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 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:

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.

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.

Friction

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

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.
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A common example of compression heating 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.

Referenced Documents

National Fire Protection Association, Inc. 1 Batterymarch Park, Box 9101, Quincy, MA 02269-9101
www.nfpa.org

NFPA 53 Recommended Practice on Materials, Equipment and Systems Used in Oxygen-Enriched Atmospheres

ASTM
100 Barr Harbor Dr.,
West Conshohocken, PA 19428-2959
www.astm.com

ASTM G128 Standard Guide for Control of Hazards and Risks in Oxygen Enriched Systems

ASTM G88 Standard Guide for Designing Systems for Oxygen Service

ASTM G-4 Standards Technology Training course Controlling Fire Hazards in Oxygen Handling Systems

ASTM video Oxygen Safety

Safe Use of Oxygen and Oxygen Systems: Guidelines for Oxygen System Design Materials Selection, Operations, Storage, and Transportation, Manual MNL36; H.D. Beeson, W.F. Stewart, and S.S. Woods, Ed., 2000–

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
ANSI/ASME B31.3 Process Piping

ASTM
100 Barr Harbor Dr.,
West Conshohocken,
PA 19428-2959
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 Flammability and Sensitivity of Materials in Oxygen-Enriched Atmospheres,
STP 812, B.L. Werley, Ed., 1983 Flammability and Sensitivity of Materials in Oxygen-Enriched Atmospheres,
Vol. 2, STP 910, M.A. Benning, Ed., 1986 Flammability and Sensitivity of Materials in Oxygen-Enriched Atmospheres,
Vol. 3, STP 986, D.W. Schroll, Ed., 1988 Flammability and Sensitivity of Materials in Oxygen-Enriched Atmospheres,
Vol. 4, STP 1040, J.M. Stoltzfus, F.J. Benz, and J.S. Stradling, Ed., 1989 Flammability and Sensitivity of Materials in Oxygen-Enriched Atmospheres,
Vol. 5, STP 1111, J.M. Stoltzfus and K. McIlroy, Ed., 1991 Flammability and Sensitivity of Materials in Oxygen-Enriched Atmospheres,
Vol. 6, STP 1197, D.D. Janoff and J.M. Stoltzfus, Ed., 1993 Flammability and Sensitivity of Materials in Oxygen-Enriched Atmospheres,
Vol. 7, STP 1267, D.D. Janoff, W.T. Royals, and M.V. Gunaji, Ed., 1995 Flammability and Sensitivity of Materials in Oxygen-Enriched Atmospheres,
Vol. 8, STP 1319, W.T. Royals, T.C. Chou, and T.A. Steinberg, Ed., 1997 Flammability and Sensitivity of Materials in Oxygen-Enriched Atmospheres,
Vol. 9, STP 1395, T.A. Steinberg, B.E. Newton, and H.D. Beeson, Ed., 2000

American Welding Society
550 NW Lejeune Rd., Box 351040,
Miami, FL 33135
www.aws.org
AWS Z49.1 Safety in Welding and Cutting and Allied Processes

Compressed Gas Association, Inc.
1725 Jefferson Davis Highway,
Suite 1004
Arlington, VA 22202
www.cganet.com
CGA Video AV-8 Characteristics and Safe Handling of Cryogenic Liquid Gaseous Oxygen
CGA G-4 Oxygen
CGA G-4.1 Cleaning Equipment for Oxygen Service
CGA G-4.4 Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems
CGA P-39 Oxygen-Rich Atmospheres. Handbook of Compressed Gases, 3rd ed., 1989

European Industrial Gas Association (EIGA)
Publication de la Soudure Autogene
32 Boulevard de la Chapelle, 75880 Paris Cedex 18, France
email: info@eiga.org
EIGA 33/86/E Cleaning of Equipment for Oxygen Service
EIGA 6/77 Oxygen Fuel Gas Cutting Machine Safety
EIGA 8/76/E Prevention of Accidents Arising from Enrichment or Deficiency of Oxygen in the Atmosphere
EIGA 13/82 The Transportation and Distribution of Oxygen by Pipelines. Recommendations for Design, Construction and Maintenance

Factory Mutual Engineering Corp.
Box 9102
Norwood, MA 02062
www.affiliatedfm.com

National Fire Protection Association, Inc.
1 Batterymarch Park,
Box 9101, Quincy,
MA 02269-9101
www.nfpa.org
NFPA 51 Standard for the Design and Installation of Oxygen Fuel Gas Systems for Welding, Cutting, and Allied Processes
NFPA 51B Standard for Fire Prevention During Welding, Cutting and Other Hotwork
NFPA 55 Standard for Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks
NFPA 99 Standard for Health Care Facilities NFPA Health Care Facilities Handbook