Oxygen System Safety

The design and operation of oxygen systems are the responsibility of the users who should obtain qualified professional assistance to ensure their safe use of oxygen.

Scope

This technical report is an overview of the unique concerns that must be addressed in order to handle oxygen safely. It is based on information found in the many source documents available from the publishers listed and is provided as a service to our customers. We are not oxygen experts or engineering consultants.

Hazards

Oxygen is a fire hazard because it promotes combustion. The serious consequences of fires in air, which contains only 21% oxygen, are well known. Increasing the oxygen concentration to more than 21% greatly increases the fire hazard. Many materials that may not be combustible in an atmosphere will burn in an oxygen-enriched atmosphere. Combustible materials are easier to ignite and burn faster and hotter. Fires spread more rapidly, often with seemingly explosive results. Ignition sources that have no effect in air can be of critical importance in oxygen systems.

Oxygen System Fires

Three elements—oxidizer, fuel, and ignition energy—are required to create a fire. Fires in the atmosphere can be prevented by removing one of the three elements, but they are inseparable in an oxygen system. The oxygen is contained within the system, usually under substantial pressure. The valves, regulators, piping, fittings, and other components that contain the oxygen are, in fact, the fuel. The ignition energy comes from within the system, often through mechanisms that do not otherwise cause ignition. Thus, although oxygen system fire potential cannot be eliminated, they can be avoided by risk management based on a careful analysis of the hazards and risks. The system design, component selection, materials of construction, fabrication methods, as well as system operation and maintenance must be developed carefully for each specific purpose.

Kindling Chain

The kindling chain begins when a small amount of energy is released in a system and ignites a material with a low ignition temperature or a particle with a small mass and large surface area. Once a small object is ignited, the heat that it generates ignites larger materials with higher ignition temperatures to generate even more heat until the fire becomes self-sustaining. Four common ignition mechanisms are:

1. Mechanical Impact
   When one object strikes another, heat is produced at the point of impact, as when a hammer strikes a surface. The heat produced by mechanical impact can act as an ignition source. For example, in an oxygen system, a mechanical component may break off and strike a pressurized container, producing heat upon impact. If the surface of the container is contaminated with oil, it can ignite and initiate the kindling sequence.

2. Particle Impact
   Small particles can be carried along with a flowing oxygen stream, often at high velocity. When the particles strike a surface in the system, the impact energy is released as heat and, because of their small mass, the particles become hot enough to ignite larger materials.

3. Friction
   When two solid materials rub together, they generate heat which can ignite other materials.

4. Compression Heating
   When a gas flows through an orifice from high to low pressure, it expands and its velocity can reach the speed of sound. If the gas flow is blocked, it recompresses to its original pressure and becomes hot. The greater the pressure difference, the higher the gas temperature. This effect is familiar to anyone who has inflated a bicycle tire; as the pressure rises in the tire, the pump gets hot. In an oxygen system, the oxygen temperature can be high enough to initiate the kindling chain.

A common example of compression heating (Fig. 1) in an oxygen system occurs when a valve (especially a fast-opening ball or plug valve) is opened quickly and the gas stream compresses the oxygen downstream against an obstruction. A closed valve or regulator is an obvious obstruction, but often the obstruction is not obvious because it exists within the valve itself. For example, the obstruction may exist at a valve seat as it is being opened, at the outlet of a partially open regulator, or at another small orifice. In addition, the gas stream can be obstructed at the angle in an elbow fitting.
The kindling chain can begin if the gas stream contains fine particles or if compression heating occurs at a polymer valve seat, an elastomer seal, or a surface contaminated with a lubricant or organic material. Such materials, in turn, can ignite a small spring, a thin diaphragm, or a filter and lead to a self-sustaining fire. The ASTM video *Oxygen Safety* describes the compression heating mechanism that is a common, though often ignored, cause of oxygen fires.

**Avoiding Oxygen Fires**

Recognizing and identifying all such sources of ignition and possible causes of fire is not simple. However, NFPA 53 gives examples of serious oxygen system fires that have occurred in many industries and applications, along with guidance on what caused them and how they can be avoided. ASTM G128 discusses these hazards, design considerations, and ignition sources in greater detail while G88 and Manual MNL36 provide specific design guidance. ASTM G4 Standards Technology Training course *Controlling Fire Hazards in Oxygen Handling Systems* provides detailed instruction in hazards analysis and risk management for oxygen systems and teaches the use of the many tools and information sources that are available.

Each of these publications, and many more, focuses on the main points of oxygen fire avoidance:

- System design operation and maintenance
- Component selection
- System fabrication
- System operation and maintenance
- System cleanliness
- Lubricant compatibility
- Polymers and other nonmetals compatibility
- Metals compatibility

The first and most important rule for the safe use of oxygen: *Consult an expert*. The ASTM standards on oxygen systems define an expert in this way:

*Qualified technical personnel*—persons such as engineers and chemists who, by virtue of education, training, or experience, know how to apply the physical and chemical principles involved in the reactions between oxygen and other materials.

Although oxygen systems present serious and unusual hazards, they are used safely throughout industry because the risk of injury and economic loss can be managed and controlled.

The knowledge and technology needed are well established, documented, and available through many public resources, some of which are listed. The ASTM course *Controlling Fire Hazards in Oxygen Handling Systems* teaches the fundamentals of oxygen safety for system and equipment designers, specifiers, and users. Persons involved with the use of oxygen in any application should take advantage of such resources.
**Other References**

The following are additional sources of information on oxygen systems, listed by publisher. Contact the publishers for their current lists of publications regarding the safe use of oxygen.

**American National Standards Institute**  
11 W. 42nd St., New York, NY 10036  
[www.ansi.org](http://www.ansi.org)

**ASTM**  
100 Barr Harbor Dr., West Conshohocken, PA 19428-2959  
[www.astm.com](http://www.astm.com)

ASTM compilation: Standards Related to Flammability and Sensitivity of Materials in Oxygen-Enriched Atmospheres PCN 03.704097.31. This compilation contains all the standards published by ASTM relating to oxygen safety, as of the date of publication.

**ASTM Annual Book of Standards**, Volume 00.01, Subject Index; Alphanumeric List

The annual Index of Standards lists all standards published through the year of issue, including those not yet included in the above compilation.

**Alternatives to Chlorofluorocarbon Fluids in the Cleaning of Oxygen and Aerospace Systems and Components**, STP 1181, C.J. Bryan and K. Gebert-Thompson, Ed., 1993


**American Welding Society**  
550 NW LeJeune Rd., Box 351040, Miami, FL 33135  
[www.aws.org](http://www.aws.org)

AWS Z49.1 Safety in Welding and Cutting and Allied Processes

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