

## Hazardous Substances

### Oxygen



**M 034e**  
**DGUV Information 213-074**  
**Edition 6/2024 (replaces the English edition 9/2018)**

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The paper at hand is focused on essential items of individual regulations and rules, and for this reason it does not mention all the measures required for a particular case. Moreover, the state of the art or the legal basis may have changed since the Code of Practice was issued.

This paper has been compiled with great care. However, this does not absolve the employer from the duty and responsibility of checking the information to be complete, correct and up to date.

The Act on the Protection at Work uses the term “employer“, the Social Security Code VII and the Accident Prevention Regulations of the Accident Insurance Institutions say “entrepreneur“. Both terms are not completely identical, because an entrepreneur does not necessarily employ workers. This fact is irrelevant for the topic treated in this paper, and the term “entrepreneur“ is used here.

## VISION ZERO

# VISION ZERO.

ZERO ACCIDENTS – HEALTHY WORK

**VISION ZERO** is the vision of a world without occupational accidents and work-related illnesses. In this connection the avoidance of lethal and severe occupational accidents and illnesses is given highest priority. The goal of a comprehensive culture of risk prevention is **VISION ZERO**.



Further information concerning the VISION ZERO Prevention Strategy is available at [visionzero.global](http://visionzero.global).

This Code of Practice particularly deals with the Golden Rule  
**"Identify Hazards – Control Risks"**

## Scope

The paper intensively treats hazards and protective measures when handling

- pure oxygen,
- gas mixtures of oxygen and nitrogen or other inert gases containing more than 21 % oxygen by volume, e. g. oxygenated air,
- other mixtures containing oxygen and inert gases which must be classified as “oxidising” according to CLP Regulation (e. g. a mixture of oxygen and argon containing more than 20 % oxygen by volume). (2)

Activities in oxygen-reduced atmosphere are not treated in this paper. They are described in DGUV Information 205-006 “Working in oxygen-reduced atmospheres”. (111)

When dealing with oxygen and its mixtures or when oxygen can be generated, e. g. as a result of chemical reactions, production or processing, this paper is intended primarily to support the supervisor in:

- Ascertaining and assessing the hazards,
- Determining the measures required for the protection of people and environment,
- Determining the behaviour in hazard cases,
- Establishing first aid measures,
- Drafting operating instructions,
- Giving verbal instructions.

The numbers in the margins refer to the bibliography.

## 1 Properties and Characteristics

### 1.1 Physical and Chemical Properties

Under normal conditions oxygen is a colourless and odourless gas. At  $-183\text{ °C}$  and normal pressure, it condenses to a blue-coloured liquid, at  $-219\text{ °C}$  it crystallises to a blue solid.

Oxygen is not flammable, but it does enable and promote combustion. Atmospheric air contains 21 vol.-% oxygen. Even a slight enrichment causes a more violent combustion, i. e. a considerable increase in the velocity of combustion. If the atmospheric oxygen concentration is raised, a smouldering fire can develop into a brisk flame.

Oxygen can cause the spontaneous combustion of oil and grease and of textiles contaminated with oil or grease.

Safety-relevant characteristic data can also change disadvantageously with increased oxygen concentrations. Examples: explosion limits, dust explosion classes, rates of pressure rise, ignition and smouldering temperatures, explosion pressures, flame temperatures.

**This creates an increased fire and explosion hazard.**

With the exceptions of precious metals and metal oxides at the highest oxidation level, all substances are combustible in oxygen, especially in compressed oxygen. That also applies to substances that cannot be ignited in atmospheric air.

Oxygen forms compounds with almost every element. Most substances react so vigorously with oxygen that they either burn after being ignited or even ignite themselves. The reactions can be strongly influenced by foreign substances that act as catalysts or inhibitors.

## 1.2 Identification and Measurement Methods

Oxygen can be detected in a range from 5 to 23 vol.-% using test tubes. Only a strong oxidising agent can interfere with this verification. However, the accuracy of the method is relatively low.

Portable oxygen measuring instruments often employ an electrochemical cell with precious metal cathode and lead anode as the measuring principle. Usage up to a maximum of about 25 vol.-% oxygen is generally recommended by the manufacturers. The lifetime of the measuring cell typically is ca. 18 months and depends on the conditions of use. Various gases shorten this time span, e. g. carbon dioxide in high concentrations. More information on use, operation, maintenance and proper keeping of oxygen measuring instruments can be found in DGUV Information 213-056 "Gas Detection Equipment for Toxic Gases/Vapours and Oxygen: Use and Operation" (Code of Practice T 021e of BG RCI). (93)

For more recent developments in the field of electrochemical cells (potentiostatic measuring method), a lower sensitivity to carbon dioxide and a measuring range of up to 100 vol.-% is indicated.

Another type of device uses the conductivity of heated zirconium dioxide for oxygen ions to generate the measurement signal. Depending on the design of the measuring cell, the analyser can be used for both exact measurements of very small concentrations or for high ranges that exceed 21 vol.-%. There are even measuring ranges up to 100 vol.-% offered. The presence of combustible gases or vapours in the gas mixture to be investigated systematically leads to falsified measured values as these additional gases react with the oxygen in the hot measuring cell.

Also widely used for the measurement of higher oxygen concentrations – up to 100 vol.-% – are instruments that utilise the paramagnetism of oxygen. An appreciable cross-sensitivity only exists to nitrogen oxides and chlorine oxides. The calibration curve is, however, dependent on the carrier gas in certain device types.

Before selecting a suitable measuring instrument, it is necessary to characterise the measurement problem. This includes answering the following questions:

- How high are the oxygen concentrations to be measured and what measurement accuracy is necessary?
- Which associated gases are present; are they combustible, corrosive or do they contain any interfering components?
- What are the temperature, pressure and moisture contents of the gas mixtures to be investigated?
- Is a portable or a fixed instrument needed?
- How quickly must a measurement be made?
- Is the gas mixture that is to be investigated combustible? Must therefore problems of explosion protection be taken into account?



A list of functionally tested gas detection equipment is available at the homepage of the Berufsgenossenschaft Rohstoffe und chemische Industrie (BG RCI): [www.bgrci.de/exinfode/dokumente/gaswarneinrichtungen-und-geraete/funktionsgepruefte-gaswarngerate/](http://www.bgrci.de/exinfode/dokumente/gaswarneinrichtungen-und-geraete/funktionsgepruefte-gaswarngerate/). (139)

## 1.3 Physical and Chemical Characteristics

Chemical Formula	O <sub>2</sub>	
Molar Mass	31.9988 kg/kmol	
Melting Point at 1.013 bar	54.37 K (–218.78 °C)	(129)
Boiling Point at 1.013 bar	90.19 K (–182.96 °C)	(129)(132)
Gas Density at 0 °C and 1.013 bar	1.429 g/l	(141)
Liquid Phase Density at 90.19 K (–182.96 °C)	1141.0 g/l	(129)(132)
Relative Gas Density (Air = 1)	1.1052	(129)
Molar Standard Volume	22.3932 m <sup>3</sup> /kmol	
Solubility in Water > at 25 °C and 1.013 bar > at 0 °C and 1.013 bar	43 mg/kg H <sub>2</sub> O 70 mg/kg H <sub>2</sub> O	(130) (129)
Latent Heat of Evaporation at 90.19 K (–182.96 °C)	213 kJ/kg	(129)(132)
Thermal Conductivity at 1.013 bar and 25 °C, gas phase	26.6 mW/m · K	(129)
Thermal Conductivity at 0.99 bar and 90 K (–183.15 °C) (liquid phase)	151.8 mW/m · K	(132)
Specific Heat C <sub>p</sub> at 1.013 bar and 21.1 °C	0.9191 kJ/kg · K	(129)
Specific Heat C <sub>v</sub> at 1.013 bar and 21.1 °C	0.6578 kJ/kg · K	(129)
Critical Temperature	154.48 K (–118.569 °C)	(141)
Critical Pressure	50.430 bar	(132)
Critical Density	0.4361 kg/l	(132)



## 1.4 Reference Numbers from Regulations

CAS Number, gas and liquid	7782-44-7	(141)
UN Number, compressed	1072	(141)
UN Number, refrigerated liquid	1073	(141)
INDEX Number	008-001-00-8	(141)
EG Number	231-956-9	(141)
Classification according to GGVSEB/ADR/ RID/ADNR:		(59)(60)(61) (62)
UN 1072		(141)
Class	2	
Code	10	
Label	2.2 + 5.1	
UN 1073		(141)
Class	2	
Code	30	
Label	2.2 + 5.1	
Classification according to GGVSee/IMDG-Code:		(63)(64)
UN 1072, UN 1073		
Classes	2.2	
Subrisk	5.1	
<b>Labelling according to GHS</b> (according to Regulation (EC) No. 1272/2008)		(141)(2)
Pictogram	 	
Signal Word	Danger	

H Statements	H270, H280 (compressed) or H281 (refrigerated liquefied)	
<b>Labelling of Mixtures:</b> According to CLP Regulation mixtures of oxygen and inert gases with an oxidising ability* > 23,5 % are considered to be oxidising		(2) (123)
Approval according to Regulation (EC) No. 1333/2008 Annex II	Food Additive E948	(3)

## 1.5 REACH

The REACH Regulation (1907/2006/EC) is also valid for oxygen. According to Article 2, Section 7, Letter b, not all titles are valid. Oxygen belongs to the chemical elements listed in Annex V No. 13, the hazardous properties and risks of which are well-known. Therewith it is exempted from the application of Title II (Registration of Substances), V (Downstream Users) und VI (Evaluation), for a registration is regarded as inappropriate or unnecessary and the exemption from these titles does not affect the target of the REACH Regulation. (1)

## 2 Production, Use, Prohibition of Use

### 2.1 Production

Oxygen is produced, for example, by the separation of air components, by low-temperature rectification (approximately at  $-180\text{ }^{\circ}\text{C}$ ), by adsorption, by membrane processes, and by electrolysis.

### 2.2 Use

Oxygen is used for many different purposes. Apart from its use in medicine as a gas for breathing and in air and space travel, oxygen is mainly needed for combustion processes and as an oxidising agent. The use of oxygen instead of air in combustion processes produces higher temperatures.

The industrial use of oxygen is mainly

- in metallurgy – in pig iron and steel production and in copper refining, (101)
- in chemical processes, e. g. in olefin oxidation (ethylene oxide), in the partial oxidation of coal and heavy oil to produce hydrogen and synthesis gas, to produce sulphuric and nitric acids, acetylene, acetaldehyde, acetic acid, vinyl acetate and chlorine,
- in autogenous techniques for welding, cutting, flame cleaning, in thermal separation e. g. of concrete,

\* The oxidising ability is determined according to DIN EN ISO 10156

- in the food industry,
- for melting processes in the glass industry,
- for the treatment of drinking and waste water,
- for the ozone production.

## 2.3 Prohibition of Use

With the exception of breathing apparatuses and medical purposes, respiratory air shall not be enriched with oxygen.

Oxygen shall not be used as a substitute for compressed air. Oxygen shall not be used for e. g. paint spraying, driving machine tools, starting engines, for blowing out swarfs and dust or for blowing out clothing, or improving the breathing air in a room.

The use of oxygen is also prohibited for purging, pressure tests of vessels and piping and as a gas buffer in liquid-containing vessels. Exceptions are vessels and piping that are intended for use with oxygen.

## 3 Health Hazards

Oxygen, a component of air vital to life, can have a toxic effect in higher concentrations. Poisoning occurs especially in therapeutic usage. Oxygen concentrations below 50–60 vol.-% at normal pressure can be regarded as harmless for adults, even when breathed over a longer period. 100 vol.-% oxygen at an (over-)pressure of 0.5 bar (50 kPa) remain without any toxic effect. On the other hand, inhaling of pure oxygen at pressures above 3 bar (300 kPa) over a short period leads to toxic effects for the central nervous system, such as dizziness, nausea, overexcitement, disturbance to sight, hearing and sense of balance, seizures, unconsciousness and even to fatalities.

Inhaling pure oxygen at normal pressure over a longer period can cause lung damage and dysfunctions of the endocrine glands and the vegetative nervous system. The lung-damaging effect occurs mainly due to long-term exposure to pure or a high-concentration of oxygen and can lead to toxic lung oedema.

Any slight breathing difficulties following an acute inhalation of highly concentrated oxygen usually disappear when the affected person goes out into the fresh air.

**Liquid oxygen can cause severe cryogenic burns.** These are not noticed immediately, particularly when only a small area is involved, for the cold anaesthetises the sense of pain. After this area has been warmed up strong pain occurs.

## 4 Risk Assessment

## 4.1 General

The German Law for Occupational Safety (Arbeitsschutzgesetz), Ordinances for the protection at work (e. g. the Ordinance on Hazardous Substances – Gefahrstoffverordnung, the German Ordinance on Industrial Safety and Health – Betriebssicherheitsverordnung, Occupational Workplace Regulations – Arbeitsstättenverordnung) Maternity Protection Act and the DGUV Regulation 1 “Principles of Prevention“ oblige the employer to determine and to assess the workplace hazards and stresses of the employees. (5)(11)(34)(6)(49)(50)(65)(98)

The risk assessment

1. must be carried out before commencing the task,
2. must be carried out by competent persons. If necessary, the employer must be consulted competently, e. g. by the OSH Professional or the works doctor,
3. must be documented and kept up to date.

The overall responsibility for the risk assessment **always** lies with the employer. The works council shall be involved.

The risk assessment for activities involving hazardous substances is divided into the following steps: (13)

- Recording of substances, mixtures and other risk factors (list of hazardous substances),
- Determination of information (e. g. safety data sheet),
- Evaluation of risks (inhalation, dermal, physico-chemical),
- Checking the possibility of substitution,
- Determination and execution of necessary protective measures,
- Documentation,
- Regular checks on effectiveness.

Activities with hazardous substances can only be started after a risk assessment has been executed, protective measures have been determined and the employees who deal with these substances have been instructed. Beyond the normal operation the start-up and shutdown of plants, maintenance and repair work and disturbances of the normal operation must be considered.

The cooperation of different companies can induce mutual risks. Therefore the coordination of external companies (e. g. carried out by a Safety Coordinator) is also part of the risk assessment. (11)(65)(98)(68)

More information on risk assessments can be found in various media which the statutory accident insurance carriers like BG RCI offers their member companies for executing the risk assessment according to the German Act on the Protection at Work:

- The Codes of Practice A 016e “Risk Assessment – Seven Steps to the Goal“ and A 017e “Risk Assessment – Hazard Catalogue“ as well as the file “Gefährdungsbeurteilung – Arbeitshilfen“ of BG RCI.(72)(73)
- They include worksheets which are part of the software “GefDok light“ in the “Kompendium Arbeitsschutz“ and they are available at [downloadcenter.bgrci.de](https://downloadcenter.bgrci.de). The Excel sheets can be filled in at the PC without special knowledge on Excel.
- “GefDok KMU“, a software for the documentation of risk assessments in small and medium sized enterprises (SME). (140)
- Forms of the file “Arbeitsschutz mit System“ (Word files and Excel sheets). (95)
- DGUV Information 213-851 “Working Safely in Laboratories – Basic Principles and Guidelines“ (66)
- Substance specific or substance class specific Codes of Practice (Series M) of BG RCI, particularly M 053 “Arbeitsschutzmaßnahmen bei Tätigkeiten mit Gefahrstoffen“ (DGUV Information 213-080).(81) et. seqq. (88)

The risk assessment for activities with gases is described in TRGS 407 "Tätigkeiten mit Gasen – Gefährdungsbeurteilung". Relevant topics for activities related to oxygen are listed in the Sections 4.2 and 4.3 herein. (15)

## 4.2 Specific Hazards related to Gases (15)

The hazardous properties of gases must be evaluated particularly in the light of their high volatility and the operation under pressure.

Potential risks of activities dealing with gases under pressure are, e. g.:

1. Risks caused by pressure:
  - a. Parts moving uncontrolled (e. g. parts blowing off, bouncing pipes),
  - b. Detonation, bursting (e. g. pressure wave),
2. Hazards due to special physical effects: noise (e. g. loud hisses caused by sudden escape of large quantities of gas from pressure release openings),
3. Contact with hot or cold media, e. g.: Burns or frostbites of the skin through contact with surfaces of pipes or compressed gas vessels which have been considerably heated or cooled down through adiabatic compression or expansion,
4. High flow velocity (e. g. the impact of a gas jet on the eye).

Knowledge on the cause of a loss from own operational experience as well as other sources shall be used as support for the risk assessment and the selection of appropriate protective measures. A hazard can have different and several reasons (e. g. leakage of a coupling due to a damaged seal or omitted leak testing after mounting or bursting of a vessel due to material fatigue, corrosion or operating errors).

The propagation of gases (lighter or heavier than air) as a function of their density and the mixture which they are incorporated in must be considered. Possible measures must be based on these, e. g. the ventilation and positioning of the gas detection equipment.

For activities dealing with gases, the risk assessment must identify all hazards due to pressure during operation according with the regulations as well as for departures from normal operation (see also TRBS 1111 und TRBS 2141). Departures from the operation according with the regulations which cannot sensibly be excluded are in particular: (35)(44)

1. Leakages (e. g. at valves, flange joints or other sealing surfaces or caused by corrosion),
2. Release of gas when opening plant sections (e. g. due to unidentified overpressure or operating error),
3. Reactions of safety devices, e. g. safety valves or bursting disks,
4. Ruptures of hose connections,
5. Exceeding allowable fill factors.

The relevance of these shall be checked and considered if necessary.

## 4.3 Specific Hazards related to Oxygen (15)

Potential high flow rates, particularly in valves, must be taken into account when dealing with compressed gas vessels and pressure systems. Ignition resulting in burn-outs of process units must be expected in the following cases:

1. Any contamination occurs in the oxygen current (see Section 5.2).
2. Safety-related inappropriate material is used (see Annex 1).
3. Safety-related inappropriate sealing agents or lubricants are used (see Section 5.3).
4. The geometry of valves, the safety of which had been tested to be appropriate, has been altered afterwards or has been manipulated by any other means.
5. The flow rate exceeds a certain limit value.

However, compression heat due to adiabatic pressure surges can ignite both material and valves which otherwise are classified to be suitable in terms of safety for the use with oxygen. Example: when the valve of a compressed gas cylinder filled with oxygen is abruptly opened, the elastomer used in standard operation of a pressure-reducing valve can be ignited, if this fitting is not balanced.

At piston compressors, turbo-driven centrifugal compressors and turboblowers intensive fires can occur which can be like an explosion. In this case people nearby machines without shielding are at extreme risk.

If contaminations like oil, fat or other organic materials come into contact with oxygen, self-ignition can occur (see Section 5.2).

The use of inappropriate material can induce an ignition hazard and thus a fire hazard.

For activities with cryogenic liquefied oxygen (see Section 3) special risks additionally emerge:

1. If unprotected skin is exposed contact frostbites can be expected.
2. As soon as liquefied oxygen comes into contact with organic material (e. g. wood, PE/PP plastic, bituminous road surfacing), even extremely low ignition energy can lead to fierce reactions which can culminate in explosions.
3. If resources made of inappropriate material are used embrittlement must be expected.

The escape of oxygen, e. g. due to leakages, leads to oxygen enrichment outside the pressure vessel or the pressure system and can also lead to oxygen enrichment in working clothes of employees (see Section 6). The same risk due to oxygen enrichment is granted for maintenance work at plants operating with oxygen. Oxygen enrichment due to leakages in combustible insulating material leads to an uncontrollable fire load in the event of an ignition.

If the formation of a hazardous explosive mixtures cannot be avoided when oxygen meets flammable or chemically unstable gases under atmospheric conditions, Annex I No. 1.6 of the Gefahrstoffverordnung is in force for the determination of potentially explosive areas and the protective measures required. Further information is given in TRGS 720, 721 and 722, 723 and 724. For detailed instructions on the classification of hazardous explosive areas into zones see Annex 4 of DGUV Regel 113-001 which presents a collection of examples. (11)(24)(25)(26)(27)(28)(106)

**Oxygen-saturated clothing bears an increased fire hazard, this also applies to flame-resistant clothing.**

## 5 Technical Protective Measures

### 5.1 General

Protective measures must comply with occupational safety and accident prevention regulations as well as generally accepted rules of safety technology, occupational medicine and hygiene, the state of the art and other

findings of ergonomic analysis. The aim of these protective measures is to avoid health hazards due to oxygen. (5)(6)(11)(34)(65)(98)

The order of measurements set by law – substitution before technical, organisational and finally personal protective measures – must be observed. Technical and organisational protective measures must be chosen in a way that the employees must use personal protective measures only exceptionally and as a completion to these measures.

## 5.2 Oil, Grease and other Contaminants

Due to the ignition danger all plant components that come in contact with oxygen must be **purged and be clean before the operation with oxygen**. On the one hand, impurities present in the process stream or substances leading to corrosion must be considered during design, for example, impurities from an upstream electrolysis. On the other hand, impurities introduced during construction or maintenance must be removed. That means they must be free from

- Loose elements or such that can become loose during operation such as slag, rust, welding and blasting material residues,
- Oil, grease, solvents and penetrants of non-destructive testing (NDT)
- Other foreign matter and bodies such as packaging material, rust prevention agents and machining swarf as well as other oxidisable substances.

Contact with oily cleaning rags or greasy fingers must also be avoided. The storage shall correspond to the cleanness requirements. Clothes soiled with oil or grease must not be worn. It is recommendable to wear white cotton gloves and white disposable suits during the installation of sensitive, purged plant components.

For pressures higher than 30 bar(a) the maximum permissible value for residual grease contents is 200 mg/m<sup>2</sup>. If the pressure is < 30 bar(a) the content of residual grease must not exceed 500 mg/m<sup>2</sup>. For cryogenic vessels a maximum acceptable level of contamination of residual grease content of 500 mg/m<sup>2</sup> is given (DIN EN ISO 23208:2020-11). EIGA makes a similar recommendation (Doc 33/18). (127)(144)(148)

### 5.2.1 Cleaning Methods

There are various methods for achieving an adequate degree of cleanliness. The size and accessibility of the parts or the system and the timing of the cleaning are important in selecting the method. It often makes sense to carry out the cleaning before the assembly or erection. In this case, renewed contamination during the erection is to be avoided, e. g. by taking special care during working and by covering the parts. If that is not possible, e. g. when welding or drilling, suitable methods such as shielded arc welding or suitable post-cleaning methods such as blowing out with oil-free air or inert gas must be used.

Examples for Cleaning Methods		
Procedure	Used for	Remarks
Immersion, Cleaning out, Washing	Oil and Grease on smaller parts, in small spaces	See Section 5.2.2 "Cleaning Agents"
Blasting	Il Foreign Substances on surfaces of simple parts and on straight pipes	With Glass, Dry Ice, Slag Material <sup>1</sup>
Pickling	Rust, Scale on Steel	Pickling agent, concentration, application temperature and neutralisation to be agreed between manufacturer and user. Caution: additional load due to weight of liquid pickling agent.
Blowing out (oil-free air or inert gas)	Loose Foreign Bodies or Parts that could be Detached from the System	Determine beforehand an effective method. Dependent on the risk eye and face protection must be used.
Wiping off	Oil and Grease on easily accessible smooth surfaces	Use a lint-free cloth. Pay attention to explosion protection if necessary.

The cleaning process must be matched to the characteristics of the plant components to be cleaned, e. g. deployment site, type and size and type of contamination. There is a risk for plaited packages that oil and grease can reach the interior. The effectivity of the cleaning method must be confirmed by a quantitative test (see Section 5.2.3).

## 5.2.2 Cleaning Agents

Cleaning agents must only be used while observing the required protective measures. It is possible to distinguish between aqueous and organic cleaning agents.

Examples of organic cleaning agents are acetone, isopropanol or mixtures of aliphatic hydrocarbons and alcohol, ether or ester. The agent shall have a vapour pressure as high as possible in order to remove it afterwards without any residue. When using organic cleaning agents the formation of a hazardous explosive mixtures must be considered. During the selection of the cleaning agent a potential corrosive effect on sealing material must be taken into account. Aqueous surfactant-based cleaning agents are suitable if they are easily to be removed, otherwise they can lead to corrosion. The manufacturer's instructions on the possible necessity of rinsing, passivation etc. shall be observed. (82)(86)

The cleaning effect can be intensified by an increased temperature, mechanical movement and ultrasound.

It must be ensured that all impurities and residues of cleaning agents are completely removed from cleaned plant components before the installation or commissioning. Residues can be removed depending on the cleaning agent and application, e. g. by

- Blowing out with oil-free air or oil-free inert gas,
- Rinsing with water of drinking quality and subsequent drying when using aqueous cleaning agents,
- Drying and evaporating.

Cleaned plant components must not smell of cleaning agents.

<sup>1</sup> Steel balls or steel granular material must not be used as a blast-cleaning abrasive, as they can be welded with the body.



Surface treatment systems in which objects or materials are cleaned using highly volatile halogenated hydrocarbons are also subject to the Second Ordinance on carrying out the German Federal Immission Control Act (Ordinance on the Emission Limitation for Highly Volatile Halogenated Organic Compounds – 2nd BImSchV), that states particular requirements. Further special measures (e. g. catch basins) can be necessary for the protection of ground water and open waters. (52)(54)

If inner surfaces and installations in spaces and vessels are cleaned with hazardous substances, TRGS 507 “Oberflächenbehandlung in Räumen und Behältern“ must be observed. According to this rule among other things special protective measures concerning ventilation and explosion protection can be necessary. If necessary, DGUV Regel 109-010 “Einrichtungen zum Reinigen von Werkstücken mit Lösemitteln“ must also be observed. (18)(99)

Practical examples of cleaning work shows the video “Umgang mit Sauerstoff“ at [www.bgrci.de/gase-unter-druck/startseite/medien/videos](http://www.bgrci.de/gase-unter-druck/startseite/medien/videos). (137)

## 5.2.3 Test Methods

Particularly recommendable **test methods** after cleaning are

(In operation, in the workshop and on site):

- Visual check with white, bright light (daylight or artificial light; > 500 lux) using the naked eye: Foreign substances and bodies must be no longer visible.
- Visible check using ultraviolet light (Test light: UV-A (315-400 nm), > 10 W/m<sup>2</sup>): In order to achieve applicable results, the surrounding area must be completely dark if possible (Ambient lighting < 20 lux). Strong fluorescence must not be ascertainable. Attention: Oils and greases on a vegetable, animal or synthetic basis do not fluoresce as mineral-based hydrocarbons do. Fluorescence also varies between mineral oils.
- Wipe-sample with lint-free cloth or paper: After vigorous wiping, the test is made with cloth or paper using one of the first two methods named.
- Water wetting test: Distilled water is sprayed on a horizontal surface. If the surface is free of oil and grease, an unbroken water film forms for some seconds. If oil or grease is present, water-free islands form very quickly.

In the Laboratory:

- Solvent Method: Also applicable for oil and grease on inaccessible surfaces. Special conditions are required. A measured quantity of fresh, suitable solvent is used. The parts to be cleaned are immersed in a bath or certain surfaces of large parts are rinsed with solvent. Afterwards the entire quantity of solvent is drained off and the dissolved oil and grease quantities determined by vaporising a sample.
- Using a Gas Chromatograph
- Automatic measuring instruments for determining carbon on surfaces using the infrared absorption method: A sample or small part of the component or material to be tested is heated in the device, together with oxygen as carrier gas, to a temperature of 500 °C. The organic carbon of the hydrocarbon (oil, grease and other impurities) is converted to carbon dioxide.

The following fluctuations of the proof limits for oil and grease residues can be taken from the literature: (131)

Test Method	Detection Limits [mg/m <sup>2</sup> ]
Bright, white Light, Daylight or Artificial Light > 500 lux	ca. 500–1700
Ultraviolet Light (Test light): UV-A (315–400 nm); > 10 W/m <sup>2</sup>	ca. 40–1500
Wipe-sample	ca. 30–600
Water wetting test	ca. 30–60

The achievable values depend on the type of oil.

### 5.3 Sealing Material and Lubricants

Only sealing material and lubricants which are suitable relating to safety technology can be used for oxygen-carrying plants or plant sections. Therefore special care must be taken when carrying out repair and installation work in order to avoid confusion between media.

The use of metallic sealing material is – where technically possible – always preferable to non-metallic sealing material. The requirements for metallic sealing material are described in Column 2 of Annex 1 “Requirements for Oxygen-carrying Plant Components and Sealing Material in Plants and Plant Components“.

According to the Columns 3 and 4 of Annex 1, non-metallic sealing material containing components which are combustible in oxygen can only be used, if the test of a professionally recognised test house has shown that they are relating to safety technology suitable for the use with the existing operating pressure, operating temperature, physical state of aggregation and method of installation based on their properties.

Lubricants should be avoided in oxygen-carrying plants or plant components if at all possible. If this is technically impossible, only lubricants which have been tested and are relating to safety technology suitable for the operating conditions (i. e. liquid or gaseous oxygen) can be used. In principle lubricants containing combustible propellants or solvents in spray cans or containers are not suitable for this purpose.

The Federal Institute for Materials Research and Testing (Bundesanstalt für Materialforschung und -prüfung – BAM), e.g. carries out tests relating to safety technology with sealing material and lubricants and issues a great number of suitable materials in the “Liste der nichtmetallischen Materialien, die von der Bundesanstalt für Materialforschung und -prüfung zum Einsatz in Anlagenteilen für Sauerstoff als geeignet befunden worden sind“. This list is published in DGUV Information 213-075 “Liste der nichtmetallischen Materialien/List of nonmetallic materials“ (Code of Practice M 034-1 of BG RCI) and is annually updated by the BAM. (158)(85)

### 5.4 Hydrocarbons and other Impurities in Liquid Oxygen

During cryogenic air separation hydrocarbons and other impurities accumulate in liquid oxygen which reach the medium-pressure (“pressure column“) or low-pressure column (“upper column“) of the air to be processed. The most dangerous hydrocarbon in this connection is acetylene which can crystallise in liquid oxygen and subsequently has a tendency to explode. A dangerous enrichment of hydrocarbons and other impurities is most probable in the condenser and can be most effectively avoided in air separation plants by the use of adsorbents (molecular sieves, silica gel at low temperatures) for pre-cleaning of gaseous air and by an adequate mode of operation (e. g. regular blowdown).

Detailed hints on safe operation of condensers in air separation plants are given in IGC Doc 65/13/E "Safe operation of reboilers/condensers in air separation units". (149)

## 5.5 Requirements for Plant Sections in Oxygen Operation

### 5.5.1 General

All incompletely oxidised substances are more or less combustible in oxygen, particularly in compressed oxygen. The higher the pressure, temperature and flow velocity in an oxygen system the greater the fire hazard. All process units must be conditioned in a way that a fire can demonstrably be excluded for the planned operating conditions. With regard to these operating conditions the manufacturer must provide proof of the suitability relating to safety technology.

Due to a potential enrichment of oxygen in the ice sheet on ultra-cold valves, pipes, vessels and equipment must only be thawed with hot air (**do not use electrical devices → ignition source!**), hot water or steam. Air, water and steam must be oil-free. Open flames or glowing objects must not be used.

Piping for blowing out and decompressing of oxygen must be arranged in a way that nobody is exposed to danger due to escaping oxygen. (EIGA IGC Doc 154/16/E "Safe location of oxygen and inert gas vents"). During decompression the occurrence of sparks must be taken into account. (152)

### 5.5.2 Valves and Safety Devices

Essential safety factors are:

- Material for bodies, stems etc.
- Design and realisation
- Type and arrangement of the sealing material
- Friction and load in operation.

Suitable material for bodies and built-in components of valves and their sealing material are listed in Annex 1.

To safely prevent personal injuries, it is recommended that valves (emergency-stop valves, bypass valves, other regulating valves as well as frequently operated manual valves) and safety devices are shielded or enclosed by a fixed, non-flammable device – see also Section 5.10 and Annex 3. Or to arrange and dimension these facilities in such a way that people are safely protected from injury. The requirement regarding the arrangement is met when valves are installed outside the working and traffic areas and are equipped with remote control capability, with access restricted within a radius of 15 m during operation.

For valves, safety devices and connected pipelines whose materials have been selected in accordance with EIGA 13/20 Appendix B or successfully tested according to ASTM G 124 (so-called "exempt materials"), no enclosure or shielding is required.

If valves with a nominal diameter greater than DN 200 and working pressures of more than 16 bar are used in unalloyed steel piping, the equipment must allow to equalise the pressures on both sides of the valve before the valve is opened in order to exclude any risk for persons when the valve is opened. These requirements do not apply to safety valves. Equipment for the equalisation of pressure are, for example, bypass lines around the valve – and the diameter of the bypass line shall not exceed a quarter of the main pipe diameter. Experience has shown that pressure ratios between 1.0 and 1.10 pose no safety hazard at pressures of up to 40 bar.

When dealing with oxygen only **pressure measurement devices** (manometer) must be used which are labelled "Oxygen! Oil- and grease-free".

When using gas cylinder valves in oxygen transporting plants, it must be noted that, depending on type and function (e.g. gas cylinder valves with integrated pressure regulator), the resistance to internal flammability under the effect of oxygen pressure surges from different connection sides must be guaranteed. For plain gas cylinders this is usually guaranteed only for the outlet side. If quick-fit adapters are used, then they must be cleaned and maintained regularly in accordance with the manufacturer's instructions.

Lockable vessels, piping and piping sections and other plant components for liquid oxygen that can be isolated must be fitted with an adequately dimensioned safety relief device against overpressure. This recommendation is complied with the installation of a safety relief valve that can release the mass flow without causing an unacceptable pressure excess.

### 5.5.3 Hoses

Hoses for the transport of oxygen including their assemblies must be suitable in type and material for the operational load.

Plant components for the transportation of gaseous oxygen shall only consist of hoses with organic constituents when piping cannot be used for the intended purpose or when the arrangement is only temporary, e. g. during the construction period.

Hoses with organic constituents must only be designated for the transportation of gaseous oxygen.

Hoses with organic constituents are, for example, suitable up to 30 bar when they comply with, e. g. DIN 8541-3:2022-02 "Schläuche für Schweißen, Schneiden und verwandte Verfahren; Sauerstoffschläuche mit und ohne Ummantelung für besondere Anforderungen; Sicherheitstechnische Anforderungen und Prüfung". Suitable metals for hoses are, e. g. copper alloys with a copper mass percentage of at least 55 % and austenitic stainless Cr Ni steels with a combined mass percentage of chrome and nickel of at least 22 %. (119)

Hoses must be protected against mechanic, thermic or chemical damage. Hose lines must be secured so they do not move uncontrollably or tear off under pressure.

More information on the use of hoses is given in DGUV Information 213-053 "Schlauchleitungen" (Code of Practice T 002 of BG RCI ).

### 5.5.4 Combustible Components, Material, Auxiliary Material and Insulants

Plant components for gaseous oxygen with working overpressures > 1 bar or for liquid oxygen must be free of combustible components on the side in contact with oxygen unless combustible constituents have been suggested that comply with other provisions of this recommendation. Combustible components can be sieves, measuring equipment, filters and supports in vessels. Combustible inner coatings must also be regarded as combustible components.

Only those materials must be used for **thermal and acoustic insulation** that do not react dangerously with oxygen, e. g. slag wool, glass wool or porous lava (perlite). The safety of the insulating material, e. g. slag wool, mineral wool, glass wool, perlite, is guaranteed when the mass percentage of organic substances, e. g. lubricant, relative to the total weight of the insulants is not greater than 0.5 % on average. The technical requirements are described in AGI-Arbeitsblatt Q118 "Dämmarbeiten an Luftzerlegungsanlagen", Section 2.4 "Zusammensetzung von Isolier- und Dämmstoffen". (133)

When using synthetic mineral fibres (SMF), products should be preferred that have the RAL quality seal (i. e. carcinogenicity index > 40). For maintenance or dismantling operations see also TRGS 521 "Abbruch-, Sanierungs- und Instandhaltungsarbeiten mit alter Mineralwolle". (20)

For **external corrosion protection** of vessels and piping for gaseous oxygen normal paint coats can be used, for underground lines bitumen bindings can also be used.

For **internal corrosion protection** of vessels and piping for gaseous oxygen with a working overpressure of more than 1 bar – if required at all – paint coats with organic constituents are not suitable due to fire hazard.

## 5.5.5 Oxygen Compressors

Special protection measures (see also Section 5.10.2 and Annex 2) must be carried out for

- Turbo-driven centrifugal processors and turboblowers with a working pressure > 1 bar,
- Dry-running reciprocating piston processors.

Manufacturers and operators developed devices in order to monitor oil leakages at piston rods of piston processors for oxygen. Trespassing of the shielded area surrounding the piston compressor is therefore no longer necessary.

## 5.5.6 Pumps for Liquid Oxygen

In suction and discharge lines of the pumps the shut-off equipment must be arranged for a safe operation. These requirements are met when self-acting non-return flow devices for the discharge lines and remotely operated emergency stop valves for the suction lines are used or the shut-off equipment is so arranged that its actuation is also possible in safety – even when the pump is damaged.

Suction lines must be provided with installations which prevent the entry of dangerous foreign particles into the pumps.

Pumps for liquid oxygen (see also ISO 24490:2016-08 "Cryogenic vessels – Pumps for cryogenic service") must be designed so that a burn-out is not expected or they must be arranged in a way to prevent persons from danger during a burn-out. (128)

Detailed information on material selection, design and installation are given in the EIGA documents Doc 148/19 "Stationary Electric-Motor-Driven Centrifugal Liquid Oxygen Pumps" und Doc 159/21 "Reciprocating Cryogenic Pumps and Pump Installations for Oxygen, Argon, and Nitrogen"; information on non-metallic material is given in DGUV Information 213-075 "Liste der nichtmetallischen Materialien für den Einsatz in Sauerstoff/List of nonmetallic materials compatible with oxygen" (Code of Practice M 034-1 of BG RCI). (151)(153)(85)

## 5.5.7 Piping

Piping including their equipment and assemblies must be suitable in type and material for oxygen as well as for the intended pressures and temperatures. Hints for the selection are given in the EIGA document Doc 13/20 "Oxygen pipeline and piping systems". (146)

As a function of pressure, the flow velocity must be limited due to possible entrained particles (caused by impurities). A flow velocity limit (pressure-dependent) is recommended for new plants in Doc 13/20. (146)

Many existing plants were designed on the basis of tests performed by the Bundesanstalt für Materialforschung und -prüfung (BAM). These gave the following results for black steel (CS) as safe flow velocity under steady flow conditions: (135)

- for operating overpressures of more than 1 bar but not more than 40 bar: 25 m/s;
- for operating overpressures of more than 40 bar: 8 m/s.

In order to determine the flow velocity, the largest throughput rate at the lowest operating overpressure was used.

If rust or other foreign particles can be entrained in the piping, it must be ensured that downstream plant components are not endangered. This requirement is met when separators and filters with differential pressure loss indicators are installed. In Chapter 5.4 of EIGA document Doc 13/20 statements on filters, filter material and risks related to filters can be found. (146)

When laying piping the following requirements should be considered:

- Protection against dangerous load due to vibration, displacement, strain or heating.
- It must be possible to shut off from a safe place piping that leads into a building.
- Wall penetrations of piping laid underground or in ducts must be technically leakproof.
- Piping must be protected against external corrosion.
- Piping for oxygen shall only be laid in the same duct with piping for combustible gases, if the leak-tightness of the piping is assured (durably technically leakproof).

Piping for moist oxygen in which condensation occurs must be dehydrated safely.

Vertical impingement of gaseous oxygen on pipe walls should be avoided. This requirement is complied with when changes in direction of piping and branches run in rounded bends instead of sharp kinks. For further hints on radii of curvature and allowable speed see EIGA document Doc 13/20. (146)

If pipes made of material without specified low temperature properties are fed by plants for liquid oxygen, they must be protected by an installation which prevents dangerous cooling of the piping. A suitable installation is e. g. a temperature-controlled, self-acting fitting which interrupts the supply of the gas flow if the heat input to the gasifier breaks down. More information on this subject is given in EIGA document Doc 133/22 "Cryogenic vaporisation systems, prevention of brittle fracture of equipment and piping". (150)

There must be a safe distance between buried piping and underground electrical cables. A distance is adequately safe when piping and cables are separated by at least 30 cm or components made of non-conducting, non-combustible material lie between piping and cables, e. g. the outer wall of a cable duct.

## 5.6 Laboratories

All activities that might lead to increased oxygen concentrations indoors must be carried out under fume hoods.

These activities are only permitted outside of the fume hoods when it is sure that there is no danger to the employees due to appropriate safety measures.

This can be achieved e. g. by the use of

- Closed-circuit systems,
- Effective local air extractors.

The book "Working Safely in Laboratories" (DGUV Information 213-851) shall be applied for laboratories. (66)

## 5.7 Ventilation

All rooms in which oxygen can escape during normal operation must be ventilated in order to prevent an enrichment of the air with oxygen. If necessary, a gas detection equipment for monitoring must be installed. If natural ventilation is not sufficient, a ventilation system is required. References can be found in German Occupational Workplace Regulations (ArbStättV), in Workplace Guideline ASR A3.6 "Lüftung" and in DGUV Regel 109-002 "Arbeitsplatzlüftung – Lufttechnische Maßnahmen". (6)(10)(99)

## 5.8 Working Areas

In areas where liquid oxygen can escape, the floor must be made of non-combustible material. Asphalt (bitumen) or wood, for example, are therefore not permitted. This also applies to outdoor areas.

Rooms in which oxygen is extracted, compressed or liquid oxygen is evaporated, must be made of non-combustible building material. (116)

In rooms where liquid oxygen can escape an adequately dimensioned area must be available around these emission points for the protection of persons. This is achieved, e. g., when the zone of protection has a radius of 5 m around the emission point.

Structural facilities in the zone of protection shall be made of non-combustible material. Moreover, the storage of combustible material is not permitted in the zone of protection and self-igniting substances must not be present. In addition, openings to subjacent rooms, to sewers without a liquid trap and combustible material must not be present in the zone of protection.

Rooms in which oxygen is extracted, compressed or liquid oxygen is evaporated, must be separated as gas-tight as possible from adjacent rooms in which a fire or explosion hazard exists so that an oxygen enrichment can be excluded from these endangered rooms.

The exits from rooms in which oxygen is produced, compressed or where liquid oxygen is evaporated, must be arranged in a way that the occupants can leave the rooms quickly in case of dangerous situations.

## 5.9 Storage and Keeping

Apart from requirements listed in Section 5.8, the following aspects concerning the storage and keeping must be observed.

TRGS 510 "Lagerung von Gefahrstoffen in ortsbeweglichen Behältern" must be considered when non-stationary compressed gas vessels are stored. (19)

When keeping available compressed gas vessels TRBS 3145/TRGS 745 "Ortsbewegliche Druckgasbehälter – Füllen, Bereithalten, innerbetriebliche Beförderung, Entleeren" must be considered. (45)

TRBS 3146/TRGS 746 "Ortsfeste Druckanlagen für Gase" regulates the storage of gases in stationary gas vessels including equipment and installation. (46)

Generally it is recommended to store liquid oxygen above ground. If this is impossible, the following measures must be taken into consideration:

- Observance of Section 6.8 "Arbeiten in Behältern und engen Räumen" herein.

- Blow-down and vent lines for oxygen must be arranged so that nobody is endangered by escaping oxygen. This implies that oxygen must not be vented in underground storage rooms.
- Ventilation and venting measures must guarantee that no atmosphere enriched with oxygen can occur. It must not be forgotten that oxygen tends to concentrate at floor level.

According to TRGS 510 more than 200 kg oxygen can only be stored without limiting with non-combustible substances (LGK 12 & 13), compressed gas vessels with inert gases (in outdoor areas all gases are permitted) and non-combustible corrosive hazardous substances (LGK 8 B). Limitations and conditions of storage with non-inert gases, combustible corrosive hazardous substances (LGK 8 A) and combustible solids (LGK 11) are listed in TRGS 510. (19)

Compressed gas vessels must be secured against falling over and falling down. The valves must be secured with a suitable guard, e. g. protective caps or wire guards/flanges. Particular safeguarding against falling or falling down is not required, if e. g. the design of the compressed gas vessels, the arrangement in larger groups or the mode of storage guarantee sufficient protection.

The transfer of gases and repair work of compressed gas vessels must not be carried out in the stock room. Special rooms must be provided for these activities.

Structural requirements for the storage of non-stationary vessels: (19)

Storage in stock rooms

1. Stock rooms must be separated from adjacent rooms by fire-retardant components (Minimum fire resistance rating: 30 min),
2. Components must be flame-resistant (Minimum fire resistance rating: 90 min), if fire or explosion hazard exists in adjacent rooms which do not serve as a stock room for gases,
3. The outer walls of stock rooms must be at least flame-resistant (Minimum fire resistance rating: 30 min). If the minimum distance from adjacent plants and installations which imply a potential risk is 5 m the outer wall can be made of non-combustible material,
4. The roofing material must be sufficiently resistant to swirling fire and radiant heat,
5. The floor cover in stock rooms for non-stationary compressed gas vessels must consist of non-combustible material.

Outdoor stores must keep a 5 m minimum distance around compressed gas vessels from adjacent plants and installations which imply a potential risk. A protective wall made of non-combustible material, at least 2 m high and sufficiently wide, is an alternative measure.

In work-rooms compressed gas vessels must only be stored in suitable safety storage cabinets with a minimum fire resistance rating of 30 min. Safety storage cabinets which comply with DIN EN 14470-2:2006-11 are particularly suitable. (122)

Pits, channels or outflow to channels without a liquid trap as well as cellar accesses or any open connections with cellar rooms in the store, or openings in walls and ceilings to adjacent rooms are not permitted in order to prevent a dangerous accumulation or spreading of gases. Moreover, no clean-out hole or any other opening of chimneys are allowed.

Storage rooms for compressed gas vessels must be sufficiently ventilated and vented. Natural ventilation is sufficient, if there are vent openings which directly lead out into the open air (right next to the storage area) with a total diameter which corresponds at least to 1/100 of the floor space in the storage room. The arrangement of the vent openings must consider the density of the gas (in the event of oxygen they must be installed near the bottom). If sufficient natural ventilation cannot be guaranteed, a technical ventilation with an air change every 30 minutes must be provided. This ventilation must be permanently active or automatically triggered by gas detection equipment, if a determined limit value is exceeded.

Additional information is given in the Code of Practice M 062e "Storage of Hazardous Substances" and DGUV Information 213-085 "Lagerung von Gefahrstoffen – Antworten auf häufig gestellte Fragen" (Code of Practice M 063 of BG RCI). (89)(90)



## 5.10 Shielding

The burn-out at an oxygen-transporting installation implies material damage due to the fierceness of the oxygen-rich fire (parts flung away). In addition, to prevent personal injuries and limit the material damage adequate, shielding can be installed. As far as shielding is required, the shielded area must not be entered during the oxygen operation. Within the shielded area combustible material must not be stored or self-igniting substances must not be present.

### 5.10.1 Shielding of Filling Stations

At the level of cylinder valves (at least) lowerable flame-resistant wire guards can be used in order to prevent at filling levels that the burn-out of valves can cause more severe damage, particularly personal injuries. For bundled filling stations an adequate shielding is also recommended.

Transparent shields made of polycarbonate with a fire protection classification have proved to be efficient.



Figure 1: Shielding of a Filling Station, open (left) and closed (right)

## 5.10.2 Shielding of Compressors

As a safeguard against fire, compressors like turbo-driven centrifugal compressors, turboblowers and dry-running reciprocating piston compressors must be provided with sufficiently dimensioned shielding when in operation.

This target with regard to the dimensions of the shielding is achieved e. g. if there is no visual contact between the parts of compressors which can cause a fire and persons. The requirements of shielding normally are:

- The shielding is generally as high as the machine parts are above the walking level, however, the minimum height is 2.0 m. Potential risks of persons on walkways above the walking level and in crane operator cabins must be in particular considered.
- For dry-running reciprocating piston compressors the shielding comprises the cylinders including the stool chamber from the upper edge of the engine housing at least.
- Oxygen-transporting components which are connected to the compressor have to be shielded including the first deflection before and after the compressor housing. A deflection is defined as a change of the flow direction  $> 30^\circ$  and a radius of curvature less than  $5 D$  ( $D$  = outer diameter). The cooling apparatus and the pulsation damper after the first deflection are not regarded as potential sources of a fire and do not have to be included in the shielding.

The realisation and the design of the shielding must consider the fact that the burn-out of the compressor can induce flying parts. This target is achieved if e. g.

- The shielding is made of concrete, brickwork, double steel plates provided with an insert made of glass wool, rock wool or a fire plate, solid covered steel plates or non-combustible plates with outer steel reinforcement,
- The room formed by the shielding is adequately ventilated,
- Existing doors are lockable,
- The venting of the room formed by the shielding takes place in a safe direction if the containment is complete.

Compressors must be run in a way that entering of the area between compressors and shielding is unnecessary during the operation of the compressor with oxygen. Ideally, intrinsically safe materials – planned and implemented by professionals – are used. This is considered safer than barriers and shielding.

Examples of shielding of compressors are given in Annex 3.

## 5.11 Oxygen mixed with other Substances

When adding oxygen to other substances it must be ensured that oxygen cannot get into the piping through which the other substances are fed into the mixing section. Contrariwise, the other substances must not get into the line feeding oxygen to the mixing section.

This is achieved, e. g. in the following cases:

- The isolating device closes and an intermediate venting opens simultaneously, as soon as the oxygen supply is interrupted.
- In blast furnaces oxygen is only added when the air flow is above a minimum value.
- The oxygen supply is automatically closed, if the sequencing or control system fails.
- The oxygen enrichment is monitored by two mutually independent measuring systems (quantity ratio and analysis).

More information is given in Chapter 3.2.8 of TRGS 407 "Besondere Gefährdung beim Mischen von Gasen". (15)

In section 1.2.7 "Anlagen zur Herstellung und Verwendung von Wasserstoff" – specifically section 1.2.7.1 "Elektrolyse" – of Annex 4 "Beispielsammlung" of DGUV Regel 113-001 "Explosionsschutz-Regeln (EX-RL)", process step- and plant type-specific explosion protection measures are listed." (106)(26)(27)

## 6 Organisational Protective Measures

### 6.1 General

Organisational protective measures only serve as an additional tool. Technical protective measures, particularly the achievement of intrinsic safety, must be preferred to organisational measures.

### 6.2 Operating Instructions

The results of a risk assessment are the basis for operating instructions. They contain exact details about the potential hazards for humans and environment in individual cases and the necessary protective measures as well as rules of behaviour to combat these hazards. (11)(22)

Behaviour in hazard cases and first-aid measures must also be considered. The operating instructions must be written in an understandable language and must be displayed at a suitable place in the workplace. The employees must be able to consult the operating instructions at any time.

Further information how to plan operating instructions are given in DGUV Information 213-051 "Betriebsanweisungen für Tätigkeiten mit Gefahrstoffen" (Code of Practice A 010 of BG RCI). (69)

### 6.3 Instruction

The employees' attention must be drawn to potential hazards when dealing with oxygen and they must be thoroughly instructed in the appropriate protective measures. The basis for the instruction are the results of a risk assessment and the operating instructions. The instruction must be given before the start of the specific work and after that at least once a year (adolescents twice a year) as a verbal, workplace-related instruction. The content and the date of the instructions must be recorded in written form and signed by the participants receiving the instructions. This document must be kept for a period of two years. (11)(22)(48)

It can be useful to complement the instruction through practical demonstration of individual measures on-site and practising of the employees led by an expert, e. g. a bottle change or operating pressure-reducing valves. Furthermore, a detailed oral agreement on work and safety on-site is mandatory. A performance review is essential, e. g. answering a workplace-related questionnaire. (87)(143)

BG RCI offers support for instructions, among other things: (76)

- Brief Safety Instructions (Sicherheitskurzgespräche – SKG), e. g. (97)

- SKG 004 up to SKG 006 deal with compressed gas cylinders
- SKG 007 "Verwendung von Sauerstoff"
- SKG 008 "Erstickungsgefahr durch Gase"
- Portal "Gase unter Druck" at [gase.bgrci.de](http://gase.bgrci.de) including films and links to E-Learning modules about oxygen (137)(138)
- publication "kurz & bündig": KB 016 "Sauerstoff – Eigenschaften, Gefährdungen und sicherer Umgang" (79)

## 6.4 Escape and Rescue Plans

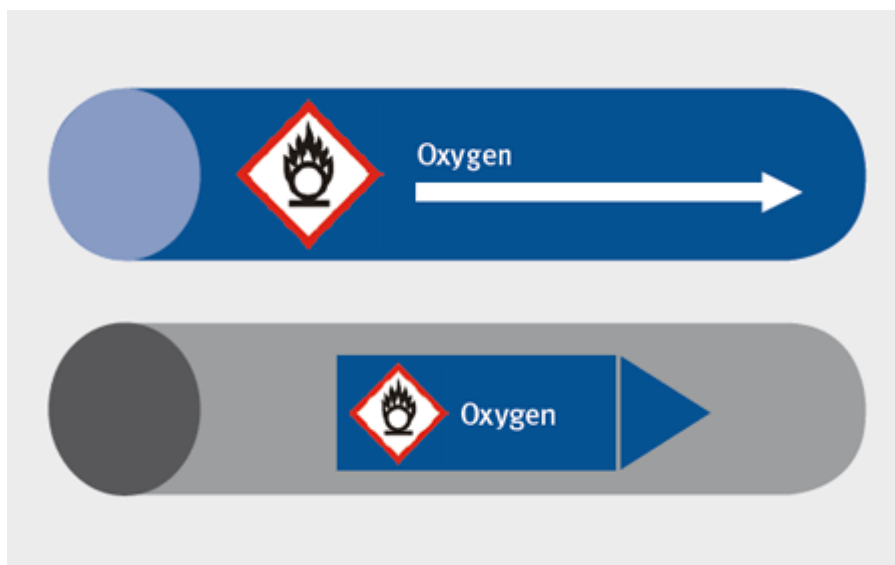
The employer must draw up an escape and a rescue plan for the workplace, if required by position, dimensions and type of use of the workplace. The escape and rescue plans must be displayed at a suitable place in the workplace. In adequate time intervals the employees must practise according to this plan how they can rescue themselves or can be saved in the event of a hazard or a disaster. (9)

For operational areas and plants subject to authorisation which are subject to the Ordinance on Industrial Accidents (Störfallverordnung), the required precautions depending on type and extent of potential hazards must be implemented to avoid incidents or to minimise the effect of an incident. They include technical, organisational and management-specific systems the requirements of which can be found in the Ordinance on Industrial Accidents. (53)

## 6.5 Marking

Devices and pipes for oxygen as well as connection or discharge points at oxygen pipes must be marked so that the hazardous substances contained therein and any associated hazards are clearly identifiable. According to the Ordinance on Hazardous Substances and TRGS 201 plant sections containing oxygen must be marked with paint coat, labels or signs. (11)(12)

Figure 2: Examples for internal marking of oxygen pipelines according to TRGS 201 and ASR A1.3 (12)(7)



## 6.6 Fire Hazard and Fire Protection

Although oxygen itself is not flammable, it does enable and promote combustion processes. An increased fire hazard exists even at oxygen concentrations of a little more than 21 vol.-%, which is the normal value in room air. The higher the oxygen concentration the greater the fire hazard.

The fire hazard in plant components containing oxygen grows with

- increasing oxygen concentration,
- increasing temperature,
- increasing pressure of oxygen and oxygen mixtures.

Smoking and the use of open flames is prohibited in rooms where oxygen is extracted, compressed or liquid oxygen is evaporated or further processed as well as in places in the open air where oxygen enrichment can occur. Signs must be placed drawing notice to these bans if a corresponding ban does not exist for the entire plant.

Rooms in which oxygen is produced, compressed or liquid oxygen is evaporated, must be separated as gas-tight as possible from adjacent rooms where a fire or explosion hazard exists so that an oxygen enrichment is unlikely within these endangered rooms. In the case of non-insulated pipe sections in which cryogenic liquefied gases are transported, it must be ensured that no hazard due to oxygen enrichment can arise from air condensation.

Due to the increased fire hazard, clothing that could contain more than 21 vol.-% oxygen shall not come in the vicinity of an open flame. An "open flame" includes combustible matches, cigarette lighters, electrical devices (e. g. hair driers) and cigarettes. The increased fire hazard exists for clothing even when it is not contaminated with oil or grease.

Clothing in which oxygen has accumulated must not be taken off immediately, for electrostatic sparks can occur<sup>2</sup>. The person concerned must stay outdoors in fresh air for 15 min. at least in order to air the clothing before taking off.

Emergency showers have proved effective in extinguishing burning clothing. Fire blankets are unsuitable.

Fire extinguishing equipment, appropriate to the type and size of the plant, must be provided and kept in a ready-for-use state. Details can be found, for example, in ASR A2.2 and DGUV Information 205-001. (8)(33) (110)

Hand-operated fire extinguishers must be within quick and easy reach at all times. The locations of fire extinguishing equipment must be clearly and permanently labelled if the fire extinguishing equipment is not automatically controlled or not centrally operated by hand. (8)

Automatic, stationary fire extinguishing equipment, e. g. with CO<sub>2</sub>, the use of which can constitute a hazard to the employees, must be fitted with an automatic warning system. An adequate number of employees must be made familiar with the handling of the fire extinguishing equipment.

## 6.7 Leakage Test

After changes at the plant, e. g. a bottle change or maintenance work, the established or closed connections must be checked for leakproofness in order to avoid an uncontrolled release of oxygen. An adequate method for pressurised plants is e. g. spraying foaming agents (surfactant solutions) at parts to be controlled or tracking

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<sup>2</sup> This concerns the enrichment by gaseous oxygen – however, when wetted with liquid (i.e. cryogenic) oxygen, preventing frostbite is crucial, see Section 8.4 for more details.

with a leak detector. The check is immediately carried out and documented by the executing employee after the modification has been finished. Executing the leakage test with oil-free nitrogen at 0.5 bar has proven its worth.

## 6.8 Working in Vessels and Confined Spaces (107)(92)(112)

Working in vessels and confined spaces always requires a work permit. In the context of the risk assessment provided, additional measures must be taken into consideration, e. g. ventilation, when oxygen concentrations of higher than 21 vol.-% can occur. The employees have to be instructed according to the results of the risk assessment.

The work must not start before the supervisor ascertains the execution of the recorded arrangements.

Details are laid down in DGUV Regel 113-004 "Arbeiten in Behältern, Silos und engen Räumen". (107)

The entering of vessels and confined spaces is only permitted, if analytical equipment has proved the oxygen concentration to be between 19 Vol-% and 21 Vol.-%.

In trenches, sewers and confined spaces which can be reached by oxygen from plants or plant components, an expert must meter the oxygen content of the indoor air using instruments supplied by the employer. The oxygen concentration must also be metered, if required, during the time spent in trenches, sewers and confined spaces. These must be ventilated if necessary.

The requirements for experts are laid down in DGUV Regel 113-004 "Arbeiten in Behältern, Silos und engen Räumen" and DGUV Grundsatz 313-002 "Auswahl, Ausbildung und Beauftragung von Fachkundigen zum Freimessen nach DGUV Regel 113-004". (112)

## 6.9 Cleaning and Maintenance Work

The following cases require a written work permit including an oral agreement on occupational safety on site

- Working in vessels, silos and confined spaces. Details are laid down in DGUV Regel 113-004 "Arbeiten in Behältern und engen Räumen", (107)
- Open flame operations, e. g. welding, cutting, soldering, pre-heating and grinding
- Working on plants, in which hazardous oxygen enrichment must be expected in the working area.

In this permit the necessary safety measures must be defined, e. g. complete draining of the equipment, purging with oil-free nitrogen or oil-free air, personal protection measures when opening, cleaning with suitable agents, concentration measurements.

Any objects which have been placed in plant sections that contain oxygen as well as in separation equipment, must be removed after the maintenance work is completed, unless they are necessary for the operation of the plant. Such objects particularly are planking, frame-work, tools, lamps, drilling chips and other combustible objects. It is highly recommended to establish an inventory.

Maintenance and service efforts shall only be carried out by suitable, reliable persons instructed by the company. If cooperating with contractors agreements must be made in context with the contract. (65)(98)(68)

When changing components original spare parts free of oil and grease must be used which are demonstrably suitable for the use in oxygen under the present operating conditions.

If oil seepage must be expected, the employer must have compressors, pumps, piping, valves and filters checked in appropriate time intervals for oil deposits, and arrange the cleaning to be done, if necessary.

Before starting the cleaning work, the plant sections listed above must be purged with air or inert gas that is oil-free. This also applies to maintenance work, if open flame operations must be carried out or sparking must be expected. Cleaning agent residues must be removed by blowing out with oil-free air or oil-free inert gas.

The removal of cleaning agents by means of blowing out is necessary to prevent remains of oil or grease after the cleaning agent has evaporated.

In the area of air induction no hydrocarbons must be emitted.

If an inert gas is temporarily compressed in an oxygen compressor, e. g. nitrogen, measures according to specific operating instructions must be taken before oxygen is reused. It must be ensured that the specific gas can only be transported into the pipeline network made for it.

## 6.10 Inspections

For the production of pressure equipment and assemblies with an internal overpressure > 0.5 bar the Pressure Equipment Directive (Directive 2014/68/EU) is in force. Oxygen is here assigned to Fluid Group 1, Subgroup 1.0 "Oxidising Gases of Category 1". (4)

For the operation of a plant the guidelines of the Ordinance on Industrial Safety and Health (BetrSichV) are in force. The inspections and inspection periods for work equipment which are required to ascertain a safe state must be determined within the frame of risk assessments and the inspections must be carried out by a Competent Person. (34) (35)(43)

The results of the inspections must be documented according to § 17 BetrSichV. For more information see also DGUV Information 213-062 "Druckprüfungen von Druckbehältern und Rohrleitungen – Flüssigkeitsdruckprüfungen, Gasdruckprüfungen" (Code of Practice T 039 of BG RCI). (34)(94)

Strength determinations by gas pressure tests must be carried out with oil-free air or oil-free inert gas. A strength determination of completely installed piping and plant sections by water (without additives) is only appropriate, if the water can be removed completely and no static problems are to expect.

Prefabricated parts of piping can also be tested with water, if water and corrosion products are completely removed before the installation.

### 6.10.1 Inspection of Piping

Piping for oxygen is work equipment which must be inspected according to § 14 of the Ordinance on Industrial Safety and Health (BetrSichV). (34)

Type and extent of the inspection, inspection periods and competence must be determined in the risk assessment according to the Ordinance on Industrial Safety and Health. A periodic leakage test for piping after five years at least is recommended. (35)(34)

### 6.10.2 Leakage Test of the Plant

Commissioning of oxygen-carrying plants or plant sections for the first time, after repair or modification is only permitted if a leakage test has been carried out.

**Leakage tests** must be carried out only by Competent Persons who are experienced in leakage tests and dealing with oxygen.(43)

The pressure used during leakage tests must not exceed the maximum working pressure. Executing the leakage test with oil-free nitrogen at 0.5 bar has proven itself.

### 6.10.3 Tests of Hoses and Flexible Piping

The inspection periods for hoses and flexible piping are determined corresponding to the operational load within the frame of the risk assessment. Examples are given in DGUV Information 213-053 "Schlauchleitungen" (Code of Practice T 002 of BG RCI) and DVS-Merkblatt 0221 "Gasversorgungsanlagen zum Schweißen, Schneiden und verwandter Verfahren – Empfehlungen für Prüfzeiten und die Gefährdungsbeurteilung". A regular test of hoses and flexible piping by a "Competent Person" once a year at least is recommended. (91)(134)(43)

### 6.11 Access Restriction

The entry of plants and work-rooms, in which oxygen from experience can occur in dangerous concentrations or amounts or if burn-out hazard exists, is only permitted for employees provided with adequate protective measures. Anybody else can only enter with express permission of the employer or the representative (e. g. plant manager). Signs like the prohibition sign D-P006 (No Admittance of Unauthorised Persons!) must be attached accordingly. (118)

Prohibition sign D-P006  
No Admittance of Unauthorised Persons!



## 7 Personal Protective Measures

### 7.1 Eye Protection (104)(67)

Adequate eye protection must be worn when dealing with liquid oxygen:

- Frame goggles with side shields including glasses integrated into safety helmets (with correction lenses for persons wearing glasses) are sufficient e. g. for supervision activities in the plant and in the laboratory.
- Suitable closed goggles must be worn for all work in which danger to the eyes caused by spattering liquid must be expected, e. g. when filling liquids or repairing malfunctions.

According to DIN EN 166:2002-04 "Personal Eye Protection" suitable safety glasses must protect against mechanical and chemical hazards belonging to Hazard Class 3 "Dripping and spattering liquids". (120)



For operational areas in which pressure gas vessels are filled with oxygen it is recommended to take eye or face protection into consideration when performing the risk assessment.

## 7.2 Body Protection (102)(67)

Depending on the extent of potential hazards due to oxygen suitable protective clothing must additionally be worn, e. g. long-sleeved, flame-retardant clothing according to DIN EN ISO 11612:2015-11 "Protective clothing – Clothing to protect against heat and flame – Minimum performance requirements" or DIN EN ISO 11611:2015-11 "Protective clothing for use in welding and allied processes". Clothing that covers the body protects against darting flames if it is fastened. (125)

Working clothes and personal protective equipment contaminated with oil or grease must be changed.

Protective screens are suitable for face protection when dealing with liquid oxygen.

Hands must be protected against contact with liquid oxygen by protection gloves insulating against the cold.

Liquid oxygen must not flow into clothing elements.

**Note: Protective clothing, however, does not protect against oxygen enrichment in the clothing and the resulting fire hazard!**

## 7.3 Gas Detection Equipment

As the human senses cannot perceive oxygen, transportable gas detection equipment can help to discover dangerous oxygen concentrations and to warn persons in time. The necessity of transportable gas detection equipment is defined when performing the risk assessment. If technically possible and economically reasonable, stationary gas detection equipment is preferable to personal gas detection equipment.

The use of personal gas detection equipment requires

- General sensitizing of employees for work hazards,
- Regular and documented instruction of employees,
- Written work instructions (e. g. operational instructions) including implementation and enforcement,
- Organisation of checks and procurement of spare parts.

Information is listed in Code of Practice T 021e "Gas Detection Equipment for Toxic Gases/Vapours and Oxygen" of BG RCI. (93)

## 8 First Aid

## 8.1 General

All persons dealing with liquid oxygen or inert gas/oxygen mixtures containing more than 21 vol.-% oxygen must be instructed in first-aid measures and be taught about how to behave in cases of occupational accidents. (109)

The first-aid instructions acknowledged by the German Social Accident Insurance Institutions corresponding to the particular degree of risk must be posted at suitable places. (108)

Each case of first aid must be recorded, e. g. in a hand-written or electronic first-aid log book, and kept for a period of 5 years. Data protection must be observed.

In case of any hazards due to oxygen, the persons affected must leave the danger zone or must be brought away from the danger zone. First-aiders must protect themselves, especially against contact with liquid oxygen (protective gloves etc.).

Medical help must be applied without delay. Details of the chemical involved and measures already taken must be communicated to the attending physician.

Foresighted consultation between company, work's doctor, hospital or emergency service can be necessary in order to give effective help.

Basic matters of first-aid training, such as "recovery position", "heart/lung resuscitation", "shock treatment", are not addressed in this publication.

In the case of operational risks, e. g. due to the impact of liquid oxygen, additional measures and first-aid measures can be necessary. These measures require certain knowledge and abilities of first-aiders, which are not part of a first-aid basic training.

The works doctor executes the continuing education of first-aiders who are apt for it.

## 8.2 Eyes

- Apply a sterile protective bandage,
- Ophthalmological treatment.

## 8.3 Respiratory Organs

- Injured persons must be brought out of the danger zone without putting oneself in danger,
- Ensuring that the patient is kept calm, prevention of heat loss,
- Medical attendance.

## 8.4 Skin

- Immediate removal of all clothing saturated with oxygen, even underwear and shoes,<sup>3</sup>
- Clothing which obstruct the blood circulation in the affected region must be removed,

<sup>3</sup> This applies in the event of wetting with liquid (or cryogenic) oxygen – if there is no risk of frostbite, the clothing should first be ventilated by staying outdoors to avoid ignition – see Section 6.6.4

- Immediate application of hand-warm, moist compresses for a maximum of 5 minutes,
- Subsequent covering up injured areas, keeping them dry and free from germs as far as possible,<sup>4</sup>
- Wrapping in a rescue blanket to prevent further heat loss,
- Medical attendance – even when initial analgesia exists (cf. Chapter on health hazards).

## 8.5 Advice for Medical Attendance

- After long-term effect of high oxygen concentrations, especially at increased pressure: look for late-occurring lung oedema (X-ray examination!),
- Use anticonvulsant (antispasmodic or convulsion-preventing agents), if necessary.

### Annex 1:

## Requirements for Oxygen-carrying Plant Components and Sealing Material in Plants and Plant Components

Material for housings and built-in components of valves as well as metallic sealing material are suitable for oxygen-transporting plants and plant components when they have been selected according to column 2 of the materials table on p. 53.

For further information see also DIN EN 1797:2002-02 “Cryogenic vessels – Gas/ material compatibility“ and DIN EN ISO 11114-1:2017-05 “Gas cylinders – Compatibility of cylinder and valve materials with gas contents – Part 1: Metallic materials“. (121)(124)

In addition, lead, tin as well as copper alloys with an aluminium concentration of < 2.5 % can be used as metallic sealing materials. Alloys containing > 2.5 % aluminium must be treated like aluminium (EIGA IGC Doc 10/09/E). (145)

According to the current state of knowledge the following metallic materials are not suitable: titanium and its alloys, zirconium and its alloys.

ASTM standard G124 describes a test method for investigating the burning behavior of metallic materials in oxygen-enriched atmospheres after artificially initiated ignition. Based on the burning behavior and burning rate determined, the metallic materials examined in this way can be compared with each other. (115)

Investigations of metallic materials according to this standard in stationary gaseous oxygen have shown that an alloying constituent of titanium of < 0.7 % can have significant effects on the burning behavior and burning rate. Therefore, the Federal Institute for Materials Research and Testing (Bundesanstalt für Materialforschung und -prüfung, BAM), recommends that metallic materials containing titanium as an alloy component should be avoided for safety reasons. Regardless of that, the safety suitability must be demonstrated through appropriate testing (e.g., according to ASTM G124). (158)(115)

Pipelines and equipment components specifically designed for the continuous transport of oxygen mixtures where the materials may be exposed to free water, – e.g. with moist oxygen (O<sub>2</sub> + H<sub>2</sub>O) from an electrolysis process with potassium hydroxide (KOH) – may require special precautions such as the use of corrosion-resistant materials or internal coatings. It is important that all internal protective coatings or corrosion inhibitors used are compatible with the oxygen process conditions. Potentially flammable coatings or inhibitors are prohibited unless compatibility has been demonstrated.

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<sup>4</sup> More information on first aid for burns due to ultra-cold material is given by the European Burns Association (EBA), the American Burn Association (ABA) or the International Society for Burn Injuries (ISBI) (155)(156)(157)

Seals that are a combination of various sealing materials and contain components that are combustible in oxygen can be used if their safety-related suitability at the given allowable working overpressures and temperatures has been tested and verified. (85)(158)

Sealing material and valves for liquid and gaseous oxygen with an operating temperature  $< -10\text{ }^{\circ}\text{C}$  must be made of material which is suitable for these temperatures. Statements on this topic can be found in AD 2000-Merkblatt W 10 ("Werkstoffe für tiefe Temperaturen – Eisenwerkstoffe"). (114)

Depending on the installation position of seals or valves and specified requirements the following materials for seals and housings are recommended in the following table:

Overpressure range in bar	Materials for metallic seals/ Materials for housings and built-in components of valves/Materials for housings of plants and plant sections	Use of non-metallic, in oxygen combustible sealing materials for valves	
		Seat	Stuffing box, cover, flange and screw connection
Over 40	Copper, copper alloys with a copper mass percentage of at least 55 %; nickel, nickel wrought alloys with copper	If tested and suitable for the specified temperatures and pressures	If tested and suitable for the specified temperatures and pressures
	High-alloy Cr-Ni steels with a combined mass percentage of Cr and Ni of at least 22 %	Not recommendable	If tested and suitable for the specified temperatures and pressures
	High-alloy Cr-Ni steels with a mass percentage of Cr of at least 22 %	Not recommendable	If tested and suitable for the specified temperatures and pressures
0 to 40	Copper, copper alloys with a copper mass percentage of at least 55 %	If tested and suitable for the specified temperatures and pressures	If tested and suitable for the specified temperatures and pressures
	High-alloy Cr-Ni steels with a combined mass percentage of Cr and Ni of at least 22 %	If tested and suitable for the specified temperatures and pressures	If tested and suitable for the specified temperatures and pressures
	High-alloy Cr-Ni steels with a mass percentage of Cr of at least 22 %	If tested and suitable for the specified temperatures and pressures	If tested and suitable for the specified temperatures and pressures
0 to 16	Grey cast iron, at least to quality EN-GJL-250	If tested and suitable for the specified temperatures and pressures	If tested and suitable for the specified temperatures and pressures
	Spheroidal cast iron, at least to quality EN-GJS-400		
0 to 10	Miscellaneous metallic materials		

## Annex 2: Oxygen Compressors

Each stage of a positive displacement compressor, each cylinder that can individually be shut off of a stage, and each housing of a turbo-driven centrifugal compressor must be provided with a safety device against excessive

pressure. It shall not be possible to disable this safety device by any shut-off equipment. In addition, it must be designed and set up so that the overpressure, for which the particular component is dimensioned, is not exceeded by more than 10 %. This safety device is not required for housings of turbo-driven centrifugal compressors and for individual, non-isolatable stages before the final stage in multi-stage positive displacement compressors, if the design and construction of the compressor enable the same safety level.

The following installations meet the requirements in terms of overpressure safety equipment:

- Safety valves,
- Bursting discs,
- Pressure-controlled devices the efficiency of which can be verified,
- Overflow valves or blow-off devices that allow venting into the suction chamber or into the atmosphere.

The safety devices against excessive pressure become effective at a pressure that is certainly above the allowable final discharge pressure, however, below the design pressure of the compressor. The design pressure is given in the operating instructions.

The same safety level can be achieved by the design and construction of the compressor without using a safety device, e. g. in turbo-driven centrifugal compressors, if their strength are designed for the highest possible discharge pressure depending on unfavourable operating conditions and with the discharge piping closed off.

Omitting the safety devices against excessive pressure at individual stages comes into consideration if the safety device is fitted to the final stage of a multistage compressor and all stages are designed for the same pressure as in the final stage.

Each stage and each individually isolatable cylinder of a positive displacement compressor and each housing of a turbo-driven centrifugal compressor must be fitted with overpressure measuring instruments that can be read at a location where the employees are not in danger.

Closed-circuit coolant systems for compressor components must be fitted with devices which ensure that the design pressure of the coolant system is not exceeded.

The design pressures and the final compression temperatures of each stage and each housing and the associated operating conditions must be given in the instruction manual.

Operating conditions are, e. g. suction pressure, cooling water temperature, pressure ratio.

Concerning dry-running reciprocating piston compressors, diaphragm compressors and turbo-driven centrifugal compressors, it must be ensured that the possibility of fire is limited and in the event of fire the propagation is automatically prevented.

These requirements are met if:

1. A device is present for each stage that triggers a warning signal when the operational compression temperature is exceeded and turns off the drive motor when the allowable compression temperature specified by the manufacturer is exceeded,
2. A non-return valve is present in the discharge line as close as possible to the compressor and, when an inlet pressure (overpressure) > 1 bar is on the suction side, an additional quick-acting shut-off device is present that automatically closes when the drive is turned off,
3. The valve plates are manufactured unnotched, as far as possible. It can be advisable to arrange temperature sensors to detect valve plate breakages promptly. The running time of the valves must be adapted to operational and plant conditions,
4. The speed is restricted to  $750 \text{ min}^{-1}$  in order to prevent a high number of valve knocking,
5. The maximum final pressure is 40 bar(g) at contacting (stuffing-box) packings and labyrinth (stuffing-box) packings,
6. The piston guide in a dry-running reciprocating piston compressor with carbon or plastic rings is so designed that tarnish on the piston body or the tension spring for the sealing elements and the piston rod at the

stuffing box chamber is prevented. The guide rings of the piston must be checked or replaced at the intervals specified by the manufacturer,

7. The pistons or the piston skirts of labyrinth reciprocating piston compressors are made of materials that adequately dissipate the frictional heat, e. g. copper alloys,
8. Diaphragm compressors are operating with a specific oil, e. g. based on polychlorotrifluoroethene (CAS No. 9002-83-9), which does not react on oxygen,
9. In turbo-driven centrifugal compressors with a final discharge pressure (limiting pump pressure) of max. 2 bar
  - a. the labyrinths are made of materials that deform easily during rubbing and dissipate the generated heat efficiently
  - b. it is ensured, even in the case of a bearing damage, that the compressor can come to rest in a safe manner,
10. In turbo-driven centrifugal compressors with a final discharge pressure (limiting pump pressure) > 2 bar overpressure there is in addition a device after each exit from the housing or before each entry into a cooler which
  - triggers a warning signal if the operating compressing temperature is exceeded,
  - immediately shuts down the drive before the final compressor temperature exceeds the value allowed by the manufacturer,
  - automatically stops the oxygen supply and discharge,
  - opens the pressure relief valves.

For more information on turbo-driven centrifugal processors see also EIGA Doc 27/23 "Centrifugal compressors for oxygen service". Information on reciprocating piston processors is given in EIGA Doc 10/17 "Reciprocating compressors for oxygen service". (147)(145)

Suction and discharge valves for reciprocating piston compressors or diaphragm compressors must have been tested as a correctly functioning assembly before being installed. The type of valve check to be made must comply with the manufacturer's instructions.

Valves and valve clusters of reciprocating piston compressors or diaphragm compressors must be so constructed that an incorrect installation is not possible. The interchange of suction and discharge valves is an example of an incorrect installation. This can result in a complete rupture of the compressor casing. The associated fixing elements such as bell-shaped tops and covers are part of the valve unit.

## Materials

Materials for piston rings, collars and stuffing-box packing that contain combustible components shall only be used when they have been tested by a testing institution and found to be suitable for use under the operating conditions. The Federal Institute for Materials Research and Testing (BAM), for example, carries out such tests. (158)

The test ensures that only materials with combustible components are used which are expected not to react with oxygen under the prevailing operating conditions. The danger of such a reaction is not present in water-lubricated oxygen compressors, if the surfaces of the materials are permanently wetted by lubricating water.

All parts of water-lubricated reciprocating piston compressors that come in contact with oxygen-saturated lubricating water must consist of materials which are very difficult to ignite and corrosion-resistant.

Copper, copper alloys and stainless steel have proved themselves as very difficult to ignite and corrosion-resistant materials. These materials own at least two of the following properties:

- high ignition temperature,
- high thermal conductivity,

- high specific thermal capacity,
- low heat of combustion.

The requirements placed on the materials do not refer to the compressor parts situated outside the regions which are in contact with compressed oxygen, as the corrosion products generated here cannot give rise to ignition.

The material selection for the reciprocating piston compressor must be performed according to the table of sealing material and housing material given in Annex 1 herein.

### **Special Protective Measures for Turbo-driven Centrifugal Processors and Dry-running Reciprocating Piston Compressors**

Turbo-driven centrifugal processors, turboblowers and dry-running reciprocating piston compressors must be shielded in operation to protect employees in the case of fire.

Protective measures according to Section 5.10.2 herein are not required for:

1. Turbo-driven centrifugal processors with a final discharge pressure  $\leq 1$  bar overpressure,
2. Water-lubricated reciprocating piston compressors and vacuum pumps,
3. Compressors which are lubricated by a water/glycerine mixture.

See also Annex 3 herein, EIGA Doc 27/23 and EIGA Doc 10/17. (147)(145)

### **Water-lubricated Reciprocating Piston Compressors**

Water-lubricated reciprocating piston compressors must be provided with an installation which guarantees a constant supply of lubricating water. Moreover, these compressors must be designed so that water hammers cannot occur.

The compressors must only be lubricated by distilled water or water which has been completely demineralised otherwise. The lubricating water must not contain any foreign substances, e. g. oil or grease. Cups and sleeves must not be greased.

Notwithstanding Section 5.10.2 compressors the engine output of which does not exceed 4 kW and final discharge pressure (overpressure) of which is  $< 330$  bar can be lubricated by a water/glycerine mixture at a ratio of 4:1.

Such compressors are called oxygen transfer pumps.

## **Annex 3: Shielding**

Examples of shielding for oxygen compressors according to Section 5.10.2 herein. Bold lines depict the shielding.

Figure 3: Example of a shielding for an oxygen reciprocating piston compressor

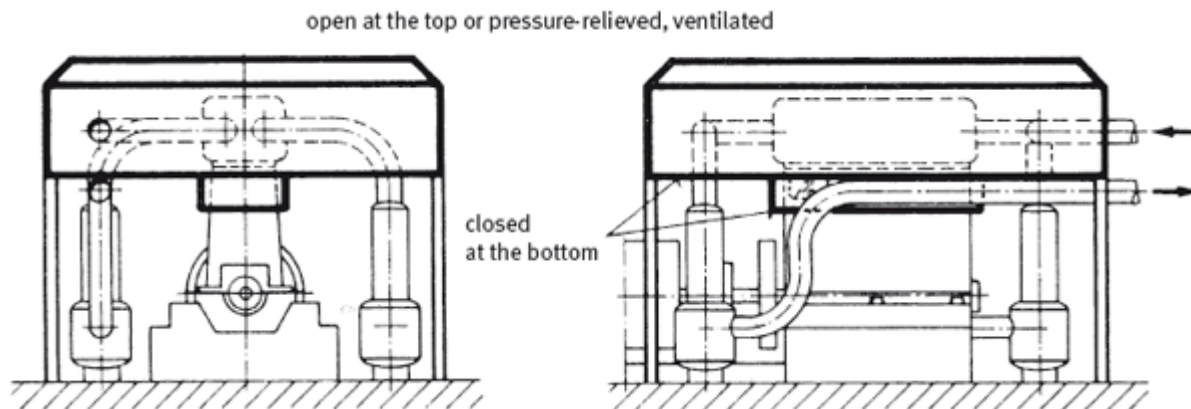


Figure 4: Example of a shielding for an oxygen reciprocating piston compressor

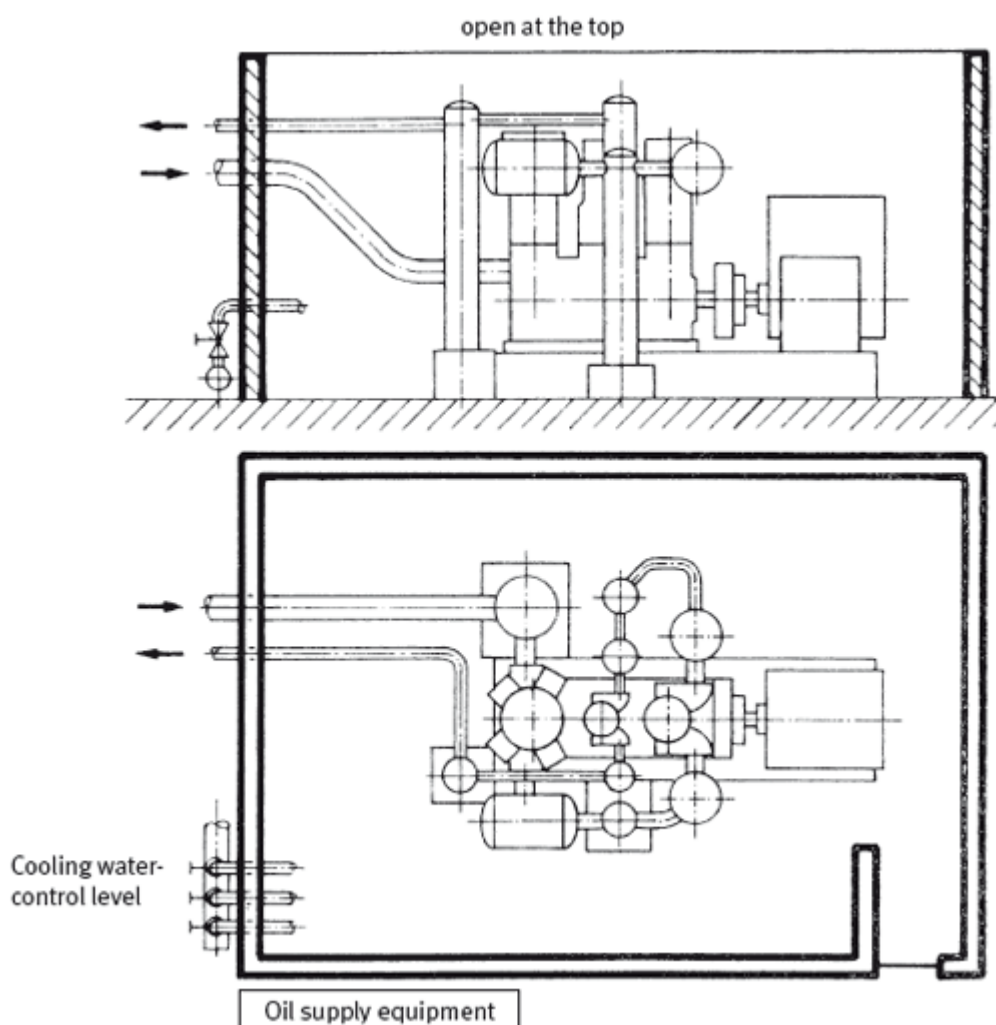




Figure 5: Example of a shielding for an oxygen reciprocating piston compressor

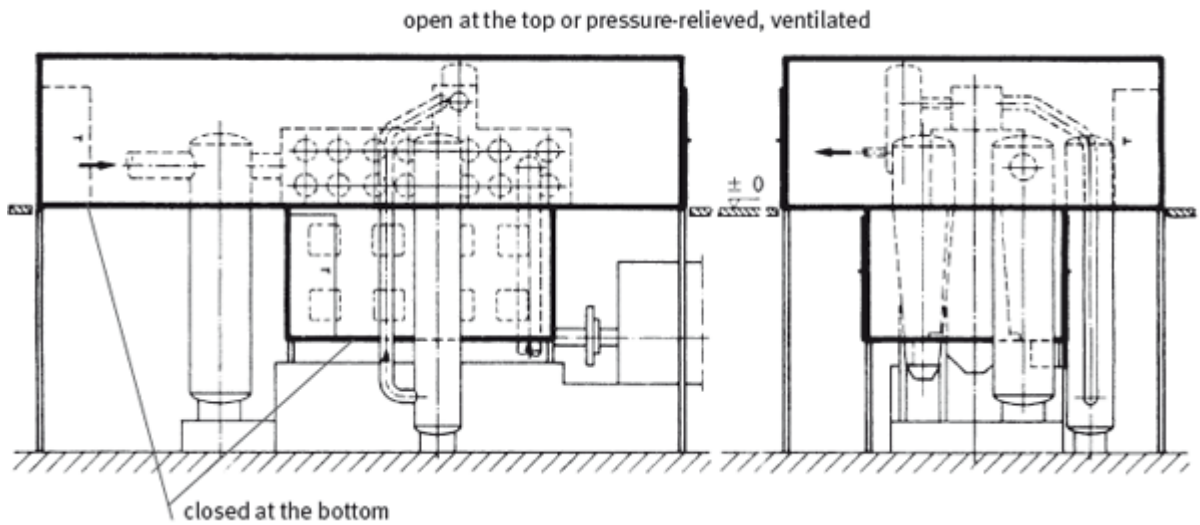


Figure 6: Example of a shielding for a turbo-driven oxygen compressor

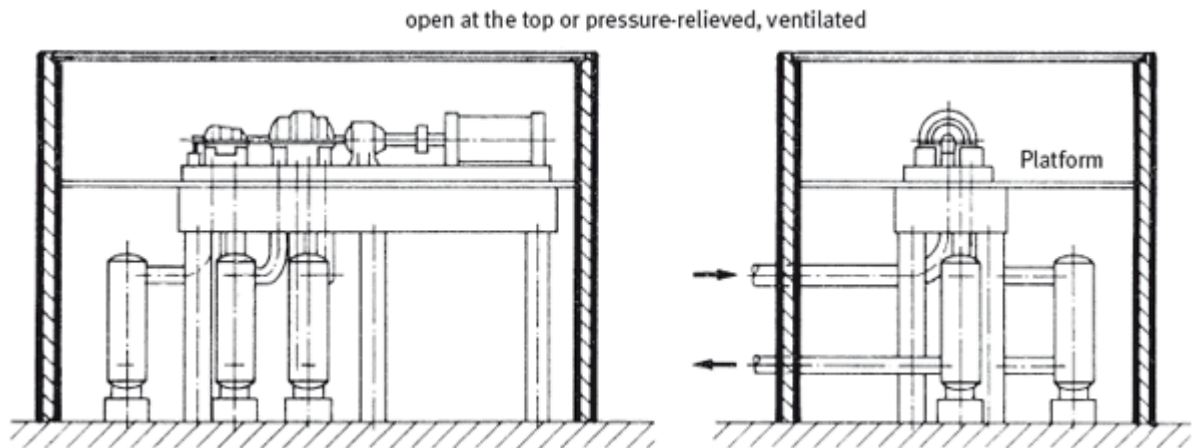
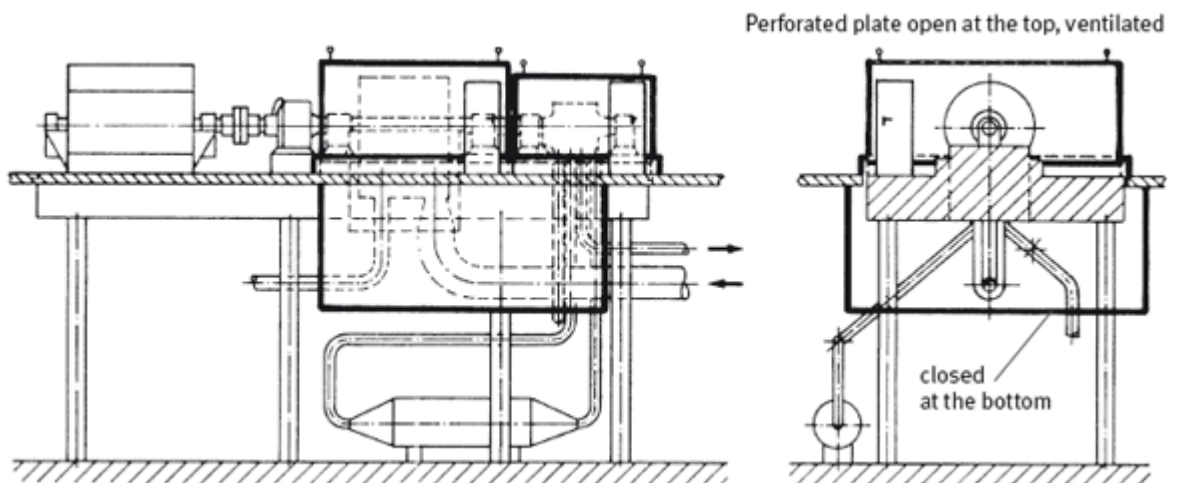


Figure 7: Example of a shielding for a turbo-driven oxygen compressor



## Bibliography

Laws, ordinances, and legal text of the Accident Prevention Regulations are **binding legal standards**. Deviations require permission of the competent authority and the competent Accident Insurance Institution (e.g. Berufsgenossenschaft or Unfallkasse). Issuing a special dispensation requires compensation measures at the same safety level at least.

Deviations from the technical rules for regulations, implementation instructions for accident prevention regulations (DGUV regulations) and DGUV rules are permitted if it is documented in the risk assessment that the same level of safety can be achieved by other means.

DGUV information, information sheets and DIN/VDE standards are not binding legal standards. They are regarded as important assessment standards and rules of technology from which deviations are possible if the same level of safety can be achieved by other means.

### Sources of Information on the Internet

The publications of the BG RCI as well as an extensive part of the state regulations and rules and those of the statutory accident insurance institutions (around 1700 titles) are available in the BG RCI's compendium of occupational safety and health. There is a charge for using the compendium on the Internet. A free, time-limited trial access is offered.

For further information see [www.kompendium-as.de](http://www.kompendium-as.de).

For detailed information on BG RCI publications and media and to order, see [medienshop.bgrci.de](http://medienshop.bgrci.de).

Numerous leaflets, annexes, and forms from leaflets and DGUV rules as well as supplementary work aids are available free of charge in the Prevention Download Center at [downloadcenter.bgrci.de](http://downloadcenter.bgrci.de).

Accident prevention regulations, DGUV rules, DGUV principles and lots of DGUV information can be found on the homepage of the German Social Accident Insurance (DGUV) at [publikationen.dguv.de](http://publikationen.dguv.de).

## 1. EU Publications in the Official Journal of the European Union

Supply Source: Bundesanzeiger-Verlag, Postfach 10 05 34, D-50445 Köln.  
Free Download at <http://eur-lex.europa.eu/de/index.htm>

- (1) Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC
- (2) Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006
- (3) Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives
- (4) Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment Text with EEA relevance

## 2. Laws, Ordinances, Technical Rules

Please note: Whenever an English translation of a publication is available, this version is cited here. However, it must be bear in mind that only the German version is legally binding.

Supply Source: Bookshops

Free download at [www.gesetze-im-internet.de](http://www.gesetze-im-internet.de) (Gesetze und Verordnungen) or [www.baua.de](http://www.baua.de) (Technical Rules)

- (5) Act on the Implementation of Measures of Occupational Safety and Health to Encourage Improvements in the Safety and Health Protection of Workers at Work (Arbeitsschutzgesetz – ArbSchG)
- (6) Occupational Workplace Regulations (Arbeitsstättenverordnung – ArbStättV) with Workplace Guidelines (Technischen Regeln für Arbeitsstätten – ASR), in particular:
  - (7) ASR A1.3: Sicherheits- und Gesundheitsschutzkennzeichnung
  - (8) ASR A2.2: Maßnahmen gegen Brände
  - (9) ASR A2.3: Fluchtwege und Notausgänge, Flucht- und Rettungsplan
  - (10) ASR A3.6: Lüftung
- (11) Ordinance on Hazardous Substances (Gefahrstoffverordnung – GefStoffV) with Technical Rules for Hazardous Substances (TRGS), in particular:
  - (12) TRGS 201: Einstufung und Kennzeichnung bei Tätigkeiten mit Gefahrstoffen
  - (13) TRGS 400: Risk Assessment for Activities involving Hazardous Substances
  - (14) TRGS 402: Identification and Assessment of the Risks from Activities involving Hazardous Substances: Inhalation Exposure
  - (15) TRGS 407: Tätigkeiten mit Gasen – Gefährdungsbeurteilung
  - (16) TRGS 460: Recommended Course of Action for Determining the State of the Art
  - (17) TRGS 500: Schutzmaßnahmen
  - (18) TRGS 507: Oberflächenbehandlung in Räumen und Behältern
  - (19) TRGS 510: Storage of Hazardous Substances in non-stationary Containers
  - (20) TRGS 521: Demolition, Reconstruction and Maintenance Work with Biopersistent Mineral Wools
  - (21) TRGS 526: Laboratorien
  - (22) TRGS 555: Working Instruction and Information for Workers

- (23) TRGS 600: Substitution
- (24) TRGS 720: Gefährliche explosionsfähige Gemische – Allgemeines
- (25) TRGS 721: Gefährliche explosionsfähige Gemische – Beurteilung der Explosionsgefährdung
- (26) TRGS 722: Vermeidung oder Einschränkung gefährlicher explosionsfähiger Gemische
- (27) TRGS 723: Gefährliche explosionsfähige Gemische – Vermeidung der Entzündung gefährlicher explosionsfähiger Gemische
- (28) TRGS 724: Gefährliche explosionsfähige Gemische – Maßnahmen des konstruktiven Explosionsschutzes, welche die Auswirkung einer Explosion auf ein unbedenkliches Maß beschränken
- (29) TRGS 725: Gefährliche, explosionsfähige Gemische – Mess-, Steuer- und Regeleinrichtungen im Rahmen von Explosionsschutzmaßnahmen
- (30) TRGS 727: Vermeidung von Zündgefahren infolge elektrostatischer Aufladungen
- (31) TRGS 745/TRBS 3145: Ortsbewegliche Druckgasbehälter – Füllen, Bereithalten, innerbetriebliche Beförderung, Entleeren
- (32) TRGS 746/TRBS 3146: Ortsfeste Druckanlagen für Gase
- (33) TRGS 800: Brandschutzmaßnahmen
- (34) Verordnung über Sicherheit und Gesundheitsschutz bei der Verwendung von Arbeitsmitteln (Betriebssicherheitsverordnung – BetrSichV) mit Technischen Regeln für Betriebssicherheit (TRBS), insbesondere
- (35) TRBS 1111: Gefährdungsbeurteilung
- (36) TRBS 1112: Instandhaltung
- (37) TRBS 1112 Teil 1: Explosionsgefährdungen bei und durch Instandhaltungsarbeiten – Beurteilungen und Schutzmaßnahmen
- (38) TRBS 1115: Sicherheitsrelevante Mess-, Steuer- und Regeleinrichtungen
- (39) TRBS 1116: Qualifikation, Unterweisung und Beauftragung von Beschäftigten für die sichere Verwendung von Arbeitsmitteln
- (40) TRBS 1201: Prüfungen von Arbeitsmitteln und überwachungsbedürftigen Anlagen
- (41) TRBS 1201 Teil 2: Prüfungen und Kontrollen bei Gefährdungen durch Dampf und Druck
- (42) TRBS 1201 Teil 3: Instandsetzung an Geräten, Schutzsystemen, Sicherheits-, Kontroll- und Regelvorrichtungen im Sinne der Richtlinie 2014/34/EU

- (43) TRBS 1203: Zur Prüfung befähigte Personen
- (44) TRBS 2141: Gefährdungen durch Dampf und Druck
- (45) TRBS 3145/TRGS 745: Ortsbewegliche Druckgasbehälter – Füllen, Bereithalten, innerbetriebliche Beförderung, Entleeren
- (46) TRBS 3146/TRGS 746: Ortsfeste Druckanlagen für Gase
- (47) Gesetz zum Schutz vor gefährlichen Stoffen (Chemikaliengesetz – ChemG)
- (48) Gesetz zum Schutz der arbeitenden Jugend (Jugendarbeitsschutzgesetz – JArbSchG)
- (49) Gesetz zum Schutz von Müttern bei der Arbeit, in der Ausbildung und im Studium (Mutterschutzgesetz – MuSchG)
- (50) Regel des Ausschusses für Mutterschutz, Nr. MuSchR 10.1.01, 2023: Gefährdungsbeurteilung
- (51) Gesetz zum Schutz vor schädlichen Umwelteinwirkungen durch Luftverunreinigungen, Geräusche, Erschütterungen und ähnliche Vorgänge (Bundes-Immissionsschutzgesetz – BImSchG) mit hierzu erlassenen Verordnungen, insbesondere
- (52) Zweite Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes (Verordnung zur Emissionsbegrenzung von leichtflüchtigen halogenierten organischen Verbindungen – 2. BImSchV)
- (53) Zwölfte Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes (Störfall-Verordnung – 12. BImSchV)
- (54) 31. Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes (Verordnung zur Begrenzung der Emissionen flüchtiger organischer Verbindungen bei der Verwendung organischer Lösemittel in bestimmten Anlagen – 31. BImSchV)
- (55) Verordnung über das Europäische Abfallverzeichnis (Abfallverzeichnis-Verordnung – AVV)
- (56) Gesetz zur Förderung der Kreislaufwirtschaft und Sicherung der umweltverträglichen Bewirtschaftung von Abfällen (Kreislaufwirtschaftsgesetz – KrWG)
- (57) Elfte Verordnung zum Produktsicherheitsgesetz (Explosionsschutzprodukteverordnung – 11. ProdSV)
- (58) Muster-Richtlinie über den baulichen Brandschutz im Industriebau (Muster-Industriebau-Richtlinie – MIndBauRL)
- (59) Verordnung über die innerstaatliche und grenzüberschreitende Beförderung gefährlicher Güter auf der Straße, mit Eisenbahnen und auf Binnengewässern (Gefahrgutverordnung Straße, Eisenbahn und Binnenschifffahrt – GGVSEB)
- (60) Accord européen relatif au transport international des marchandises Dangereuses par Route (ADR); deutscher Titel: Europäische Übereinkommen über die internationale Beförderung gefährlicher Güter auf der Straße

- (61) Règlement International concernant le transport des marchandises Dangereuses chemins de fer (RID); deutscher Titel: Internationale Ordnung für die Beförderung gefährlicher Güter mit der Eisenbahn
- (62) Accord européen relatif au transport international des marchandises dangereuses par voie de navigation intérieure Rhin; deutscher Titel: Europäisches Übereinkommen über die Beförderung gefährlicher Güter auf dem Rhein
- (63) Verordnung über die Beförderung gefährlicher Güter mit Seeschiffen (Gefahrgutverordnung See – GGVSee)
- (64) International Maritime Dangerous Goods Code (IMDG-Code); deutscher Titel: Internationaler Code für die Beförderung gefährlicher Güter mit Seeschiffen

### **3. Accident Prevention Regulations (DGUV Regulations), DGUV Rules, DGUV Principles, DGUV Information, Codes of Practice and other publications of the Accident Insurance Institutions**

Supply Source: Berufsgenossenschaft Rohstoffe und chemische Industrie, Postfach 10 14 80, D-69004 Heidelberg, [medienshop.bgrci.de](http://medienshop.bgrci.de) or Jedermann-Verlag GmbH, Postfach 10 31 40, D-69021 Heidelberg, [www.jedermann.de](http://www.jedermann.de), [verkauf@jedermann.de](mailto:verkauf@jedermann.de)

Member companies of BG RCI may obtain the listed papers free of charge (until the next source is cited) in quantities commensurate to the size of the company. Some publications are available at [downloadcenter.bgrci.de](http://downloadcenter.bgrci.de) (free download).

- (65) DGUV Regulation 1: Principles of Prevention
- (66) DGUV Information 213-851: Working Safely in Laboratories – Basic Principles and Guidelines
- (67) Merkblatt A 008: Persönliche Schutzausrüstungen
- (68) Merkblatt A 009: Zusammenarbeit im Betrieb – Sicherheitstechnisches Koordinieren
- (69) DGUV Information 213-051: Betriebsanweisungen für Tätigkeiten mit Gefahrstoffen (Merkblatt A 010)
- (70) DGUV Information 213-052: Beförderung gefährlicher Güter (Merkblatt A 013)
- (71) DGUV Information 213-012: Gefahrgutbeförderung in Pkw und in Kleintransportern (Merkblatt A 014)
- (72) Code of Practice A 016e: Risk Assessment – Seven Steps to the Goal
- (73) Code of Practice A 017e: Risk Assessment – Hazard Catalogue
- (74) Code of Practice A 017-1e: Responsibility of Managers with regard to Occupational Safety – Hazard-Orientated Key Issues related to Code of Practice A 017e
- (75) Merkblatt A 023: Hand- und Hautschutz

- (76) Merkblatt A 026: Gefährdungsorientiertes Unterweisen – Medien- und Gestaltungsvorschläge nach Gefährdungsfaktoren
- (77) Merkblatt A 027: Mutterschutz im Betrieb
- (78) Merkblatt A 039-1: Big Points im Arbeitsschutz – 10 Punkte, auf die Sie als Führungskraft unbedingt achten müssen
- (79) kurz & bündig KB 016: Sauerstoff – Eigenschaften, Gefährdungen und sicherer Umgang
- (80) kurz & bündig KB 023: Tätigkeiten mit Gefahrstoffen – Einführung, Grundpflichten, Gefährdungsbeurteilung
- (81) DGUV Information 213-070: Säuren und Laugen (Merkblatt M 004)
- (82) DGUV Information 213-072: Lösemittel (Merkblatt M 017)
- (83) Merkblatt M 020: Chlor
- (84) DGUV Information 213-073: Sauerstoff (Merkblatt M 034)
- (85) DGUV Information 213-075: Liste der nichtmetallischen Materialien zu Merkblatt M 034 „Sauerstoff“ (DGUV Information 213-073)/List of nonmetallic materials supporting document to code of practice M 034e „Oxygen“ (Merkblatt M 034-1)
- (86) Merkblatt M 040: Chlorkohlenwasserstoffe
- (87) DGUV Information 213-079: Tätigkeiten mit Gefahrstoffen (Merkblatt M 050)
- (88) DGUV Information 213-080: Arbeitsschutzmaßnahmen bei Tätigkeiten mit Gefahrstoffen (Merkblatt M 053)
- (89) DGUV Information 213-084: Lagerung von Gefahrstoffen (Merkblatt M 062)
- (90) DGUV Information 213-085: Lagerung von Gefahrstoffen – Antworten auf häufig gestellte Fragen (Merkblatt M 063)
- (91) DGUV Information 213-053: Schlauchleitungen – Sicherer Einsatz (Merkblatt T 002)
- (92) DGUV Information 213-055: Retten aus Behältern, Silos und engen Räumen (Merkblatt T 010)
- (93) Code of Practice T 021e: Gas Detection Equipment for Toxic Gases/Vapours and Oxygen: Use and Operation
- (94) DGUV Information 213-062: Druckprüfungen von Druckbehältern und Rohrleitungen – Flüssigkeitsdruckprüfungen, Gasdruckprüfungen (Merkblatt T 039)
- (95) Praxishilfe-Ordner: Arbeitsschutz mit System

- (96) Praxishilfe-Ordner: Aus Arbeitsunfällen lernen
  
- (97) Sicherheitskurzgespräche
  - SKG 004: Umgang mit Druckgasflaschen im Labor
  - SKG 005: Umgang mit Druckgasflaschen im Betrieb
  - SKG 006: Umgang mit Druckgasflaschen in Betriebslagern
  - SKG 007: Verwendung von Sauerstoff
  - SKG 008: Erstickungsgefahr durch Gase
  - SKG 009: Erste Hilfe
  
- Supply Source: Deutsche Gesetzliche Unfallversicherung e. V., Glinkastraße 40, D-10117 Berlin  
Free Download at [publikationen.dguv.de](http://publikationen.dguv.de)
  
- (98) DGUV Regulation 1: Principles of Prevention
  
- (99) DGUV Regel 109-002: Arbeitsplatzlüftung – Lufttechnische Maßnahmen
  
- (100) DGUV Regel 109-010: Einrichtungen zum Reinigen von Werkstücken mit Lösemitteln
  
- (101) DGUV Regel 109-601: Branche Erzeugung von Roheisen und Stahl
  
- (102) DGUV Regel 112-189: Benutzung von Schutzkleidung
  
- (103) DGUV Regel 112-190: Benutzung von Atemschutzgeräten
  
- (104) DGUV Regel 112-192: Benutzung von Augen- und Gesichtsschutz
  
- (105) DGUV Regel 112-195: Benutzung von Schutzhandschuhen
  
- (106) DGUV Regel 113-001: Explosionsschutz-Regeln (EX-RL)
  
- (107) DGUV Regel 113-004: Arbeiten in Behältern, Silos und engen Räumen
  
- (108) DGUV Information 204-005/-003: Aushang „First Aid/Erste Hilfe“
  
- (109) DGUV Information 204-006: Anleitung zur Ersten Hilfe
  
- (110) DGUV Information 205-001: Arbeitssicherheit durch vorbeugenden Brandschutz
  
- (111) DGUV Information 205-006: Working in oxygen-reduced atmospheres
  
- (112) DGUV Grundsatz 313-002: Auswahl, Ausbildung und Beauftragung von Fachkundigen zum Freimessen nach DGUV Regel 113-004
  
- (113) DGUV Grundsatz 313-003: Grundanforderungen an spezifische Fortbildungsmaßnahmen als Bestandteil der Fachkunde zur Durchführung der Gefährdungsbeurteilung bei Tätigkeiten mit Gefahrstoffen



## 4. Standards

Supply Source: Beuth Verlag GmbH, Burggrafstraße 6, D-10787 Berlin, [www.beuth.de](http://www.beuth.de)

- (114) AD-2000-Codes of Practice, Series W, in particular  
AD 2000-Merkblatt W 10:2023-05: Werkstoffe für tiefe Temperaturen – Eisenwerkstoffe
  
- (115) ASTM G 124:2018: Bestimmung des Verbrennungsverhaltens von metallischen Werkstoffen in sauerstoffangereicherten Atmosphären
  
- (116) DIN 4102-1:1998-05: Fire behaviour of building materials and building components – Part 1: Building materials; concepts, requirements and tests
  
- (117) DIN 4102-4:2016-05: Brandverhalten von Baustoffen und Bauteilen – Teil 4: Zusammenstellung und Anwendung klassifizierter Baustoffe, Bauteile und Sonderbauteile
  
- (118) DIN 4844-2:2021-11: Graphische Symbole – Sicherheitsfarben und Sicherheitszeichen – Teil 2: Registrierte Sicherheitszeichen
  
- (119) DIN 8541-3:2022-02: Schläuche für Schweißen, Schneiden und verwandte Verfahren – Teil 3; Sauerstoffschläuche mit und ohne Ummantelung für besondere Anforderungen; Sicherheitstechnische Anforderungen und Prüfung
  
- (120) DIN EN 166:2002-04: Personal eye protection – Specification
  
- (121) DIN EN 1797:2002-02: Cryogenic vessels – Gas/materials compatibility
  
- (122) DIN EN 14470-2:2006-11: Fire safety storage cabinets – Part 2: Safety cabinets for pressurised gas cylinders
  
- (123) DIN EN ISO 10156:2017-12: Gas cylinders – Gases and gas mixtures – Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets (ISO 10156:2017)
  
- (124) DIN EN ISO 11114-1:2024-01: Gas cylinders – Compatibility of cylinder and valve materials with gas contents - Part 1: Metallic materials
  
- (125) DIN EN ISO 11611:2015-11: Protective clothing for use in welding and allied processes
  
- (126) DIN EN ISO 11612:2015-11: Protective clothing – Clothing to protect against heat and flame – Minimum performance requirements
  
- (127) DIN EN ISO 23208:2020-11: Cryogenic vessels – Cleanliness for cryogenic service
  
- (128) DIN EN ISO 24490:2016-08: Cryogenic vessels – Pumps for cryogenic service

## 6. Other Literature

Supply Source: Book Trade

- (129) Ullmanns Encyclopedia of Industrial Chemistry, Volume A 18, 1991, VCH Verlagsgesellschaft, Weinheim, ISBN 3-527-20118-1
- (130) Ullmanns Enzyklopädie der technischen Chemie, Bd. 20, 1981, Verlag Chemie, Weinheim, ISBN 3-527-20020-7
- (131) M. A. Benning (Ed.), Flammability and Sensitivity of Materials in Oxygen-Enriched Atmospheres, Second Volume, ASTM STP 910, S. 204–211 (1986), American Society for Testing and Materials (ASTM)
- (132) CRC Handbook of Chemistry and Physics, 96th Edition, 2015, CRC Press, Boca Raton, ISBN 978-1-4822-6096-0
- (133) AGI-Arbeitsblatt Q118: Dämmarbeiten an Luftzerlegungsanlagen; Arbeitsgemeinschaft Industriebau e.V. (AGI), Neuhofstraße 9, 64625 Bensheim, [www.agi-online.de](http://www.agi-online.de)
- (134) DVS-Merkblatt 0221: Gasversorgungsanlagen zum Schweißen, Schneiden und verwandter Verfahren – Empfehlungen für Prüffristen und die Gefährdungsbeurteilung; DVS – Deutscher Verband für Schweißen und verwandte Verfahren e.V.; Aachener Straße 172, D-40223 Düsseldorf, [www.die-verbindungs-spezialisten.de](http://www.die-verbindungs-spezialisten.de)
- (135) W. Wegener, Untersuchungen über die sicherheitstechnisch zulässige Strömungsgeschwindigkeit von Sauerstoff in Stahlrohrleitungen, Stahl und Eisen, 84, 1964

## 6. Online-Databases and Information from the Internet

- (136) Information system on hazardous chemicals "GisChem" of BG RCI and BGHM at [www.gischem.de](http://www.gischem.de), including components like "GisChem-Interaktiv" to create individual operational instructions, "Gefahrstoffverzeichnis" or "Gemischrechner" for the classification of mixtures according to the CLP-Regulation.
- (137) Information portal "Gase unter Druck" of BG RCI at [www.bgrci.de/gase-unter-druck](http://www.bgrci.de/gase-unter-druck)
- (138) Downloadcenter der BG RCI, [downloadcenter.bgrci.de](http://downloadcenter.bgrci.de)
- (139) Explosion Protection Portal of BG RCI at [exinfo.de](http://exinfo.de)
- (140) GefDok KMU, a software for the documentation of risk assessments in small and medium-sized enterprises (SME), free download at [downloadcenter.bgrci.de](http://downloadcenter.bgrci.de)
- (141) GESTIS – Information system on hazardous substances of DGUV at [www.dguv.de/ifa/GESTIS](http://www.dguv.de/ifa/GESTIS)
- (142) "Länderausschuss für Arbeitsschutz und Sicherheitstechnik" at [lasi-info.com](http://lasi-info.com)

- (143) Industriegaseverband e.V. (IGV), Französische Straße 8, 10117 Berlin [www.industriegaseverband.de](http://www.industriegaseverband.de)  
Codes of Practice:
- Sauerstoffanreicherung
  - Umgang mit Sauerstoff im medizinischen Bereich
  - Richtiges Verhalten bei Austritt von Sauerstoff oder Stickstoff aus nicht kennzeichnungspflichtigen Gefahrguttransporten
- (144) European Industrial Gases Association, Avenue des Arts 3-5, B-1210 Brüssel, [www.eiga.eu](http://www.eiga.eu)  
→ Publications → EIGA Documents; particularly:
- (145) Doc 10/17: Reciprocating compressors for oxygen service. Code of practice
- (146) Doc 13/20: Oxygen pipeline and piping systems
- (147) Doc 27/23: Centrifugal compressors for oxygen service
- (148) Doc 33/18: Cleaning of equipment for oxygen service.
- (149) Doc 65/20: Safe operation of reboilers/condensers in air separation units
- (150) Doc 133/22: Cryogenic Vaporisation Systems – Prevention of Brittle Fracture of Equipment and Piping
- (151) Doc 148/19: Stationary Electric-Motor-Driven Centrifugal Liquid Oxygen Pumps
- (152) Doc 154/16: Safe location of oxygen and inert gas vents
- (153) Doc 159/21: Reciprocating cryogenic pumps and pump installations for oxygen, argon, and nitrogen
- (154) E-Learning „Sauerstoff“ [www.eiga.eu/elearning-courses/oxygen-elearning-german-course/](http://www.eiga.eu/elearning-courses/oxygen-elearning-german-course/)
- (155) European Burns Association (EBA), [www.euroburn.org](http://www.euroburn.org)
- (156) American Burn Association (ABA), [www.ameriburn.org](http://www.ameriburn.org)
- (157) International Society for Burn Injuries (ISBI), [www.worldburn.org](http://www.worldburn.org)
- (158) Bundesanstalt für Materialforschung und -prüfung (BAM), Unter den Eichen 87, 12205 Berlin, [www.bam.de](http://www.bam.de)

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**Edition 6/2024** (replaces the English edition 9/2018)

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Prävention, Grundsatzfragen und Information, Medien  
Postfach 10 14 80, 69004 Heidelberg
- E-Mail: [medien@bgrci.de](mailto:medien@bgrci.de)
- Contact form: [www.bgrci.de/kontakt-schriften](https://www.bgrci.de/kontakt-schriften)