

Why is “oil and grease-free” so important in oxygen systems?

1. Foreword

Oxygen – this vital gas is more complex in its use than one would imagine when considering how matter-of-factly we inhale and exhale every day. Industry, in particular, is constantly confronted with new challenges in the handling of oxygen.

SERTO AG, a manufacturer of tube connecting elements and valves, meets these upmarket demands and has developed a special cleaning process for this purpose. This technical bulletin is a summary of intensive research in the subject matter. It addresses the properties of oxygen as a gas and focuses on the essential points of working with this gas.

2. Oxygen (O₂)

Oxygen is found in large quantities in nature. Approximately half of the Earth's mass is made of chemically combined oxygen. Atmospheric air contains about 21% oxygen (oxygenium). The chemical element oxygen is a colourless and odourless gas. Pure oxygen does not burn; it is, however, absolutely necessary for combustion and breathing. Oxygen bonds with all elements. When oxygen bonds with another substance, this is referred to as oxidation. Combustion is an oxidation. If this process is rapid, a flame occurs; if it is sudden, we call it an explosion. Most substances burn fast and intensely with compressed or pure oxygen. This is also true of substances which cannot be combusted in atmospheric air. Some substances react so violently with oxygen that they either combust after igniting or even self-ignite, such as for example oils and greases. The Professional Association of the Chemical Industry has taken issue with this subject matter among other. In their accident prevention guidelines¹ they define oxygen as follows:

- Pure oxygen
- All compounds with a volume content of > 21% oxygen

2.1. Manufacture and application

The cryogenic process used for oxygen recovery was developed over 100 years ago by Carl von Linde and named after him. In this process, air is freed of water vapour, dust and carbon dioxide, compressed, and cooled down to a very low temperature. Subsequently, it is separated into components through distillation (fractionation). At -196°C nitrogen is first to vaporise and nearly pure oxygen remains, which only transforms into the gaseous state at -183°C. Today, other physical processes are also used to separate and clean air gases, for example separation through a membrane or adsorption. In these methods, some elements are adsorbed via a special material while others pass through unhindered.



Air separation unit

source: Linde

¹ Unfallverhütungsvorschrift 62 „Sauerstoff“, Fassung vom 1. Januar 1997 (Accident prevention guideline 62 „Oxygen“, version dated 1 January 1997)

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Oxygen is used in diverse applications. Besides being utilised as a respiratory gas in medicine, aviation and space travel, oxygen is also used in industry mainly as an oxidising agent in combustion processes where high temperatures are needed:

- in metallurgy, for manufacturing pig iron and steel and for refining copper
- in chemical processes, for olefin oxidation, for partial oxidation of coal and heavy oil to create hydrogen and synthetic gases, for the production of sulphuric and nitric acids, of acetylene,...
- in autogenous technology for fusion, cutting, flame treatment, for thermal cutting, e.g. of concrete
- in rocket technology
- in treatment of drinking water and waste water
- for ozone production



Other significant fields of application are measurement technology, fuel cells, semiconductor technology and biological processes.

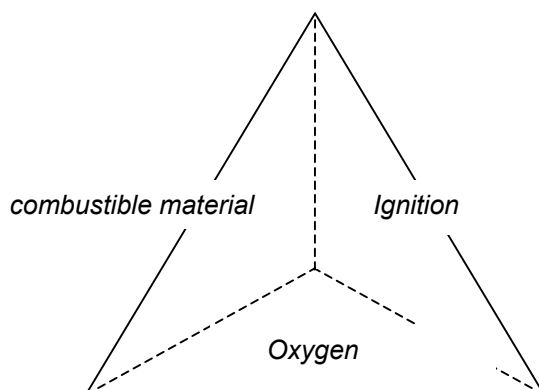


3. Hazards in oxygen systems

The EIGA² examines this subject matter in its IGC 04/00³ documentation – because oxygen is more dangerous than one would think! Even though oxygen itself does not burn, and is actually essential for life, it harbours a high risk potential. Hence, a great deal of caution is required in handling oxygen. Oxygen does not only support combustion, but in its purest form it will cause most known substances to combust rapidly or even suddenly (explosion) when under pressure. It is not possible to detect the presence of high doses of oxygen without technical instruments.

3.1. What is necessary to ignite a fire?

Generally speaking, three elements are necessary: fuel, oxygen and a source of ignition. If one element is missing, there can be no fire.



The fire triangle is a common method used to illustrate

Principally, the higher the oxygen content,

- the greater the risk of an oxygen fire
- the lower the ignition temperature
- the higher the flame temperature and thus the more destructive the fire

² European Industrial Gases Association

³ Fire Hazards of Oxygen and Oxygen-enriched Atmosphere

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3.2. Combustible materials

Basically all materials can burn with oxygen; this also holds true for most metals and metal alloys. Oils and greases consist to a large extent of carbon and are particularly dangerous in oxygen systems since these are highly combustible and explosive. Igniting oils and greases in oxygen plants often leads to a chain reaction, which finally ends in metals melting or burning. Some of the melted material may splatter around, possibly causing oxygen to be emitted which would in turn cause the fire to spread more rapidly.

3.3. Oxygen

Oxygen is inseparable in these systems, i.e. the fuel (tubes, unions, valves or seals) comes unequivocally into contact with oxygen.

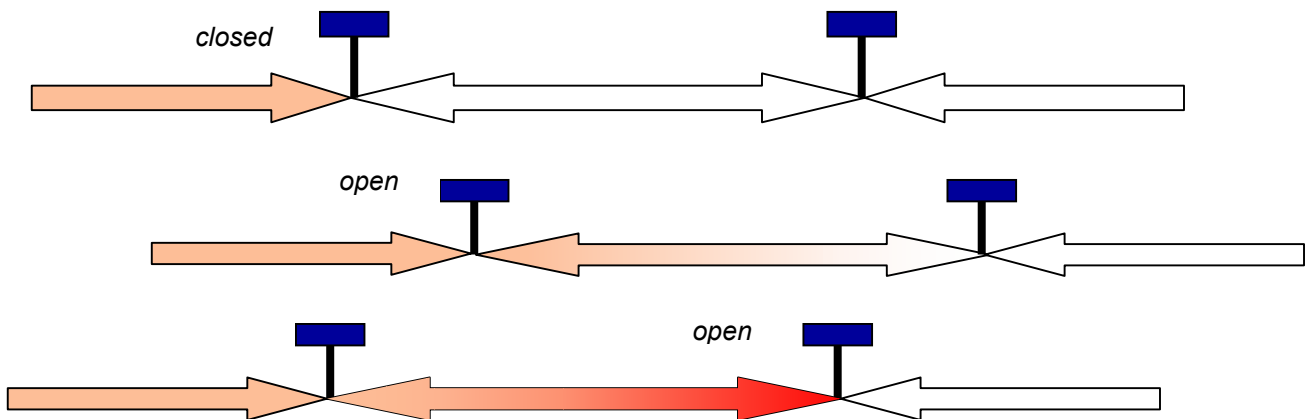
3.4. Source of ignition

In systems that are under pressure, the source of ignition is not as obvious as an open flame or hot surface. The fire may have the following origins:

- friction
- mechanical influences
- electric sparks
- high flow velocity simultaneous with the presence of particles
- heating-up from turbulence
- heating-up from adiabatic compression

Adiabatic compression takes place when oxygen under high pressure is injected abruptly into a system with low pressure. In such instances, the gas can flow at the speed of sound. This situation often occurs with valves and fittings. When a gas collides at great speed with a resistance, the temperature rises very quickly due to adiabatic compression. This is always the case when gases are compressed so fast that no thermal energy can get lost. The general rule is: the higher the initial pressure, the higher the temperature. This circumstance is put to use in the diesel engine. Most often, said resistance is represented by closed valves.

Adiabatic compression



4. Design and materials in oxygen systems

4.1. General

Safety in oxygen systems begins with the construction, respectively the design, of the system. Owing to the risk potential of such systems, it is absolutely necessary to work exclusively with specialists and professionals qualified in this matter. The information contained herein is only a recommendation; the builder is in no way released from consulting a competent and trained professional. The ASTM G88⁴ standard defines a professional as follows: "Qualified professional: person, such as a chemist or engineer, who on the grounds of his or her training and experience knows how to apply physical and chemical principles that occur in the reaction of oxygen with other materials."

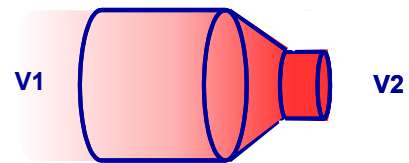
Should there be in such professional in your vicinity, your oxygen supplier can surely be of assistance.

4.2. Risks and hazards in oxygen systems

To increase the safety of oxygen systems and to avoid potential risks, it is important that the possible sources of danger are recognised.

4.3. Flow velocity

The flow velocity determines whether the gas can catch fire or not. At high velocities, particles can self-ignite when colliding with pipes and fittings and thus start a chain reaction. It is therefore essential that there are no high velocities. Sudden transitions from large to small diameters are to be avoided in particular. Abrupt changes in direction or turbulence can also lead to high temperatures, which in turn can cause the gas to ignite. For these reasons, it is important to ensure that fittings, tees and other similar fixtures are not placed too closely to the pressure unit, e.g. the pressure pump.



4.4. Materials

Only flame resistant materials should be used. The alloying composition, the component strength (wall thickness), the temperature, the pressure and the purity of the oxygen are all key elements which influence flammability. If the pressure is under a certain limit⁵, the velocity is no longer a risk as such.

4.5. Adiabatic compression

This can occur, for example, when a valve is opened quickly and oxygen under high pressure hits on a closed valve. To prevent this from happening, it is important that manually operated valves are only opened slowly.

4.6. Cleanliness

The cleanliness of the system and the components is decisive. All reputable institutions, organisations and manufacturers have guidelines, specifications and norms which treat this subject explicitly. Especially noteworthy in this regard is ASTM G93-96.

⁴ Standard Guide for Designing Systems for Oxygen Service

⁵ IGC 13/02 Anhang D

The safety of the system can be improved considerably by the respective design. In one particular instance, a ball valve that was under high pressure on one side was opened accidentally during operation. The gas flowed at high speed into the low pressure area behind it and hit upon a tee. This impact caused the system to ignite, burning the stainless steel tube and the valve.

There are different ways of designing an oxygen system so that oxygen fires can be prevented; it is nevertheless advisable to consult a specialist in each case.

5. Materials

The correct materials selection is extremely important because how and where oxygen fires spread depends greatly on the flame resistance of the materials used. The right materials in the right places can, for example, prevent a potential fire from spreading.

5.1. Metallic materials

Copper-based alloys, such as brass, bronze or copper-nickel alloys, have a long history of use in oxygen systems and are very suitable for such purposes. Stainless steels can also be implemented. The combustion resistance of stainless steel alloys (per DIN 1.4xxx) lies between the copper alloys and C steel alloys. C steel should only be used, if at all, in systems with less than 2 bar operating pressure.

5.2. Non-metallic materials

These are not as suitable for oxygen systems and are usually used only for gaskets, lubricants or valve packing to create a better seal or to reduce friction. According to IGC Doc 13/02⁶, PTFE and FEP are best suited for oxygen applications. Elastomers, such as Kalrez®, Viton®, etc., are also suitable. However, toxic gases may be emitted when burned.

Thread seals are often made of plastics; it is therefore essential that a sealant is selected which is compatible with oxygen. Thread wrapped with PTFE tape has proven very effective in practice.

6. Cleaning and cleanliness

As indicated above, the cleanliness of the components is a very important factor in rendering oxygen systems safe. A system is considered clean when the removal of organic and inorganic contamination has been warranted. The removal of such contamination, for example greases, oils, thread seals, lubricants, shavings, etc., is decisive. Periodic inspection of the system is recommended.

To ensure the necessary degree of cleanliness, all reputable institutions, such as ASTM, CGA, EIGA, NPF, specify that the components (valves, unions, tubes) must be pre-cleaned by the supplier.

6.1. Organic contamination

*Mineral oils and greases are largely composed of carbon compounds. The carbon bonds with many substances, but especially with hydrogen and oxygen. Since carbon oxidises very easily together with oxygen, extremely high temperatures can occur rapidly (to some extent explosively) which again can lead to self-ignition of the materials in its environment and thus to a chain reaction. It is therefore indispensable that all component surfaces which come into contact with oxygen are **oil and grease-free**. For this reason, oils and greases may never be used as lubricants in oxygen systems.*

⁶ Oxygen Pipeline System

7. Cleaning and assembly of system parts and components from SERTO AG in piping systems with enriched oxygen

As a manufacturer of metal-to-metal sealing, radial (dis)mountable, compression ferrule tube unions and valves, we strive to meet the requirements of the market. There are numerous norms and guidelines pertaining to the cleaning of system parts, which demonstrates how important this is. The ASTM⁷ norm G93-96⁸ is dedicated to this subject matter and serves as the basis for the entire cleaning process used at SERTO AG.

7.1. Contamination

In Paragraph 10.3.1 "General conservative target" it is stated: "For the majority of systems, a cleanliness target parameter of ca. 1-5 mg/ft² (11-55mg/m²) or less of undesirable oils and greases is recommended...". SERTO has set a target of 33 mg/m² of non-volatile residual contamination. This corresponds to the cleanliness level B⁹ according to ASTM.

7.2. Cleaning the components

In order to achieve this high level of cleanliness of the surfaces which come into contact with the media, we have developed, in collaboration with specialists, a multi-level process. The components to be cleaned are placed individually in special baskets; this ensures optimal off-flow of the cleansing and rinsing agents. Depending on the material – brass or stainless steel – the components go through a series of alkaline and acid cleaning baths. The SERTO company takes special care that only environmentally friendly substances are used. The parts are rinsed several times, but particularly at the end of the process, in warm DI-ultrasound water baths and then dried with filtered air to warrant a residue-free cleanliness. The selected cleaning process is described in ASTM G131¹⁰. During implementation of the process, the EMPA¹¹ was consulted and the surface cleanliness of the cleaned components was tested by them using diverse methods. These tests are done periodically.



Cleaning station SERTO AG

7.3. Monitoring and control

The process stability is very important, which is why various measures and procedures were defined for this purpose. For example, the quality of the cleansing and rinsing agents is monitored electronically in the entire cleaning system. All the production steps are carried out by specially trained personnel and are documented accordingly. The quality of the surface cleanliness is checked and warranted periodically by means of the test methods contained in ASTM G144¹². Each step in the cleaning process is documented and traceable.

7 American Society for Testing and Materials

8 Standard Practice for Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen-Enriched Environments

9 ASTM 93-96 Kapitel 11.4.3

10 Standard Practice for Cleaning of Materials and Components by Ultrasonic Techniques

11 Eidgenössische Materialprüfungsanstalt (Swiss Federal Materials Testing Institute)

12 Standard Test Method for Determination of Residual Contamination of Materials and Components by Total Carbon Analysis Using a High Temperature Combustion Analyzer

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7.4. Assembly

To make sure that the components are not re-contaminated after cleaning, a separate production and assembly cell, which is directly adjacent to the cleaning system, was set up especially for the assembly of these products. Personnel working in this area must follow strict regulations.

7.5. Lubricants

According to IGC¹³ 13/02, lubricants should be avoided whenever possible. If this is not feasible, a lubricant which has been tested and approved for use in oxygen systems must be used. SERTO uses a lubricant tested and approved for use in oxygen system components by BAM¹⁴. The lubricant was selected so that the normal application upper limits of the products, +200°C and 220 bar, did not need to be reduced.

7.6. Seals

O-rings and other seals are necessary in regulating and check valves. Since these are generally made of non-metallic materials, special attention must be given to these parts. SERTO only uses materials from manufacturers whose products are BAM-approved.

7.7. Testing

The valves are tested in such a way as to prevent re-contamination after function testing.

7.8. Packaging

In order to maintain the cleanliness during transport and storage until the components are used on site, the parts are packaged individually in weld-sealed plastic bags. The bags are specially marked so that the contents can be identified without having to open the bags.

The "oil and grease-free" cleaned and packaged components from SERTO AG, are safe for use with oxygen – provided that all the necessary precautions were taken, especially in the final assembly, so that the components are not re-contaminated. The entire cleaning, assembly and monitoring process is contained in SERTO's own CSO-OX cleaning regulations.

Attention

The content of this technical documentation is intended to make our customers more aware of the dangers involved in handling oxygen. We consider this a service to our customers. For safe, trouble-free operation, the complete system design must be taken into consideration when selecting a product. The system builder and the user are responsible for the functioning of the products, the material compatibility, the respective performance characteristics and application limits as well as adherence to the regulations concerning handling, operation and maintenance. We strongly recommend consulting a specialist in this case. SERTO AG is not a specialist in this field and denies all liability and responsibility.



¹³ Industrial Gas Council

¹⁴ Bundesanstalt für Materialforschung und Prüfung (German Federal Institute for Materials Research and Testing)