Designation: G88 – 13

Standard Guide for Designing Systems for Oxygen Service[1]

This standard is issued under the fixed designation G88; 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 applies to the design of systems for oxygen or oxygen-enriched service but is not a comprehensive document. Specifically, this guide addresses system factors that affect the avoidance of ignition and fire. It does not thoroughly address the selection of materials of construction for which Guides G63 and G94 are available, nor does it cover mechanical, economic or other design considerations for which well-known practices are available. This guide also does not address issues concerning the toxicity of nonmetals in breathing gas or medical gas systems.

NOTE 1—The American Society for Testing and Materials 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.

1.2 *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 and health practices and determine the applicability of regulatory requirements prior to use.*

1.3 This standard guide is organized as follows:

Section Title	Section
Referenced Documents	2
ASTM Standards	2.1
ASTM Adjuncts	2.2
ASTM Manuals	2.3
NFPA Documents	2.4
CGA Documents	2.5
EIGA Documents	2.6
Terminology	3
Significance and Use	4
Purpose of G88	4.1
Role of G88	4.2
Use of G88	4.3
Factors Affecting the Design for an Oxygen or Oxygen-Enriched System	5
General	5.1
Factors Recognized as Causing Fires	5.2
Temperature	5.2.1
Spontaneous Ignition	5.2.2
Pressure	5.2.3
Concentration	5.2.4
Contamination	5.2.5
Particle Impact	5.2.6
Heat of Compression	5.2.7
Friction and Galling	5.2.8
Resonance	5.2.9
Static Electric Discharge	5.2.10
Electrical Arc	5.2.11
Flow Friction	5.2.12
Mechanical Impact	5.2.13
Kindling Chain	5.2.14
Other Ignition Mechanisms	5.2.15
Test Methods	6
System Design Method	7
Overview	7.1
Final Design	7.2
Avoid Unnecessarily Elevated Temperatures	7.3
Avoid Unnecessarily Elevated Pressures	7.4
Design for System Cleanness	7.5
Avoid Particle Impacts	7.6
Minimize Heat of Compression	7.7
Avoid Friction and Galling	7.8
Avoid Corrosion	7.9
Avoid Resonance	7.10
Use Proven Hardware	7.11
Design to Manage Fires	7.12
Anticipate Indirect Oxygen Exposure	7.13
Minimize Available Fuel/Oxygen	7.14
Avoid Potentially Exothermic Material Combinations	7.15
Anticipate Common Failure Mechanism Consequences	7.16
Avoid High Surface-Area-to-Volume (S/V) Conditions where Practical	7.17

[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.

Current edition approved Oct. 1, 2013. Published November 2013. Originally approved in 1984. Last previous edition approved in 2005 as G88 – 05. DOI: 10.1520/G0088-13.

Section Title	Section
Avoid Unnecessarily-Elevated Oxygen Concentrations	7.18
Anticipate Permutations from Intended System Design	7.19
Avoid Designs and Failure Scenarios that can Introduce Potential Flow Friction Ignition Hazards	7.20
Use Only the Most Compatible of Practical Materials and Designs	7.21
Provide Thorough Safety Training for All Personnel Working with Oxygen or Oxygen-Enriched Components or Systems, including Design, Cleaning, Assembly, Operations, and Maintenance as Applicable to Personnel	7.22
Miscellaneous	7.23
Examples	8
Key Words	9
References	

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

G93 Practice for Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen-Enriched Environments

G94 Guide for Evaluating Metals for Oxygen Service

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

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

NOTE 2—The latest versions of these referenced documents should be consulted.

2.2 *ASTM Adjuncts:*[3]

ADJG0088 Oxygen Safety Videotape and Separate

2.3 *ASTM Manual:*

Manual 36 Safe Use of Oxygen and Oxygen Systems: Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation

2.4 *NFPA Standards*[4]

NFPA 50 Standard for Bulk Oxygen Systems at Consumer Sites

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

2.5 *Compressed Gas Association Documents:*

CGA E-4 Standard for Gas Pressure Regulators

CGA G-4.1 Cleaning Equipment for Oxygen Service

CGA G-4.4 Oxygen Pipeline and Piping Systems

CGA G-4.6 Oxygen Compressor Installation and Operation Guide

CGA G-4.7 Installation Guide for Stationary Electric Motor Driven Centrifugal Liquid Oxygen Pumps

CGA G-4.8 Safe Use of Aluminum Structured Packing for Oxygen Distillation

CGA G-4.9 Safe Use of Brazed Aluminum Heat Exchangers for Producing Pressurized Oxygen

CGA G-4.11 Reciprocating Oxygen Compressor Code of Practice

CGA G-4.13 Centrifugal Compressors for Oxygen Service

CGA P-8.4 Safe Operation of Reboilers/Condensers in Air Separation Units

CGA P-8 Safe Practices Guide for Air Separation Plants

CGA P-25 Guide for Flat Bottomed LOX/LIN/LAR Storage Tank Systems

CGA PS-15 Toxicity Considerations of Nonmetallic Materials in Medical Oxygen Cylinder Valves

CGA SB-2 Definition of Oxygen Enrichment/Deficiency Safety Criteria

2.6 *European Industrial Gases Association Documents:*

EIGA/IGC 4 Fire Hazards of Oxygen and Oxygen Enriched Atmospheres

EIGA/IGC 10 Reciprocating Oxygen Compressors For Oxygen Service

EIGA/IGC 13 Oxygen Pipeline and Piping Systems

EIGA/IGC 27/12 Centrifugal Compressors For Oxygen Service

EIGA/IGC 33 Cleaning of Equipment for Oxygen Service Guideline

EIGA/IGC 65 Safe Operation of Reboilers/Condensers in Air Separation Units

EIGA/IGC 73/08 Design Considerations to Mitigate the Potential Risks of Toxicity when using Non-metallic Materials in High Pressure Oxygen Breathing Systems

EIGA/IGC 115 Storage of Cryogenic Air Gases at Users Premises

EIGA/IGC 127 Bulk Liquid Oxygen, Nitrogen and Argon Storage Systems at Production Sites

EIGA/IGC 144 Safe Use of Aluminum-Structured Packing for Oxygen Distillation

EIGA/IGC 145 Safe Use of Brazed Aluminum Heat Exchangers for Producing Pressurized Oxygen

EIGA/IGC 147 Safe Practices Guide for Air Separation Plants

EIGA/IGC 148 Installation Guide for Stationary Electric-Motor-Driven Centrifugal Liquid Oxygen Pumps

EIGA/IGC 154 Safe Location of Oxygen, Nitrogen and Inert Gas Vents

EIGA/IGC 159 Reciprocating Cryogenic Pump and Pump Installation

[2] For referenced ASTM adjuncts and 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.

[3] Available from ASTM Headquarters, Order ADJG0088.

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

EIGA/IGC 179 Liquid Oxygen, Nitrogen, and Argon Cryogenic Tanker Loading Systems

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *characteristic elements*—those factors that must be present for an ignition mechanism to be active in an oxygen-enriched atmosphere.

3.1.2 *direct oxygen service*—service in contact with oxygen during normal operations. Examples: oxygen compressor piston rings, control valve seats.

3.1.3 *galling*—a condition whereby excessive friction between high spots results in localized welding with subsequent splitting and a further roughening of rubbing surfaces of one or both of two mating parts.

3.1.4 *indirect oxygen service*—service in which oxygen is not normally contacted but in which it might be as a result of a reasonably foreseeable malfunction (single fault), operator error, or process disturbance. Examples: liquid oxygen tank insulation, liquid oxygen pump motor bearings.

3.1.5 *oxygen-enriched atmosphere*—a fluid (gas or liquid) mixture that contains more than 25 mol % oxygen.

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

4. Significance and Use

4.1 *Purpose of Guide G88*—The purpose of this guide is to furnish qualified technical personnel with pertinent information for use in designing oxygen systems or assessing the safety of oxygen systems. It emphasizes factors that cause ignition and enhance propagation throughout a system's service life so that the occurrence of these conditions may be avoided or minimized. It is not intended as a specification for the design of oxygen systems.

4.2 *Role of Guide G88*—ASTM Committee G04's abstract standard is Guide G128, and it introduces the overall subject of oxygen compatibility and the body of related work and related resources including standards, research reports and a video[3] G04 has developed and adopted for use in coping with oxygen hazards. The interrelationships among the standards are shown in Table 1. Guide G88 deals with oxygen system and hardware design principles, and it is supported by a regulator ignition test (see G175).Other standards cover: *(1)* the selection of materials (both metals and nonmetals) which are supported by a series of standards for testing materials of interest and for preparing materials for test; *(2)* the cleaning of oxygen hardware which is supported by a series of standards on cleaning procedures, cleanliness testing methods, and cleaning agent selection and evaluation; *(3)* the study of fire incidents in oxygen systems; and *(4)* related terminology.

4.3 *Use of Guide G88*—Guide G88 can be used as an initial design guideline for oxygen systems and components, but can also be used as a tool to perform safety audits of existing oxygen systems and components. When used as an auditing tool for existing systems, Guide G88 can be applied in two stages: first examining system schematics/drawings, then by visually inspecting the system (that is, "walking the pipeline"). Guide G88 can be used in conjunction with the materials selection/hazards analysis approach outlined in Guides G63

TABLE 1 Role of Guide G88 with Respect to Other ASTM G04 Standard Guides and Practices and their Supporting Test Methods[A],[B]

G128 Guide to Control of Hazards and Risks in Oxygen-Enriched Systems
G88 Designing Systems for Oxygen Service
G175 Evaluating the Ignition Sensitivity and Fault Tolerance of Oxygen Regulators

G63 Evaluating Nonmetallic Materials
D2512 Compatibility of Materials With Liquid Oxygen (Mechanical Impact)
D2863 Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion (Oxygen Index)
D4809 Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)
G72 Autogenous Ignition Temperature of Liquids and Solids in High-Pressure Oxygen Enriched Atmospheres
G74 Ignition Sensitivity of Materials to Gaseous Fluid Impact
G86 Determining Ignition Sensitivity of Materials to Mechanical Impact in Pressurized Oxygen Environments
G114 Aging Oxygen-Service Materials Prior to Flammability Testing
G125 Measuring Liquid and Solid Material Fire Limits in Gaseous Oxidants

G94 Evaluating Metals
G124 Determining the Combustion Behavior of Metallic Materials in Oxygen Enriched Atmospheres

G93 Cleaning Methods for Material and Equipment
G120 Determination of Soluble Residual Contamination in Materials and Components by Soxhlet Extraction
G136 Determination of Soluble Residual Contaminants in Materials by Ultrasonic Extraction
G144 Determination of Residual Contamination of Materials and Components by Total Carbon Analysis Using a High Temperature Combustion Analyzer
G127 Guide to the Selection of Cleaning Agents for Oxygen Systems
G122 Test Method for Evaluating the Effectiveness of Cleaning Agents
G121 Preparation of Contaminated Test Coupons for the Evaluation of Cleaning Agents
G131 Cleaning of Materials and Components by Ultrasonic Techniques

G145 Studying Fire Incidents in Oxygen Systems

G126 Terminology Related to the Compatibility and Sensitivity of Materials in Oxygen-Enriched Atmospheres
Manual 36 – Safe Use of Oxygen and Oxygen Systems: Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation

[A] ASTM D2863 is under the jurisdiction of Committee D20 on Plastics, and D4809 is under the jurisdiction of Committee D02 on Petroleum Products and Lubricants but both are used in the asessment of flammability and sensitivity of materials in oxygen-enriched atmospheres.
[B] ASTM Manual 36 – Safe Use of Oxygen and Oxygen Systems can be used as a handbook to furnish qualified technical personnel with pertinent information for use in designing oxygen systems or assessing the safety of oxygen systems. However, Manual 36 is not a balloted technical standard.