

Product Safety Assessment

Gaseous Oxygen

General

Oxygen is the only gas that supports life, and is the second largest component of the atmosphere, comprising 21% by volume. Gaseous oxygen is colorless, odorless, tasteless, and nonflammable. Oxygen will react with nearly all organic materials and metals.

It is a strong oxidizer that combines readily with many materials to form oxides. Oxygen is also necessary to support combustion. Oxygen is non-flammable, but it vigorously accelerates and supports combustion. Equipment used in oxygen service must meet stringent cleaning requirements. Any system must be constructed of materials that are nonreactive with oxygen under the service conditions, and have high ignition temperatures. Vessels should be manufactured to American Society of Mechanical Engineers (ASME), or other applicable codes, and designed to withstand the temperatures and pressures involved.

Applications

Oxygen is a colorless, odorless and tasteless gas that supports life and combustion. All elements, except rare gases, react with oxygen, over a wide range of temperatures, to form oxides. Oxygen is 1.1 times heavier than air and is slightly soluble in water.

Oxygen is present in the atmosphere at a concentration of 21.0%. Oxygen is recovered from air in an Air Separation Unit (ASU) where it is drawn off as a cryogenic liquid at about -298°F. Oxygen can then be distributed as a cryogenic liquid or as a gas in cylinders. Oxygen can also be generated onsite, using various techniques.

The major uses of oxygen are based on its combustion-sustaining, oxidizing and life-supporting attributes. Whether used directly or to enrich combustion air, oxygen is widely used with fuel gases in furnaces, smelters, kilns, welding and metal cutting. Oxygen is used in chemical production as a raw material and in pulp manufacturing as a bleaching agent. Most importantly, oxygen is used for medical reasons to save and protect life.

Health Effects

Air normally contains 21% oxygen; however, there have been adverse health effects to people exposed to concentrations up to 50% at 1 atmosphere for 24 hours or longer.

The inhalation of 80% oxygen at 1 atmosphere for more than 12 hours may cause irritation of the respiratory tract, progressive decrease in vital capacity, coughing, nasal stuffiness, sore throat, and chest pain, followed by tracheobronchitis and later by pulmonary congestion/edema.

Inhalation of pure oxygen at atmospheric pressure or less can cause pulmonary irritation and edema after 24 hours. Respiratory symptoms can occur in two to six hours at pressures above 1 atmosphere.

A characteristic neurological syndrome can be observed when pure oxygen is inhaled at pressures greater than 2 or 3 atmospheres. Signs and symptoms may include such symptoms as nausea, dizziness, vomiting, tiredness, mood changes, euphoria, confusion, muscular twitching, burning/tingling sensations, and loss of consciousness. The effects are reversible after reduction of oxygen pressure.

Premature infants may develop irreversible eye damage if placed in incubators to breathe oxygen in concentrations greater than in air. Within six hours after an infant is placed in a high-oxygen atmosphere, vasoconstriction of the immature vessels of the retina occurs, which is reversible if the child is immediately returned to air but irreversible if oxygen-rich therapy is continued. Fully developed blood vessels are not sensitive to oxygen toxicity.

Table 1 Gaseous Oxygen Properties

Chemical Formula	O ₂
Boiling Point @ 1 atm	-297 °F (-183 °C)
Melting Point @ 1 atm	-362 °F (-219 °C)
Critical Temperature	-182 °F (-118C)
Critical Pressure	729 psia (50 atm)
Density, Gas @ 68 °F (20 °C), 1 atm	0.08 lb/scf
Specific Volume @ 68 °F (20 °C), 1 atm	12.08 scf/lb
Density, Liquid, @ BP, 1 atm	71 lb/scf
Heat of Vaporization	92 Btu/lb
Expansion Ratio, Liquid to Gas, BP to 68 °F (20 °C)	1 to 861
Molecular Weight	32

Containers

Gaseous oxygen is shipped and stored in high-pressure cylinders, tubes, or tube trailers, which are designed and manufactured according to applicable codes and specifications for the pressures and temperatures involved. These vessels are manufactured according to Department of Transportation (DOT) regulations, which specify the material of construction, method of manufacture, testing, and with what products they are permitted to be filled, as well as other details. The quantity of product a container can hold is determined by its pressure rating and internal volume.

Permanent gaseous storage vessels are constructed to ASME codes, which specify the material of construction, method of manufacture, testing, and with what products they are permitted to be filled, as well as other details.

Cylinders

The most commonly used high-pressure cylinders are designed to hold gases at pressures up to 2200 psig; some ultra-high pressure commercial cylinders will contain gas at pressures up to 6000 psig.

High-pressure cylinders come in a variety of pressure ratings and capacities. The most commonly used cylinders for oxygen, nitrogen, argon, and helium are rated at 2200 psig. At 2200 psig, a typical large industrial cylinder contains about 244 cu ft of oxygen. Other commonly used cylinders are 2485 psig units, which contains about 276 cu ft of oxygen, and 2640 psig cylinders, which contains about 330 cu ft of oxygen.

The common 2200 psig, 244 cu ft oxygen cylinder weighs about 150 lb, depending on the grade of steel used in the cylinder body. Each cylinder has a valve on top and a steel cap that screws over the valve to protect it from damage. Each valve has a safety device designed to release pressure if the cylinder pressure becomes too high.

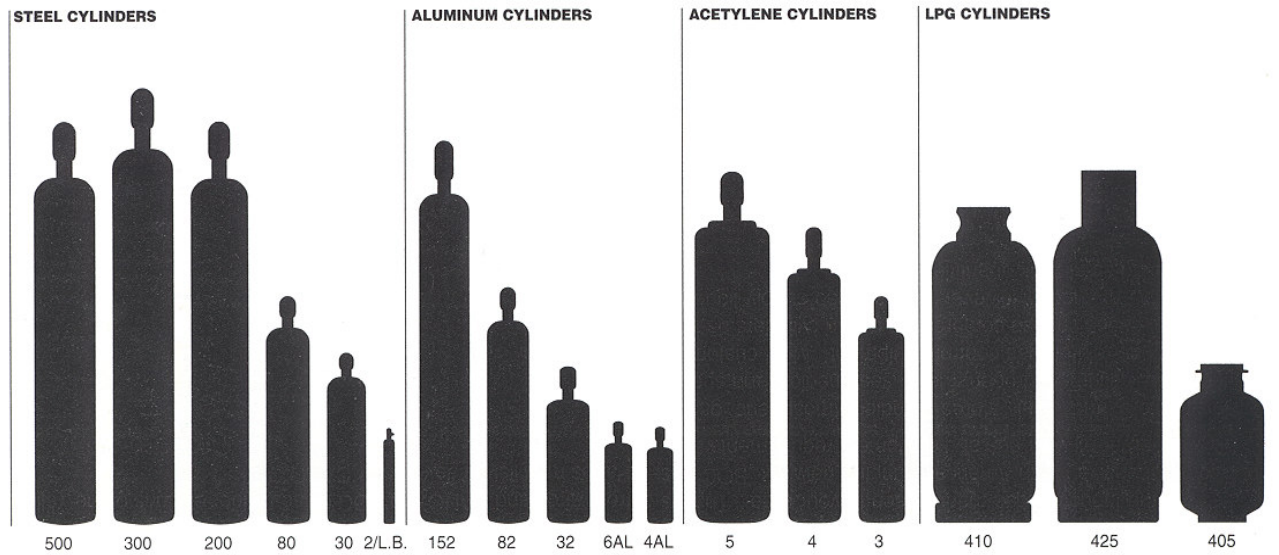
If the valve of a high-pressure gas cylinder is broken off, the contents of the cylinder may jet from a hole about 1/4" in diameter. The escaping gas could have enough thrust to turn the cylinder into a rocket, depending on the cylinder's size and weight.

Tubes

A tube is a pipe tapered at both ends. Each end is threaded to allow the installation of valves, connections, or relief devices.

Tubes for transportation are manufactured according to DOT regulations. Tubes manufactured for permanent storage are made to ASME codes. Tubes are generally mounted on a truck-trailer chassis or railcar bed, or placed at stationary locations when large amounts of oxygen are needed.

Typical Cylinder Shapes and Sizes

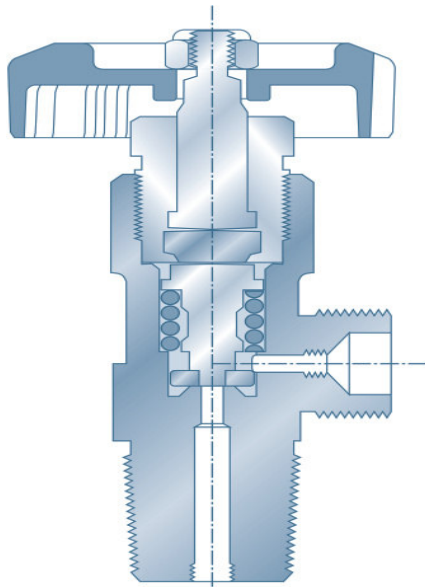


Valve Connections

The Compressed Gas Association (CGA) recommends different connections for oxygen, depending on the pressure rating of the container, or type of service industry, such as medical or semiconductor. The following table shows these different connections (for detailed drawings of these connections, consult CGA Pamphlet V-1).

Table Oxygen Service Connections

<u>Cylinder Service</u>	<u>CGA Connection</u>
Oxygen < 3,000 psig	540
Oxygen at 3,001 to 4,000 psig	577
Oxygen at 4,001 to 5,500 psig	701
Medical oxygen with post valve	870
Semiconductor	714



WARNING: Do NOT use adapters to make cylinder connections!

Pressure-Relief Devices

Oxygen containers are equipped with pressure-relief devices to protect from over pressurization and possible rupture. Cylinders less than 65" long use a rupture disk device. Cylinders over 65" use a combination device consisting of a rupture disk backed by a fusible alloy. Combination devices require that both the temperature and pressure requirements be reached before the device will relieve.

For ASME tubes, pressure relief valves are also used to protect from over-pressurization.

Systems used in oxygen service must meet stringent cleaning requirements to eliminate any incompatible contaminants. CGA Pamphlet G-4.1, "Cleaning Equipment for Oxygen Service," describes cleaning methods for equipment used in oxygen service and CGA Pamphlet O2-DIR, "Directory of Cleaning Agents for Oxygen Service," provides comparative information on cleaning agents used to clean oxygen equipment. Also, review the appropriate Material Safety Data Sheet (MSDS).

Container Stampings

Each cylinder or tube is identified by stampings in the metal of the shoulder. These markings refer to its service pressure rating, date of manufacture, and testing.



Key to Cylinder Stampings

1. Cylinder Specification

- DOT—Department of Transportation, which is the regulatory body that governs the use of cylinders.
- Specification of the cylinder type or material of construction (e.g., 3AA).
- Service or working pressure in pounds per square inch (e.g., 2,015 psi).

2. Cylinder Serial Number

3. Registered Owner Symbol

- Symbol used to indicate the original owner of the cylinders.
- ARCO or AGA is a Registered Owner Symbol for Linde.

4. Date of Manufacture

- This date (month-year) also indicates the original hydrostatic test.

5. Neck Ring Identification

- The cylinder neck ring displays the name of the current owner of the cylinder.

6. Retest Markings

- The format for a retest marking is: Month—Facility—Year—Plus Rating— Star Stamp.
- The + symbol (Plus Rating) indicates that the cylinder qualifies for 10% overfill.
- The . symbol (Star Stamp) indicates that the cylinder meets the requirements for 10-year retest.

7. Cylinder Manufacturer's Inspection Marking

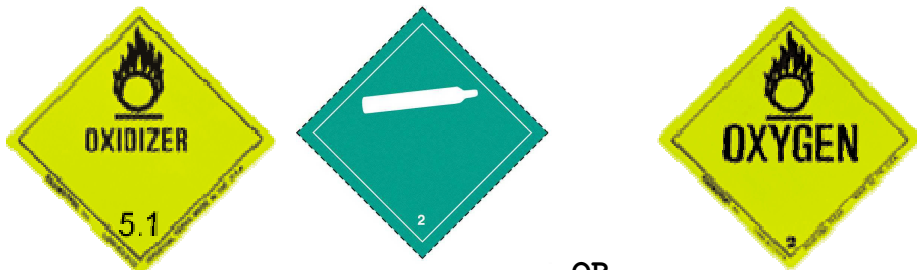
Shipment of Gaseous Oxygen

All shipments of compressed oxygen must comply with DOT regulations. This applies to motor freight, rail, air, and water shipments. For air shipments (which for oxygen is very restrictive) all packages must not only comply with DOT regulations but also comply with International Air Transport Association/International Civil Air Organization (IATA/ICAO) Dangerous Goods regulations. (**Presently Oxygen air shipments must be placed in an over pack which meets ATA 300 specifications**). Water vessel shipments must also be prepared in accordance with the International Maritime Organization (IMO) regulations. All packaging used to transport oxygen must be either "UN/DOT Specification" or "UN/DOT Authorized" and in proper condition for transport. DOT Code of Federal Regulations, Title 49, also specifies the following labeling and identification requirements:

DOT Shipping Name: Oxygen, Compressed

DOT Hazard Class: 2.2

DOT Shipping Label: Nonflammable Gas and Oxidizer (For domestic shipments, only the oxygen label may be used)



Identification Number: UN1072

Safety Considerations

Fire is the primary hazard associated with gaseous oxygen. Although nonflammable, oxygen readily supports combustion. Explosions may occur in locations where a mixture of fuel gas and oxygen can accumulate.

It is important to note that fire chemistry starts to change in oxygen-enriched environments. The CGA has established the definition of an oxygen-enriched atmosphere as being any atmosphere containing at least 23% oxygen. Materials easily ignited in air not only become more susceptible to ignition, but also burn with added violence. These materials can include clothing and hair, which have air spaces that readily trap oxygen. Oxygen levels of 23% can be reached very quickly, and all personnel must be aware of the hazard.

Buildings

Adequate ventilation must be provided in areas where oxygen is in use. Keep them clear of combustible materials and post signs indicating the hazard. Also post "No Smoking" signs. Test the atmospheres in confined work areas for oxygen content. Oxygen-enriched atmospheres can cause materials that burn in air to burn more violently or even explosively. Oxygen concentrations in excess of 23% increase the hazard exposure to personnel and material. These guidelines can be found in NFPA 55

Storage

- Store cylinders outside whenever possible, but always protect them from the weather and from direct sunlight. Cylinders stored inside should be placed in a dry, well-ventilated storage area, preferably constructed of fire-resistant materials.
- Do not allow any part of a cylinder to exceed 125° F.
- Never store the cylinder near elevators, truck-loading platforms, or gangways; under operating cranes; or where something might drop on them, hit them, or knock them over.
- Place caps on cylinders that are being stored or moved.
- Place conspicuous "No Smoking" and "No Open Flames" signs in oxygen storage and use areas.
- Oxygen must be separated by at least 20 feet or by a half-hour fire wall from flammables and combustibles, such as oil, grease, gasoline, paint, and dirty rags.

Handling

- Adapters must NOT be used.
- Never hammer, pry, or wedge a stuck or frozen cylinder valve to loosen it, and never use a wrench. Contact the gas distributor if the valve will not open by hand
- Never drop, drag, roll or slide cylinders. Tilt the cylinder sideways and roll along its bottom edge, or use a specifically designed hand-truck for cylinder movement.
- Never lift a cylinder by its cap, or valve, or with chains, slings, or magnets. If a crane is needed to move a number of cylinders, the cylinders should be secured on a platform or in a cradle.
- Do not drop a cylinder.
- Never use a cylinder unless the gas it contains is clearly stenciled on it or marked with a decal. Altering or defacing the name, numbers, or other markings on a cylinder is illegal and hazardous.
- Do not rely on the color of a cylinder to identify the gas inside. Suppliers use different color codes.

- Do not allow grease, oil, or other combustible materials to touch any part of a cylinder. Grease or oil that oxidizes very slowly in air will burst into flame in pure oxygen. Only oxygen compatible lubricants can be used.
- Do not modify or tamper with the safety devices on valves or cylinders.
- Rapid system pressurization will occur if the cylinder valve is opened too fast.
- Use specially designed strap-wrench to remove over-tightened or rusted caps.
- All piping and associated equipment used must be designed for the encountered pressures.
- All vents should be piped to the outside, and should be in compliance with local regulations.
- Check valves should be used to prevent reverse gas flow into the cylinders.
- It is a violation of federal law to refill or ship compressed gas cylinders without the consent of the owner.
- Keep cylinders away from electrical circuits and excessive heat. The cylinders will conduct electricity.
- Never ground a cylinder or place it near an electrical conductor, including piping, plumbing, or anything that might carry electrical current.

Personal Protective Equipment (PPE)

Personnel must be thoroughly familiar with properties and safety considerations before being allowed to handle oxygen and its associated equipment. Safety glasses, safety shoes, and leather work gloves are recommended when handling cylinders.

Only trained and certified emergency responders should respond to emergency situations. Clothing which is fire-resistant in air may be readily ignitable in oxygen-enriched atmospheres.

First Aid

When breathing oxygen mixtures are used at pressures above 1 atmosphere, seek medical advice for proper health instructions.

Fighting Fires

Since oxygen is nonflammable, but supports combustion, fire-fighting actions require shutting off the source of oxygen, when ever possible, then fighting the fire according to the material involved. Most cylinders are designed to vent contents when exposed to elevated temperatures. Cylinders may vent rapidly and/or rupture violently when exposed to intense heat or flame.

Emergency Response System

Product Safety Information

- Call: 1-800-424-9300 (Continental U.S. and Puerto Rico)
- Call: 1-703-527-3887 (other locations)
- 24 hours a day, 7 days a week

For assistance involving Linde, Inc. products

For MSDS, Product Safety Assessment, and Product Safety Information,
www.linde.com

Information Sources

- www.us.lindegas.com
- Compressed Gas Association (CGA)
www.cganet.com

For More Information

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