Designation: G128/G128M − 15 (Reapproved 2023)

Standard Guide for
Control of Hazards and Risks in Oxygen Enriched Systems[1]

This standard is issued under the fixed designation G128/G128M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers an overview of the work of ASTM Committee G04 on Compatibility and Sensitivity of Materials in Oxygen-Enriched Atmospheres. It is a starting point for those asking the question: "What are the risks associated with my use of oxygen?" This guide is an introduction to the unique concerns that must be addressed in the handling of oxygen. The principal hazard is the prospect of ignition with resultant fire, explosion, or both. All fluid systems require design considerations, such as adequate strength, corrosion resistance, fatigue resistance, and pressure safety relief. In addition to these design considerations, one must also consider the ignition mechanisms that are specific to an oxygen-enriched system. This guide outlines these ignition mechanisms and the approach to reducing the risks.

1.2 This guide also lists several of the recognized causes of oxygen system fires and describes the methods available to prevent them. Sources of information about the oxygen hazard and its control are listed and summarized. The principal focus is on Guides G63, G88, Practice G93, and Guide G94. Useful documentation from other resources and literature is also cited.

NOTE 1—This guide is an outgrowth of an earlier (1988) Committee G04 videotape adjunct entitled *Oxygen Safety* and a related paper by Koch[2] that focused on the recognized ignition source of adiabatic compression as one of the more significant but often overlooked causes of oxygen fires. This guide recapitulates and updates material in the videotape and paper.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* FOR SPECIFIC PRECAUTIONARY STATEMENTS SEE SECTIONS 8 AND 11.

NOTE 2—ASTM takes no position respecting the validity of any evaluation methods asserted in connection with any item mentioned in this guide. Users of this guide are expressly advised that determination of the validity of any such evaluation methods and data and the risk of use of such evaluation methods and data are entirely their own responsibility.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D2512 Test Method for Compatibility of Materials with Liquid Oxygen (Impact Sensitivity Threshold and Pass-Fail Techniques)

D2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)

D4809 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)

G63 Guide for Evaluating Nonmetallic Materials for Oxygen Service

G72 Test Method for Autogenous Ignition Temperature of Liquids and Solids in a High-Pressure Oxygen-Enriched Environment

G74 Test Method for Ignition Sensitivity of Nonmetallic Materials and Components by Gaseous Fluid Impact

G86 Test Method for Determining Ignition Sensitivity of Materials to Mechanical Impact in Ambient Liquid Oxygen and Pressurized Liquid and Gaseous Oxygen Environments

G88 Guide for Designing Systems for Oxygen Service

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[1] This guide is under the jurisdiction of ASTM Committee G04 on Compatibility and Sensitivity of Materials in Oxygen Enriched Atmospheres and is the direct responsibility of Subcommittee G04.02 on Recommended Practices.

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[2] Koch, U. H., "Oxygen System Safety," *Flammability and Sensitivity of Materials In Oxygen-Enriched Atmospheres* , Vol 6, ASTM STP 1197, ASTM, 1993, pp. 349–359.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

G93 Guide for Cleanliness Levels and Cleaning Methods for Materials and Equipment Used in Oxygen-Enriched Environments

G94 Guide for Evaluating Metals for Oxygen Service

G124 Test Method for Determining the Combustion Behavior of Metallic Materials in Oxygen-Enriched Atmospheres

G126 Terminology Relating to the Compatibility and Sensitivity of Materials in Oxygen Enriched Atmospheres

G175 Test Method for Evaluating the Ignition Sensitivity and Fault Tolerance of Oxygen Pressure Regulators Used for Medical and Emergency Applications

2.2 *ASTM Adjuncts:*

Video: Oxygen Safety[4]

2.3 *ASTM CHETAH Analytical Computer Software Program:*

CHETAH Chemical Thermodynamic and Energy Release Evaluation[5]

2.4 *Compressed Gas Association (CGA) Standards:*[6]

G-4.1 Cleaning Equipment for Oxygen Service

G-4.4 Oxygen Pipeline and Piping Systems

2.5 *European Industrial Gas Association (EIGA) Standards:*[7]

33/XX/E Cleaning of Equipment for Oxygen Service

13/XX/E Oxygen Pipeline and Piping Systems

2.6 *National Fire Protection Association (NFPA) Standards:*[8]

51 Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting and Allied Processes

53 Recommended Practice on Material, Equipment, and Systems Used in Oxygen Enriched Atmospheres

55 Compressed Gases and Cryogenic Fluids Code

99 Health Care Facilities Code

2.7 *Military Specifications:*[9]

MIL-PRF-27617 Performance Specification, Grease, Aircraft and Instrument, Fuel and Oxidizer Resistant

DOD-PRF-24574 (SH) Performance Specification, Lubricating Fluid for Low and High Pressure Oxidizing Gas Mixtures

3. Terminology

3.1 *Definitions:*

3.1.1 See Terminology G126 for the terms listed in this section.

3.1.2 *autoignition temperature (AIT), n*—the lowest temperature at which a material will spontaneously ignite in an oxygen-enriched atmosphere under specific test conditions.

3.1.3 *hazard, n*—source of danger; something that could harm persons or property.

3.1.4 *ignition mechanisms, n*—these are the specific physical attributes and system conditions that cause the initial fire within a system. A system designer must evaluate an oxygen-enriched system for all possible ignition mechanisms. A common ignition mechanism for metals is particle impact. A common ignition mechanism for non-metals is adiabatic compression.

3.1.5 *ignition temperature, n*—the temperature at which a material will ignite under specific test conditions.

3.1.6 *impact-ignition resistance, n*—the resistance of a material to ignition when struck by an object in an oxygen-enriched atmosphere under a specific test procedure.

3.1.7 *nonmetal, n*—a class of materials consisting of polymers, certain composite materials (polymer matrix and brittle matrix composites in which the most easily ignited component is not a metallic constituent), ceramics, and various organic and inorganic oils, greases, and waxes. **nonmetallic**, adj.

3.1.8 *oxidant compatibility, n*—the ability of a substance to coexist at an expected pressure and temperature with both an oxidant and a potential source(s) of ignition within a risk parameter acceptable to the user.

3.1.9 *oxygen-enriched, adj*—containing more than 23.5 mol percent oxygen.

3.1.9.1 *Discussion*—Other standards such as those published by NFPA and OSHA differ from this definition in their specification of oxygen concentration.

3.1.10 *qualified technical personnel, n*—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 oxidants and other materials.

3.1.11 *risk, n*—probability of loss or injury from a hazard.

3.1.12 *system conditions, n*—the physical parameters of a specific system. These can include local and system-wide pressure, temperature, flow, oxygen concentration, and others.

3.1.13 *wetted material, n*—any component of a fluid system that comes into direct contact with the system fluid.

4. Significance and Use

4.1 The purpose of this guide is to introduce the hazards and risks associated with oxygen-enriched systems. This guide explains common hazards that often are overlooked. It provides an overview of the standards and documents produced by ASTM Committee G04 and other knowledgable sources as well as their uses. It does not highlight standard test methods that support the use of these practices. Table 1 provides a graphic representation of the relationship of ASTM G04 standards. Table 2 provides a list of standards published by ASTM and other organizations.

4.2 The standards discussed here focus on reducing the hazards associated with the use of oxygen. In general, they are not directly applicable to process reactors in which the deliberate reaction of materials with oxygen is sought, as in burners,

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[4] Available from ASTM International Headquarters. Order Adjunct No. ADJG0088.

[5] Available from ASTM International Headquarters, 100 Barr Harbor Drive, West Conshohocken, PA 19428, Order # DSC 51C, Version 7.2.

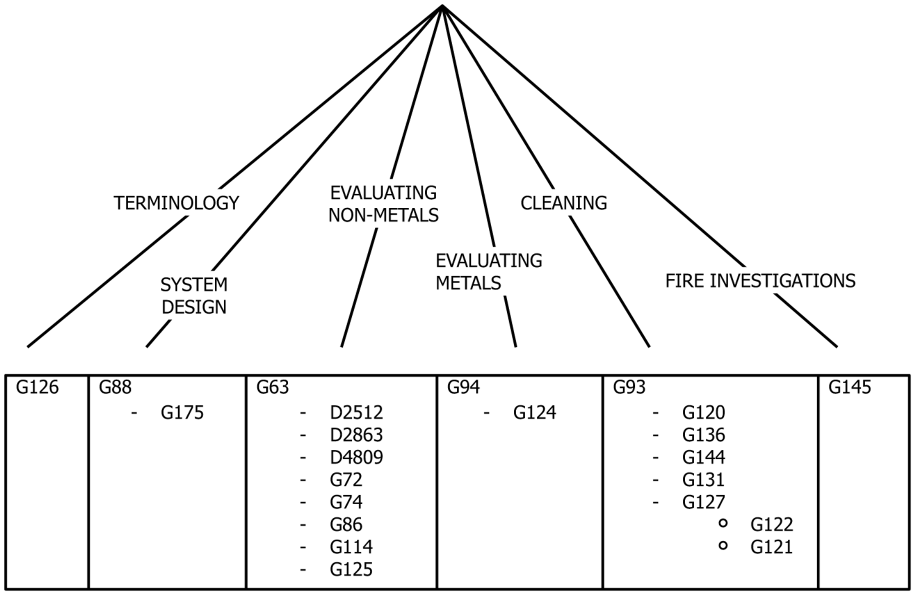
[6] Available from Compressed Gas Association (CGA), 4221 Walney Rd., 5th Floor, Chantilly, VA 20151-2923, http://www.cganet.com.

[7] Available from European Industrial Gas Association, Publication de la Soudure Autogene, 32 Boulevard de la Chapelle, 75880 Paris Cedex 18, France.

[8] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

[9] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://dodssp.daps.dla.mil.

TABLE 1 Relationship of ASTM Standards for Oxygen-Enriched Systems



bleachers, or bubblers. Other ASTM Committees and products (such as the CHETAH program[5]) and other outside groups are more pertinent for these.

4.3 This guide is not intended as a specification to establish practices for the safe use of oxygen. The documents discussed here do not purport to contain all the information needed to design and operate an oxygen-enriched system safely. The control of oxygen hazards has not been reduced to handbook procedures, and the tactics for using oxygen are not simple. Rather, they require the application of sound technical judgment and experience. Oxygen users should obtain assistance from qualified technical personnel to design systems and operating practices for the safe use of oxygen in their specific applications.

5. Summary

5.1 Oxygen and its practical production and use are reviewed. The recognized hazards of oxygen are described. Accepted and demonstrated methods to reduce those hazards are reviewed. Applicable ASTM standards from Committee G04 and how these standards are used to help mitigate oxygen-enriched system hazards are discussed. Similar useful documents from the National Fire Protection Association, the Compressed Gas Association, and the European Industrial Gas Association also are cited.

6. Oxygen

6.1 Oxygen is the most abundant element, making up 21 % of the air we breathe and 55 % of the earth's crust. It supports plant and animal life. Oxygen also supports combustion, causes iron to rust, and reacts with most metals. Pure oxygen gas is colorless, odorless, and tasteless. Liquid oxygen is light blue and boils at −183 °C [−297 °F] under ambient pressure.

6.2 Oxygen has many commercial uses. For example, it is used in the metals industry for steel making, flame cutting, and welding. In the chemical industry it is used for production of synthetic gas, gasoline, methanol, ammonia, aldehydes, alcohol production, nitric acid, ethylene oxide, propylene oxide, and many others. It is also used for oxygen-enriched fuel combustion and wastewater treatment. For life support systems it is used in high-altitude flight, deep-sea diving, clinical respiratory therapy or anesthesiology, and emergency medical and fire service rescues.

7. Production and Distribution

7.1 Most oxygen is produced cryogenically by distilling liquid air. The demand for ultrahigh purity within the semiconductor industry has led to a more thorough distillation of cryogenic oxygen. Further, noncryogenic production has become significant in recent years. The principal difference among these sources of oxygen is the resulting oxygen purity detailed below. The hazards of oxygen are affected greatly by purity and, in general, higher purity is more hazardous However, fire events can and do occur in any oxygen–enriched atmosphere.

7.2 *Cryogenic Production*—Cryogenically produced oxygen is distilled in a five-step process in which air is: (*1*) filtered to remove particles; (*2*) compressed to approximately 700 kPa [100 psig] pressure; (*3*) dried to remove water vapor and carbon dioxide; (*4*) cooled to −160 °C [−256 °F] to liquefy it partially; and (*5*) distilled to separate each component gas. The end products are oxygen, nitrogen, and inert gases such as argon and neon; the principal secondary products are nitrogen and argon. Commercial oxygen is produced to a minimum 99.5 % purity, but typical oxygen marketed today is more likely to be near 99.9 % purity.