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Standard Guide for Designing Systems for Oxygen Service¹

This standard is issued under the fixed designation G 88; 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.

^{ε1} NOTE—Keywords were added editorially in March 1998.

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 address the selection of materials of construction for which Guides G 63 and G 94 are available, nor does it concern mechanical, economic or other design considerations for which well-known practices are available.

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 limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- G 63 Guide for Evaluating Nonmetallic Materials for Oxygen Service²
- G 72 Test Method for Autogenous Ignition Temperature of Liquids and Solids in a High-Pressure Oxygen-Enriched Environment²
- G 74 Test Method for Ignition Sensitivity of Materials to Gaseous Fluid Impact²
- G 93 Practice for Cleaning Methods for Material and Equipment Used in Oxygen-Enriched Environments²
- G 94 Guide for Evaluating Metals for Oxygen Service²

2.2 ASTM Adjuncts:

¹ This guide is under the jurisdiction of ASTM Committee G-4 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 *Annual Book of ASTM Standards*, Vol 14.02.

Oxygen Safety Video³

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

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

3.1.2 *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, operator error, or process disturbance. Examples: liquid oxygen tank insulation, liquid oxygen pump motor bearings.

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

3.1.4 *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 The purpose of this guide is to furnish qualified technical personnel with pertinent information to use in designing 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.

5. Factors Affecting the Design for an Oxygen or Oxygen-Enriched System

5.1 *General*—An oxygen system designer should understand that oxygen, fuel, and heat (source of ignition) must be present to start and propagate a fire. Since combustible materials and oxygen are usually present, the design of a system for oxygen or oxygen enriched service is primarily a matter of understanding the factors that are potential sources of ignition or which aggravate consequential propagation. The goal is to eliminate these factors or compensate for their

³ Available from ASTM Headquarters, Order PCN 12-700880-31.

presence. Preventing fires involves both minimizing system environments that enhance fire and maximizing the use of system materials with properties that resist ignition and combustion.

5.2 Factors Recognized as Causing Fires:

5.2.1 Temperature—As the temperature of a material increases, the amount of energy that must be added to produce ignition decreases. Operating a system at unnecessarily elevated temperatures, whether locally or generally elevated, reduces this safety margin. The ignition temperature of the most easily ignited material in a system is related to that temperature measured by Test Method G 72 but is also a function of the system pressure, configuration and operation, and the thermal history of the material. Elevated temperature also facilitates sustained combustion of materials that might otherwise be self-extinguishing.

5.2.2 Pressure—As the pressure of a system increases, the ignition temperatures of its components typically decrease, and the rates of fire propagation increase. Therefore, operating a system at unnecessarily elevated pressures increases the probability and consequences of a fire. It should be noted that pure oxygen, even at lower than atmospheric pressure, may still pose a significant hazard with noncompatible materials such as hydrocarbon pump oils.

5.2.3 Concentration—As oxygen concentration decreases from 100 % with the balance being inert gases, there are progressive decreases in the likelihood and intensity of a potential reaction. Greater latitude may therefore be exercised in the design of a system for dilute oxygen service.

5.2.4 Contamination—Contamination can be present in a system because of inadequate initial cleanness, introduction during assembly or service life, or generation within the system by abrasion, flaking, etc. Contaminants may be liquids, solids, or gases. Such contamination may be highly flammable and readily ignitable, for example, hydrocarbon oils. Accordingly, it is likely to ignite and promote consequential system fires. However, even normally inert contaminants, such as rust, may produce ignition through particle impact (see 5.2.5) or friction (see 5.2.7) or through augmenting of resonance heating effects (see 5.2.8).

5.2.5 Particle Impact—Collisions of inert or ignitable solid particles entrained in an oxidant stream are associated with potential ignition. Such ignition may result from the particle being flammable and igniting upon impact and, in turn, igniting other system materials. Ignition may also result from heating of the particle and subsequent contact with system plastics and elastomers, from fine flammable particles produced during the collision, or from the direct transfer of kinetic energy during the collision. Absolute removal of particles is not possible, and systems can self-regenerate particles. Hence, a system must be designed to tolerate at least some particle presence. The hazard associated with particles increases with both the particles' heat of combustion and their kinetic energies. The quantity of particles in a system will tend to increase with the age of the system.

5.2.6 Heat of Compression—Heat is generated from the conversion of mechanical energy when a gas is compressed from a low to a high pressure. This can occur when high-

pressure oxygen is released into a dead-ended tube or pipe, quickly compressing the residual oxygen that was in the tube ahead of it. (Example: a downstream valve in a dead-ended high-pressure oxygen manifold.) The elevated temperatures produced can ignite contaminants or elevate system components above their ignition temperature. The hazard of heat of compression increases with system pressure and with pressurization rates.

TABLE 1 Theoretical Maximum Temperature Obtained when Compressing Oxygen Adiabatically from 20°C and One Standard Atmosphere to the Pressures Shown^A

Final Pressure, P_f		Pressure Ratio P_f/P_i	Final Temperature, T_f	
kPa	PSIA		°C	°F
345	50	3.4	143	289
690	100	6.8	234	453
1000	145	9.9	291	556
1379	200	13.6	344	653
2068	300	20.4	421	789
2758	400	27.2	480	896
3447	500	34.0	530	986
5170	750	51.0	628	1163
6895	1000	68.0	706	1303
10000	1450	98.6	815	1499
13790	2000	136.1	920	1688
27579	4000	272.1	1181	2158
34474	5000	340.1	1277	2330
100000	14500	986.4	1828	3322
1 000 000	145000	9863.9	3785	6845

^A See 5.2.6.

5.2.6.1 Equation—A formula for the theoretical maximum temperature that can be developed when pressurizing a gas rapidly without heat dissipation from one pressure and temperature to an elevated pressure is as follows:

$$T_f/T_i = [P_f/P_i]^{(n-1)/n} \quad (1)$$

where:

T_f = final temperature, abs,

T_i = initial temperature, abs,

P_f = final pressure, abs,

P_i = initial pressure, abs, and

$$n = \frac{C_p}{C_v} = 1.40 \text{ for oxygen} \quad (2)$$

where:

C_p = specific heat at constant pressure, and

C_v = specific heat at constant volume.

5.2.6.2 Table 1 gives the theoretical temperatures which could be obtained by compressing oxygen adiabatically from 20°C and one standard atmosphere to the pressures shown.

5.2.7 Friction—The rubbing together of two surfaces can produce heating and can generate particulates. Such heating may elevate a system component above its ignition temperature. Particulates can participate as contaminants (see 5.2.4) or in particle impacts (see 5.2.5). The hazard associated with friction generally increases with the loading and rubbing rates.

5.2.8 Resonance—Acoustic oscillations within resonant cavities are associated with rapid heating. The temperature rises more rapidly and achieves higher values where particles are present or where there are high gas velocities. Resonance