# Product Safety Assessment

## Liquid Oxygen

### General

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.

Liquid oxygen is a cryogenic liquid, pale blue and extremely cold. Cryogenic liquids are liquefied gases that have a normal boiling point below –238°F (–150°C). Liquid oxygen has a boiling point of –297.3°F (–183.0°C).

### Manufacture

Oxygen, nitrogen and argon are recovered from air using a cryogenic method developed by Carl von Linde more than 100 years ago. Particulates are removed from the incoming air, which is then repeatedly compressed and cooled. Water, hydrocarbons and carbon dioxide are then removed. With further processing, the air eventually becomes a liquid and the individual gases are separated by distillation. These plants are called air separation units, or Air Separation Units (ASU). Many of the world's ASUs have been built by Linde's engineering division.

### Applications

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**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, coordination, 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.

Contact with liquid oxygen may cause freeze burns to exposed tissue.

**Table Liquid Oxygen Properties**

| | |
|---|---|
| Chemical Formula | O2 |
| 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, @ Boiling Point, 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**

Several types of containers, depending upon the quantity, is used to store, ship, and handle liquid oxygen. Containers utilized are dewars, cryogenic liquid cylinders, and cryogenic storage tanks, and storage volumes vary from a few gallons to many thousands of gallons. Vaporization takes place continuously to maintain cold temperature. The vaporization rate varies depending on the design of the container and the volume of stored product.

Containers are designed and manufactured according to the applicable codes and specifications for the temperatures and pressures involved.

Dewars

A typical, vacuum-jacketed dewar is shown below. A loose-fitting dust cap over the outlet of the neck tubes prevents atmospheric moisture from plugging the neck and allows gas produced from vaporized liquid to escape. This type of container is non-pressurized. The most common unit of measure for the capacity of a dewar are liters, which range from 5 - to 200-liters. Liquid oxygen may be removed from small dewars by pouring, while larger sizes will require a transfer tube. *Cryogenic liquid cylinders which are pressurized vessels are sometimes incorrectly referred to as dewars.*

Cryogenic Liquid Cylinders

A cryogenic liquid cylinder is an insulated, vacuum-jacketed, pressure vessel. They are equipped with pressure-relief valves and rupture disks to protect the cylinders from pressure buildup. Liquid containers operate at pressures up to 350 psig and have capacities between 80 and 450 liters of liquid. Oxygen may be withdrawn as a gas or liquid, depending upon valve use for withdrawal.

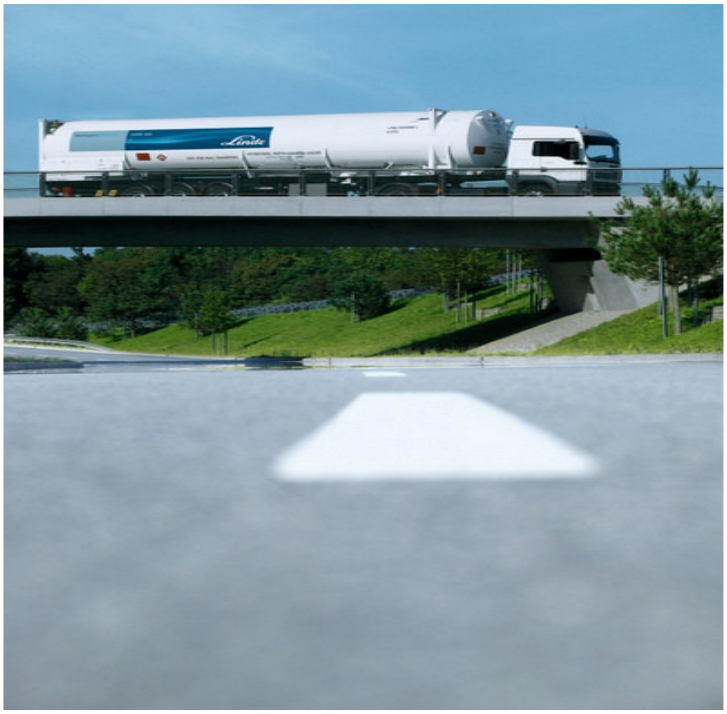
NOTE: Liquid cylinders designed to dispense gaseous oxygen have valves equipped with standard Compressed Gas Association (CGA) outlets. Suitable pressure-regulating equipment may be attached. Valves provided for the withdrawal of liquid product are also equipped with standard CGA outlets but differ from connections used for gaseous withdrawal. This prevents cross connections between processes using the liquid or gaseous product.


Cryogenic Storage Tanks

Cryogenic storage tank installations generally include a tank, vaporizer, and pressure control manifold. Tanks are mainly cylindrical in shape and mounted in fixed locations as stationary vessels. Sizes range from 500 to 420,000 gallons. All tanks are vacuum insulated, and may contain other insulating materials in the annular space.  Tanks are designed to ASME specifications.

**Typical Cryogenic Storage Tanks**

**Shipment of Liquid Oxygen**

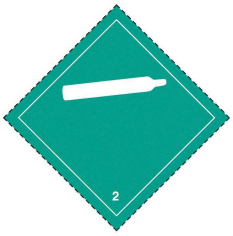


All shipments of oxygen, refrigerated liquid (liquid oxygen), must comply with DOT regulations. This applies to motor freight, rail, air, and water shipments. Air shipment of oxygen, refrigerated liquid is forbidden. Water vessel shipments must also be prepared in accordance with the International Maritime 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, Refrigerated Liquid

DOT Hazard Class: 2.2

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




**OR**


Identification Number: UN1073

**Safety Considerations**

Liquid oxygen cannot be handled in carbon or low alloy steel. 18-8 and 18-10 stainless steel are acceptable as are copper and its alloys, nickel and its alloys, brass bronze, silicon alloys, Monel®, Inconel® and beryllium. Teflon®, Teflon® composites, or Kel-F® are preferred non-metallic gasket materials.

Equipment to contain oxygen must be “cleaned for oxygen service”. Check with supplier to verify oxygen compatibility for the service conditions. Stationary customer site vessels should operate in accordance with the manufacturer's and BOC’s instruction. Do not attempt to repair, adjust or in any other way modify the operation of these vessels. If there is a malfunction or other type of operations problem with the vessel, contact the closest Linde location immediately.

Oxygen, refrigerated liquid is delivered to a customer into stationary, vacuum-jacketed vessels at the customer's location or in portable vacuum-jacketed “liquid" cylinders. Post “NO SMOKING OR OPEN FLAMES” signs in storage and use areas. There should be no sources of ignition in storage and use areas. Containers of liquid oxygen should be separated from flammable gas containers by a minimum distance of 20 ft., or by a barrier of non-combustible material at least 5 ft. high having a fire resistance rating of ½ hour.

Liquid oxygen vessels should be used only in well ventilated areas in accordance with manufacture and BOC's instructions. Cylinders must always be kept upright. Specialized trucks are needed for their movement. Do not tip, drag, slide, or roll cylinders. Full and empty cylinders should be stored away from flammable and combustible products. Valve protection caps must remain in place unless container is secured with valve outlet piped to use point. If user experiences any difficulty operating container valve discontinue use and contact supplier. Do not insert any object (i.e.: screwdriver) into valve cap openings as this can damage the valve causing leakage. Use a pressure reducing regulator when connecting cylinder to lower pressure piping or systems. Do not heat containers by any means to increase the discharge rate of product from the cylinder. Use a check valve or trap in the discharge line to prevent hazardous back flow into the system.

Protect containers from physical damage. Store in cool, dry, well-ventilated area, away from heavily trafficked areas, and emergency exits. Containers should be stored upright and firmly secured to prevent falling or being knocked over. Full and empty cylinders should be segregated. Use a "first in-first out" inventory system to prevent full containers being stored for excessive periods of time.

Never allow any unprotected part of the body to touch uninsulated pipes or vessels containing cryogenic fluids. The extremely cold metal will cause the flesh to stick and tear when you attempt to remove it.

For additional recommendations, consult Compressed Gas Association Pamphlets G-4, P-12, P-2.6, PS-4, AV-10, G-4.1, G-4.3, G-4.9, O2-DIR, P-8.1, P-8.2, SP-E, TB-12, and SB-9.

Never carry a compressed gas cylinder or a container of a gas in cryogenic liquid form in an enclosed space such as a car trunk, van or station wagon. A leak can result in a fire, explosion, asphyxiation or a toxic exposure.

CGA’s Pamphlet O2-DIR, “Directory of Cleaning Agents for Oxygen Service,” provides comparative information on cleaning agents used to clean oxygen equipment.

Also, review the Material Safety Data Sheet (MSDS) and follow all recommendations.

**Buildings**

Liquid Oxygen has a large expansion ratio of liquid-to-gas (~850 to 1), it is very important to provide adequate ventilation in areas where liquid oxygen is in use.. CGA has established the definition of an oxygen-enriched atmosphere as one containing at least 23% oxygen.

NOTE: oxygen has no warning properties!

**Storage & Handling**

- Liquid oxygen vessels should be used only in well ventilated areas in accordance with manufacture and Linde's instructions.
- Cryogenic containers are equipped with pressure relief devices designed to control the internal pressure by venting periodically. Do not plug, remove or tamper with any pressure relief device.
- Full and empty cylinders should be stored away from flammable and combustible products.
- "No Smoking" and "No Open Flames" signs need to be posted.
- Storage locations must be installed in accordance with the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids National Fire Protection Association (NFPA) Standard 55.
- Cylinders must always be kept upright. Specialized trucks are needed for their movement.
- Do not tip, drag, slide, or roll cylinders.
- Full and empty cylinders should be stored away from flammable and combustible products.
- Valve protection caps must remain in place unless container is secured with valve outlet piped to use point.
- Do not use adaptors.
- Use only transfer lines and equipment designed for use with cryogenic liquids. Some elastomers and metals, such as carbon steel, may become brittle at extremely low temperatures and may easily fracture. These materials must be avoided in cryogenic service.
- It is recommended that all vents be piped to the exterior of the building.
- On liquid systems pressure relief devices must be used in lines where there is the potential to trap liquid between valves.

**Personal Protective Equipment (PPE)**

Individuals must be thoroughly familiar with properties and safety considerations before being allowed to handle liquid oxygen and its associated equipment.

Wear chemical goggles with face shields where contact with liquid is possible.

Protective gloves made of any suitable material appropriate for the job. Insulated gloves recommended for cryogenic liquids. Gloves must be clean and free from oil and grease.

Safety shoes, emergency eyewash station are also recommended

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

**First Aid**

Never introduce ointment or oil into the eyes without medical advice! In case of freezing or cryogenic "burns" caused by rapidly evaporating liquid, DO NOT WASH THE EYES WITH HOT OR EVEN TEPID WATER!
Remove victim from the source of contamination. For contact with small amounts of liquid, open the eyelids wide to allow the liquid to evaporate. For contact with large amounts, rinse with a low pressure stream of cool water for 15 minutes. Refer the victim to an ophthalmologist for treatment and follow up. If the victim cannot tolerate light, protect the eyes with dark glasses. The use of bandages is not recommended as keeping the eyelids closed or exerting pressure on the eyelid may cause further damage.

SKIN:

For dermal contact or frostbite: Remove contaminated clothing and flush affected areas with lukewarm water.
DO NOT USE HOT WATER. A physician should see the patient promptly if contact with the product has resulted in blistering of the dermal surface or in deep tissue freezing.

INGESTION:

A physician should see the patient promptly if the cryogenic "burn" has resulted in blistering of the dermal surface or deep tissue freezing.

INHALATION:

Overexposure to oxygen is not anticipated under normal working conditions. High oxygen concentrations in the air may present a fire and explosion hazard. PROMPT MEDICAL ATTENTION IS MANDATORY IN ALL CASES OF OVEREXPOSURE WHEN OXYGEN IS INHALED UNDER PRESSURE (i.e.: as in scuba diving). Conscious persons should be removed from exposure and inhale fresh air. Quick removal from the source of exposure or contaminated area is most important. Further treatment should be symptomatic and supportive. Inform the treating physician that the patient could be experiencing hyperoxia.

**Fighting Fires**

High oxygen concentrations vigorously accelerate combustion. Will support or initiate combustion/ explosion of organic matter and other oxidizable material. Many materials that are not combustible in air will burn in oxygen enriched atmosphere. Cylinder may vent rapidly or rupture violently from pressure when involved in a fire situation.

EXTINGUISHING MEDIA:

Water spray to keep cylinders cool. Extinguishing agent appropriate for the combustible material.

FIRE FIGHTING INSTRUCTIONS:

DO NOT SPRAY WATER DIRECTLY ON TO LIQUID OXYGEN SINCE THIS WILL INCREASE THE RATE OF VAPROIZATION AND CAUSE FREEZING OF THE WATER.

If possible, stop the flow of oxygen which is supporting the fire. Immediately cool containers with water spray from maximum distance. Do not direct water spray at container vent. Move cooled containers from fire area if it can be done without risk. Firefighters should wear respiratory protection (SCBA) and full turnout or Bunker gear. Continue to cool fire-exposed cylinders until well after flames are extinguished.

ACCIDENTAL RELEASE MEASURES:

Evacuate all personnel from affected area. A leak near combustible or flammable materials may represent a severe fire or explosion hazard.

Eliminate all ignition sources. Use appropriate protective equipment. Stop the flow of gas or remove cylinder to outdoor location if this can be done without risk.

Ventilate enclosed areas. To increase vaporization rate, spray large amounts of water onto the spill from an upwind position. If leak is in user's equipment, be certain to purge piping with inert gas prior to attempting repairs.

If leak is in container or container valve, contact the appropriate emergency telephone number listed below or call your closest Linde location.

**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
Linde,
575 Mountain Ave
Murray Hill, NJ 07974-2082