 > c \geq 13,0$ vol. %]

must undergo occupational health examinations pursuant to DGUV Principle G 28 „Working in Oxygen-reduced Atmospheres“ prior to taking up their duties and subsequently at regular intervals.

The aim of the examination is to determine whether these persons have any health concerns with regard to working in technically oxygen-reduced atmospheres.

These persons may only work in rooms with oxygen-reduced atmospheres if the health examination was undertaken pursuant to DGUV Principle G 28.

**German Social Accident
Insurance e.V. (DGUV)**

Glinkastraße 40

10117 Berlin

Telefon: 030 13001-0 (Zentrale)

Fax: 030 13001-9876

E-Mail: info@dguv.de

Website: www.dguv.de