



Designation: **G63–99 (Reapproved 2007) G63 – 15**

Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service¹

This standard is issued under the fixed designation G63; 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 nonmetallic materials, (hereinafter called materials) under consideration for oxygen or oxygen-enriched fluid service, direct or indirect, as defined below. It is intended for use in selecting materials for applications in connection with the production, storage, transportation, distribution, or use of oxygen. It is concerned primarily with the properties of a material associated with its relative susceptibility to ignition and propagation of combustion; it does not involve mechanical properties, potential toxicity, outgassing, reactions between various materials in the system, functional reliability, or performance characteristics such as ~~aging, shredding, or sloughing of particles,~~ physical aging, degradation, abrasion, hardening, or embrittlement, except when these might contribute to an ignition.

1.2 When this document was originally published in 1980, it addressed both metals and nonmetals. Its scope has been narrowed to address only nonmetals and a separate standard Guide **G94** has been developed to address metals.

1.3 *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.*

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.

NOTE 2—In evaluating materials, any mixture with oxygen exceeding atmospheric concentration at pressures higher than atmospheric should be evaluated from the hazard point of view for possible significant increase in material combustibility.

2. Referenced Documents

2.1 ASTM Standards:²

D217 Test Methods for Cone Penetration of Lubricating Grease

D566 Test Method for Dropping Point of Lubricating Grease **G63-15**

D1264 Test Method for Determining the Water Washout Characteristics of Lubricating Greases **G63-15**

D1743 Test Method for Determining Corrosion Preventive Properties of Lubricating Greases

D1748 Test Method for Rust Protection by Metal Preservatives in the Humidity Cabinet

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)

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

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

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 March 15, 2007; Nov. 1, 2015. Published May 2007/January 2016. Originally approved in 1980. Last previous edition approved in 1999/2007 as **G63–99/G63–99(2007)**. DOI: 10.1520/G0063-99R07:10.1520/G0063-15.

² 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.

2.2 Federal Standard:

Fed. Test Method Std. 91B Corrosion Protection by Coating: Salt Spray (Fog) Test³

2.3 Other Standard:

BS 3N:100: 1985 Specification for General Design Requirements for Aircraft Oxygen Systems and Equipment⁴

2.4 Other Documents:

CGA Pamphlet G4.4 Industrial Practices for Gaseous Oxygen Transmission and Distribution Oxygen Pipeline and Piping System⁵

EIGA IGC 13-12 Oxygen Pipeline and Piping Systems

NSS 1740.15 NASA Safety Standard for Oxygen and Oxygen Systems⁶

3. Terminology

3.1 Definitions:

3.1.1 *autoignition temperature*—the temperature at which a material will spontaneously ignite in oxygen under specific test conditions (see Guide conditions G88).

3.2 Definitions of Terms Specific to This Standard:

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

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

3.2.3 *indirect oxygen service*—not normally in contact with oxygen, but which 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.

3.2.4 *maximum use pressure*—the maximum pressure to which a material can be subjected due to a *reasonably* foreseeable malfunction, operator error, or process upset.

3.2.5 *maximum use temperature*—the maximum temperature to which a material can be subjected due to a *reasonably* foreseeable malfunction, operator error, or process upset.

3.2.6 *nonmetallic*—any material, other than a metal, or any composite in which the metal is not the most easily ignited component and for which the individual constituents cannot be evaluated independently.

3.2.7 *operating pressure*—the pressure expected under normal operating conditions.

3.2.8 *operating temperature*—the temperature expected under normal operating conditions.

3.2.9 *oxygen-enriched*—applies to a fluid (gas or liquid) that contains more than 25 mol % oxygen.

3.2.10 *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.

3.2.11 *reaction effect*—the personnel injury, facility damage, product loss, downtime, or mission loss that could occur as the result of an ignition.

4. Significance and Use

4.1 The purpose of this guide is to furnish qualified technical personnel with pertinent information for use in selecting materials for oxygen service in order to minimize the probability of ignition and the risk of explosion or fire. It is not intended as a specification for approving materials for oxygen service.

5. Factors Affecting Selection of Material

5.1 *General*—The selection of a material for use with oxygen or oxygen-enriched atmospheres is primarily a matter of understanding the circumstances that cause oxygen to react with the material. Most materials in contact with oxygen will not ignite *without a source of ignition energy*. When an energy-input rate, as converted to heat, is greater than the rate of heat dissipation, and the temperature increase is continued for sufficient time, ignition and combustion will occur. ~~Thus considered: the A~~ material's minimum ignition temperature, temperature and the energy ignition sources that will produce a sufficient increase in the temperature of the material. ~~These material must therefore be considered. Ignition temperatures and ignition sources should be viewed in the context of the entire system design so that the specific factors listed below will assume the proper relative significance. To Therefore: summarize: material it depends on the application. suitability for oxygen service is application-dependent.~~

³ Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, <http://www.access.gpo.gov>.

⁴ Available from British Standards Institute (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., <http://www.bsi-global.com>.

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

⁶ National Aeronautics and Space Administration, Office of Safety and Mission Assurance, Washington, DC.

NOTE 3—For the safe use of materials in oxygen, in addition to the flammability and ignitability properties of the material, it is necessary to consider other physical and chemical properties such as mechanical properties, potential toxicity, etc. Consequently, because ignition and physical (or chemical) properties may be conflicting for selecting a material, it may be necessary in such cases to perform component tests simulating the most probable ignition mechanisms (e.g., a rapid pressurization test on a valve if heat of compression is analyzed as severe).

5.2 Properties of the Material:

5.2.1 Factors Affecting Ease of Ignition—Generally, ~~in when~~ considering a material for a specific oxygen application, one of the most significant factors is its minimum ignition temperature in oxygen. Other factors that will affect its ignition ~~are include~~ relative resistance to ~~impact~~, various ignition energies, geometry, configuration, specific heat, relative porosity, thermal conductivity, preoxidation or passivity, and “heat-sink effect.” ~~The latter~~Heat-sink effect is the heat-transfer ~~aspect~~capacity of the material relative to that of the ~~mass~~material in intimate contact with it, with respect to both the amount and the physical arrangement of each and to their respective physical properties. ~~considering the mass, physical arrangement, and physical properties of each.~~ For instance, a gasket material may have a relatively low ignition temperature but be extremely resistant to ignition when confined between two steel flanges. The presence of a small amount of an easily ignitable ~~material~~contaminant, such as a hydrocarbon oil or a grease film, can promote the ignition of the base material. Accordingly, cleanliness is vital to minimize the risk of ignition (1).⁷ See also Practice G93 and Refs. 2–3.

5.2.2 Factors Affecting Propagation—~~After~~Once a material is ignited, combustion may be sustained or may halt. Among the factors that affect whether fire will continue are the basic composition of the material, the ~~pressure~~, presence of heat-sink effects, the pressure, the initial temperature, the geometric state of the matter, and whether ~~the available oxygen will be consumed or the accumulation of combustion products reduce the availability of oxygen sufficiently to stop~~there is oxygen available to sustain the reaction. Combustion may also be interrupted by the presence of a heat sink.

5.2.3 Properties and Conditions Affecting Potential Resultant Damage—~~A material’s heat of combustion, its mass, the oxygen concentration, flow conditions before and after ignition, and the flame propagation characteristics affect the potential damage if ignition should occur and should~~The material properties and system conditions that could affect the damage potential if ignition occurs should be taken into account ~~in when~~ estimating the reaction effect in 7.5. These properties and conditions include the material’s heat of combustion, its mass, the oxygen concentration, flow conditions before and after ignition, and the flame propagation characteristics.

5.3 Operating Conditions—Conditions that affect the suitability of a material include ~~the other materials of construction and their arrangement in the equipment and~~ pressure, temperature, concentration, flow, and velocity of the oxygen gas velocity, and the ignitability of surrounding materials. Pressure and temperature are generally the most significant, and their effects show up in the estimate of ignition potential (5.4) and reaction effect (5.5), as explained in Section 7.

5.3.1 Pressure—The operating pressure is important, not only because it generally affects the generation of potential ignition mechanisms, but also because it ~~usually significantly~~ affects the destructive effects if ignition should occur. While generalizations are difficult, ~~rough scales approximate reaction effects~~ would be as given in Table 1.

NOTE 4—While the pressure generally affects the reaction as indicated in Table 1, tests indicate that it has varying effects on individual flammability properties. For example, for many materials, increasing pressure results in the following:

- (1) An increase in propagation rate, with the greatest increase in rate at lower pressures but with significant increases in rate at high pressures;
 - (1) An increase in propagation rate, with the greatest increase in rate at lower pressures but with significant increases in rate at high pressures;
 - (2) A reduction in ignition temperature, with the greatest decrease at low pressure and a smaller rate at high pressure, however, it should be noted that increasing autoignition temperatures with increasing pressures have been reported for selected polymers, due to competing kinetics (4);
 - (3) An increase in sensitivity to mechanical impact;
 - (4) A reduction in oxygen index, as measured in an exploratory study (5), with sharper initial declines in materials of high oxygen index but with only slight relative declines in general above 10 atmospheres and up to at least 20 atmospheres;
 - (5) A negligible change in heat of combustion; and
 - (6) An increase in the likelihood of compression heating ignition, with the greatest likelihood at the highest pressures.
- (2) A reduction in ignition temperature, with the greatest decrease at low pressure and a smaller rate at high pressure, however, it should be noted that increasing autoignition temperatures with increasing pressures have been reported for selected polymers, due to competing kinetics (4);

⁷ The boldface numbers in parentheses refer to the list of references at the end of this standard.

TABLE 1 Reaction Effect Assessment for Typical Pressures

kPa	psi	Reaction Effect Assessment
0–70	0–10	relatively mild
70–700	10–100	moderate
700–7000	100–1000	intermediate
7000–20 000	1000–3000	severe
Over 20 000	over 3000	extremely severe

- (3) An increase in sensitivity to mechanical impact;
- (4) A reduction in oxygen index, as measured in an exploratory study (5), with sharper initial declines in materials of high oxygen index but with only slight relative declines in general above 10 atmospheres and up to at least 20 atmospheres;
- (5) A negligible change in heat of combustion; and
- (6) An increase in the likelihood of adiabatic compression ignition, with the greatest likelihood at the highest pressures.

In the case of friction, increased pressure may improve heat dissipation and make ignition at constant frictional energy input less likely than at lower pressure. Increased pressure also reduces the likelihood of spark generation at constant electric field strength through increased breakdown voltage values.

5.3.2 *Temperature*—Increasing temperature obviously increases the risk of ignition but does not generally contribute to the reaction effect. The material should have a minimum ignition temperature, as determined by an acceptable test procedure, that exceeds the maximum use temperature (as defined in 3.2.5) by a suitable safety margin.

5.3.3 *Concentration*—As oxygen concentration decreases from 100 %, the likelihood and intensity of a potential reaction also decrease; therefore, greater latitude may be exercised in the selection of materials.

5.4 *Ignition Mechanisms*—For an ignition to occur, it is necessary to have three elements present: oxidizer, fuel, and ignition energy. The oxygen environment is obviously the oxidizer, and the material under consideration is the fuel. Several potential sources of ignition energy are listed below. The list is neither all-inclusive nor in order of importance nor in frequency of occurrence.

5.4.1 *Friction*—The rubbing of two solid materials results in the generation of heat. Example: the rub of a centrifugal compressor rotor against its casing.

5.4.2 *Heat of Compression*—Heat is generated from the conversion of mechanical energy when a gas is compressed from a low pressure 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. As the ratio of final pressure to initial pressure increases, so, too, does the final theoretical temperature generated from the compression event. Example: a downstream valve in a dead-ended high-pressure oxygen manifold.

5.4.2.1 *Equation*—An equation that can be used to estimate the theoretical maximum temperature that can be developed when pressurizing oxygen rapidly from one pressure and temperature to an elevated pressure is as follows:

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

where:

- T_f = final temperature, abs,
- T_i = initial temperature, abs,
- P_f = final pressure, abs,
- P_i = initial pressure, abs, and
- $n = \frac{C_p}{C_v} = 1.40$ for oxygen,

where: <https://standards.iteh.ai/catalog/standards/sist/6275b421-6d25-4512-8673-b274e2f0e5ce/astm-g63-15>

- C_p = specific heat at constant pressure, and
- C_v = specific heat at constant volume.

Table 2 gives the theoretical temperatures which could be obtained by compressing oxygen from one atmosphere (absolute) and 20°C to the pressures shown.

TABLE 2 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
10 000	1450	98.6	815	1499
13 790	2000	136.1	920	1688
27 579	4000	272.1	1181	2158
34 474	5000	340.1	1277	2330
100 000	14 500	986.4	1828	3322
1 000 000	145 000	9883.9	3785	6845

^A See 5.4.2.

NOTE 5—The final temperature calculated by Eq 1 is conservative because the equation assumes instantaneous pressurization with no heat loss (adiabatic). The equation is also conservative because it treats oxygen as an ideal gas, which potentially results in calculated final temperature values being much higher than would be realistic and higher than if calculated using real gas equations.

5.4.3 *Heat From Mass Impact*—Heat is generated from the transfer of kinetic energy when an object having relatively large mass or momentum strikes a material. Example: hammer striking oxygen-saturated macadam.

5.4.4 *Heat from Particle Impact*—Heat is generated from the transfer of kinetic and possibly thermal energy when small particles (sometimes incandescent), moving at high velocity, strike a material. Example: dirt particles striking a valve seat in an inadequately cleaned high-velocity pipeline.

5.4.5 *Static Electric Discharge*—Electrical discharge from static electricity, possibly generated by high fluid flow under certain conditions, may occur, especially where particulate matter is present. Example: arcing in poorly cleaned, inadequately grounded piping.

5.4.6 *Electrical Arc*—Electrical arcing may occur from motor brushes, electrical control equipment, instrumentation, lightning, etc. Example: defective pressure switch.

5.4.7 *Resonance*—Acoustic oscillations within resonant cavities are associated with rapid temperature rise. This rise is more rapid and achieves higher values where particulates are present or where there are high gas velocities. Ignition can result. For example: a gas flow into a tee and out of the side port when the remaining port presents a resonant cavity.

5.4.8 *Internal Flexing*—Continuous rapid flexing of a material can generate heat. Such heating may add to environmental factors and increase the possibility of ignition. For example: a gasket protruding into the fluid flow stream.

5.4.9 *Other*—Since little is known about the actual cause of some oxygen fires or explosions, other mechanisms, not readily apparent, may be factors in, or causes of such incidents. These might include external sources, such as defective electric resistance-heating elements, careless-smoking, welding sparks or spatter, and nearby open flames; flames, or internal sources such as flow friction and material fracture.

5.5 *Reaction Effect*—The effect of an ignition (and subsequent combustion propagation, if it should occur) has a strong bearing on the selection of a material. While it is an obviously imprecise and strongly subjective judgment, it must be balanced against factors such as those given in 5.6. Suggested criteria for rating the reaction effect severity are given in Table 3, and a method of applying the rating in a material selection process is given in Section 7. The user should keep in mind that, in many cases, the reaction effect severity rating for a particular application can be lowered by changing other materials that may be present in the system, changing component locations, varying operating procedures, or using barricades or shields and the like-shields.

5.6 *Extenuating Factors*—Performance requirements, prior experience with the material, availability, and cost enter into the decision. For instance, while a particular material may be rated relatively low based on conventional acceptance criteria, many years of successful safe usage or full-life cycle tests might indicate its continued acceptance.

6. Test Methods

6.1 *Calorimeter Test, Heat of Combustion, Test Method D4809*—This is a measurement of the heat evolved per unit of sample specimen mass when a material is completely burned in 25 to 35 atm (2.5 to 3.5 MPa) of oxygen at constant volume. The results are reported in calories per gram (or megajoules per kilogram). For many materials, measured amounts of combustion promoter must be added to ensure complete combustion. Heat of combustion is a test readily conducted and many differing bomb calorimeter methods provide results with adequate accuracy for use with this guide.

6.2 *Ignition Sensitivity of Materials to Mechanical Impact in Ambient and Pressurized Oxygen Environments, Test Method G86*—This is a determination of the drop-height required to produce a reaction when energy from a known mass is transmitted

TABLE 3 Reaction Effect Assessment for Oxygen Applications

Rating		Effect on Personnel Safety	Effect on System Objectives	Effect on Functional Capability
Code	Severity Level			
A	Negligible	No injury to personnel	No unacceptable effect on production, storage, transportation, distribution, or use as applicable	No unacceptable damage to the system
B	Marginal	Personnel-injuring factors can be controlled by automatic devices, warning devices, or special operating procedures	Production, storage, transportation, distribution, or use as applicable is possible by utilizing available redundant operational options	No more than one component or subsystem damaged. This condition is either repairable or replaceable within an acceptable time frame on site
C	Critical	Personnel injured (1) operating the system, (2) maintaining the system, or (3) being in vicinity of the system	Production, storage, transportation, distribution, or use as applicable impaired seriously	Two or more major subsystems are damaged—This condition requires extensive maintenance
D	Catastrophic	Personnel suffer death or multiple injuries	Production, storage, transportation, distribution, or use as applicable rendered impossible—major unit is lost	No portion of system can be salvaged—total loss

through a striker pin in contact with a sample specimen immersed in liquid oxygen or exposed to gaseous oxygen. Results are reported in drop-height and number of reactions in 20 drops. Test Method **G86** is currently the only mechanical impact test that is fully standardized, although other procedures are used in some laboratories. For this reason, and for the large quantity of background data already obtained using this procedure, Test Method **G86** is the recommended screening test to evaluate materials for mechanical impact sensitivity.

NOTE 6—Previous mechanical impact data in ambient pressure liquid oxygen may have been obtained following Test Method **D2512** procedures. In 1997, Test Method **G86** was updated to include a LOX impact test procedure that includes a more strict calibration procedure as an alternative to Test Method **D2512**. At a given plummet drop height the pressurized LOX mechanical impact system provides significantly lower impact energy than the ambient pressure LOX mechanical impact system; however, the relative ranking of materials was maintained.

NOTE 7—~~This test method~~ Test Method **G86** was developed as a screening technique for selection of nonmetallic materials for use in liquid and gaseous oxygen service components and systems; the test has proven to be consistent in its rankings. For tests in liquid oxygen, since the material specimen is immersed in liquid oxygen prior to impact, and since the liquid oxygen surrounding the specimen is maintained at atmospheric pressure, two concerns must be stated. The first concern relates to the physical changes ~~incurred~~ (for example, contraction, sub- T_g transitions, phase transitions) that occur in a specimen when the specimen temperature is reduced to cryogenic conditions. Sensitivity of selected materials may be significantly affected by ~~this~~ such physical ~~change~~ changes. The second concern relates to test severity. Experience indicates that most materials are more sensitive to ambient or heated gaseous oxygen environments, as opposed to cryogenic oxygen environments. Also, experience shows most materials have a tendency to display increasing sensitivity with increasing oxygen pressure. As a result, tests in ambient pressure liquid oxygen may not be sufficiently severe to discriminate materials for use in ambient or elevated temperature, high-pressure gaseous oxygen systems.

6.3 Limiting Oxygen Index Test, Index, Test Method D2863—This is a determination of the minimum concentration of oxygen in a flowing mixture of oxygen and nitrogen at 1 atm (0.1 MPa) that will just support flaming combustion from top ignition. The minimum oxygen concentration that will support combustion of materials in configurations that differ from the test configuration may be greater or less than the measured oxygen index value.

NOTE 8—Oxygen index data are reported as a volume percent oxygen (0 to 100). However, early work reported the volume fractional oxygen (0 to 1.0).

NOTE 9—Experience with oxygen index tests indicates that elevated temperatures enable combustion in lower oxygen concentrations and that passage of hot combustion products across an unaffected surface may preheat and promote combustion of materials in concentrations below the oxygen index value. In exploratory work to measure oxygen indices at elevated pressures up to 20 atm (2.0 MPa), it was found that the oxygen index decreased with increasing pressures, but that the ranking of materials was unchanged.

6.4 Autogenous Ignition Temperature Test, Temperature, Test Method G72—This is a determination of the minimum sample specimen temperature at which a material will spontaneously ignite when heated in an oxygen or oxygen-enriched atmosphere. Autogenous ignition (commonly called the autoignition temperature) should be measured at or above the maximum anticipated oxygen concentration. The test should be continued up to the ignition point or at least to 100°C above the maximum use temperature. The temperature that will produce autoignition of materials in configurations that differ from the test configuration may be greater or less than the measured autoignition temperature. System materials and contaminants may catalyze and lower ignition temperatures. Sample Specimens with large surface area to volume ratios (such as powders) typically ignite at lower temperatures. Flammable vapors that evolve at elevated temperatures may promote lower ignition temperatures, or if dissipated, result in higher autoignition temperatures.

NOTE 10—Pressure has its greatest effect on autoignition temperatures at lower levels pressures. For instance, an autoignition temperature of a typical elastomer as measured by Test Method **G72** may decrease 80°C between 1.5 and 15 psig (10 and 100 kPa), but may only decrease 10°C between 150 and 750 psig (1000 and 5000 kPa). The autoignition temperature test measures a highly behavioral property of a material, especially among polymers. Because it depends upon geometry, heating rate, temperature history of the material, trace contaminants and even catalytic effects of the environment, data collected on differing apparatuses using differing techniques may yield widely differing results. One should therefore not confuse the measured autoignition temperature minimum with the minimum temperature at which the material might ignite in actual hardware.

6.5 Gaseous Fluid Impact Test, Impact, Test Method G74—This is a test in which the material is subjected to a rapid oxygen pressure rise in a closed end tube. The procedure may be used as a fixed-pressure screening method or to measure a threshold pressure.

NOTE 11—This test method provides a reliable means for ranking nonmetallic materials for use in gaseous oxygen service components and systems. The test is configuration dependent and severe. Reaction threshold pressures obtained for most materials are below those pressures that would produce ignition in most common systems.

6.6 Additional Candidate Test Methods:

6.6.1 Thermal Analysis Tests—In these tests, a material's tendenci ~~estendency~~ tendency to undergo exothermic or endothermic activity are observed as temperature is raised. Pilot studies have been accomplished with Accelerating Rate Calorimeters (ARC) and Pressurized Differential Scanning Calorimeters (PDSC), and data have been published for autoignition temperatures measured by Differential Thermal Analysis (DTA). These tests indicate that material reactions occur at temperatures significantly different from those measured ~~with the autoignition temperature by~~ Test Method **G72**.

NOTE 12—Although some thermal analysis tests report lower autoignition temperatures than Test Method **G72**, one should not infer that ~~even~~ these measurements represent the lowest levels at which ignition could conceivably occur in real systems.

6.6.2 Friction/Rubbing Test—The material is heated by friction and rubbing resulting from contact between rotating and stationary test specimens. This test ~~method~~ permits evaluation of materials under various axial loads while exposed to elevated pressure oxygen or oxygen-enriched environments.

NOTE 13—There is no standard friction rubbing test for polymers and no plans to develop test. Preliminary tests were conducted by NASA in the late 1970s, and polymers proved difficult to ignite. At that time, test development focused on the study of metals which are more likely to experience severe rubs in actual systems. In the case of polymers, in particular nylon, the polymers melted and flowed from the friction zone.

6.6.3 *Particle Impact Test*—The material is struck by particles while exposed to a flowing oxygen environment.

NOTE 14—There is no standard test method for studying the ignition of nonmetals during particle impact and none is planned. Preliminary tests conducted by NASA suggest that polymers may be more difficult to ignite than metals under particle impact, possibly due to their ability to cushion an impact.

6.6.4 *Promoted Ignition Test*—The material is heated by exposure to an electrically-ignited promoter material ~~of having a known heat content~~ of combustion. This test method is currently being developed and permits evaluation of materials while subjected to elevated-pressure oxygen or oxygen-enriched environments.

NOTE 15—Polymers have much lower autoignition temperatures than metals and tend to ignite in a range of 150 to 450°C. Further, the combustion temperatures of most polymers exceeds the autoignition temperature of virtually all polymers. Hence tests to evaluate the ability of a promoter material or amount of promoter necessary to ignite polymers are not deemed meaningful and rather, the concept of a promoted ignition test is usually applied only to metals for which there are enormous ranges of ignition temperatures and for which the amount of polymer or metal necessary to cause ignition is more amenable to experiment.

6.6.5 *Electrical Arc*—This test is designed to evaluate the arc ignition characteristics of materials in pressurized oxygen or oxygen-enriched atmospheres.

NOTE 16—There is no standard test method for electrical arc ignition of nonmetals, and none is planned. Experience in oxygen and limited testing in air suggests that arc ignition of polymers as a result of static charge separation is unlikely at low pressures, perhaps also at high pressures. Further, reports on incident studies of NASA suggest that probable arcing at high pressures in oxygen did not produce ignition.

6.6.6 *Special Tests*—Depending on circumstances, a unique test may be required to qualify a material for a specific application, such as a resonance, internal flexing, or hot-wire ignition test.

7. Material Selection Method

7.1 *Overview*—To select a material for an application, first review the application to determine the probability that the chosen material will be exposed to significant ignition phenomena in service (7.2). Then consider the prospective material's susceptibility to ignition (7.3) and its destructive potential or capacity to involve other materials (7.4) once ignited. Next, consider the potential reaction effects of an ignition on the system environment (7.5). Finally, compare the demands of the application with the level of performance anticipated from the material in the context of the necessity to avoid ignition and decide whether the material will be acceptable (7.6).

7.2 *Ignition Probability Assessment*—In assessing a material's suitability for a specific oxygen application, the first step is to review the application for the presence of potential ignition mechanisms and the probability of their occurrence under both normal and *reasonably* foreseeable abnormal conditions. As shown in the Materials Evaluation Data sheets, **Appendix X1**, values may be assigned, based on the following probability scale:

- 0—Almost impossible
- 1—Remote
- 2—Unlikely
- 3—Probable
- 4—Highly probable

This estimate is quite imprecise and generally subjective, but furnishes a basis for evaluating an application through helping to focus on the most important properties. These ratings may in some cases be influenced by the materials present in the system.

7.3 *Ignition-Susceptibility Determination*—The next step is to determine its rating with respect to those factors which affect ease of ignition (5.2.1), assuming the material meets the other performance requirements of the application. If required information is not available in published literature or from prior related experience, one or more of the applicable tests described in Section 6 should be conducted to obtain it. The application and materials present will play a strong role in defining the most important criterion in determining the ignition susceptibility.

NOTE 17—Until an ASTM ~~procedure~~ test method is established for a particular test, test results are to be considered provisional.

7.4 *Post-Ignition Property Evaluation*—The properties and conditions that could affect potential resultant damage if ignition should occur (5.2.3) should be evaluated. Of particular importance is the total heat release potential, that is, the material's heat of combustion times its mass (in consistent units). When available, other important postignition data of interest are the ~~rate of resulting combustion~~ combustion reaction rate and the oxygen index.

7.5 *Reaction Effect Assessment*—Based on the evaluation of 7.4, and the conditions of the complete system in which the material is to be used, the reaction effect severity should be assessed using **Table 3** as a guide. In judging the severity level for entry on the Material Evaluation Data Sheets, **Appendix X1**, it is important to note that the severity level is defined by the most severe of any of the effects, that is, effect on personnel safety *or* on system objectives *or* on functional capability. The materials present in the system can affect the reaction effect assessments.

7.6 *Final Selection*—In the final analysis, the selection of a material for a particular application involves a complex interaction of the above steps, frequently with much subjective judgment, external influences, and compromises involved. While each case must ultimately be decided on its own merits, the following generalizations apply:

7.6.1 Use the least reactive material available consistent with sound engineering and economic practice. Attempt to maximize autoignition temperature, oxygen index, mechanical impact ignition energy, and gaseous impact pressure threshold. Attempt to minimize heat of combustion and total heat release. Not every test need be conducted for every application, but it is best to base material selections on more than one test method.

7.6.1.1 If the damage or personnel injury potential is high (Severity Level C or D) use the best (least reactive) practical material available (see Table 3).

7.6.1.2 If the damage or personnel injury potential is low (Severity Level A or B) and the ignition mechanism probability is low (2 or less) a material with a medium resistance to ignition may be used.

7.6.1.3 If one or more potential ignition mechanisms have a relatively high probability of occurrence (3 or 4 on the probability scale, 7.2) use only a material which has a very high resistance to ignition.

7.6.2 The higher the maximum use pressure, the more critical is the resistance to ignition (see 5.3.1).

7.6.3 Prefer a material whose autoignition temperature in oxygen (as determined by 6.4) exceeds the maximum use temperature by at least 100°C. A larger temperature differential may be appropriate for high use pressures (see 7.6.2) or other mitigating factors.

7.6.4 Autoignition temperatures of 400°C or higher are preferred; 160°C or lower, lower are unsuitable for all but the mildest applications (see 6.4).

7.6.5 Resistance to ignition by impact from drop heights of 43.3 in. (1100 mm) on repeated trials is preferred, while susceptibility to ignition at 6.0 in. (152 mm) or lower would render a material unsuitable for all but the mildest applications (see 6.2).

7.6.6 Heats of combustion of 2500 cal/g (10.5 MJ/kg) or less are preferred; heats of combustion of 10 000 cal/g (41.9 MJ/kg) or higher are unsuitable for all but the mildest applications (see 6.1).

7.6.7 Materials with high oxygen indices are preferable to materials with low oxygen indices. For demanding applications, choose a material with an oxygen index above 55. Materials with oxygen indices below 20 are unsuitable for all but the mildest applications (see 6.3).

NOTE 18—With respect to guidelines 7.6.3 – 7.6.7, the use of materials that yield intermediate test results is a matter of judgment involving consideration of all significant factors in the particular application.

7.6.8 Experience with a given material in a similar application or a similar material in the same application frequently forms a sound basis for a material selection. However, discretion should be used in the extrapolation of conditions.

7.6.9 Since some materials vary from batch to batch, it may be necessary to test each batch for some applications.

7.7 *Documentation*—Table X1.1 (Appendix X1) is a materials evaluation sheet filled out for a number of different applications. It indicates how a materials evaluation is made and what documentation is involved. Pertinent information such as operating conditions should be recorded; estimates of ignition mechanism probability and reaction effect ratings filled in; and a material selection made on the basis of the above guidelines. Explanatory remarks should be indicated by a letter in the “Remarks” column and noted following the table.

7.8 *Examples*—The following examples illustrate the material selection procedure applied to three different hypothetical cases involving valve seats, and one case of a gasket:

7.8.1 *High-Pressure Manifold Shutoff Valve:*

7.8.1.1 *Application Description*—An ambient-temperature 1-in. (2.54-cm) stainless steel manifold requires a manual shutoff valve located 20 ft (6.1 m) from a primary 5000-psig (34.5-MPa) pressure source. The line is to be located outdoors but near attended equipment. A primary pressure valve upstream can be opened rapidly, hence the line might be rapidly pressurized to 5000 psig. A soft-seated valve is desirable to allow ease of operation.

7.8.1.2 *Ignition Probability Assessment (see 7.2)*—Due to a small contact area and small quantity of rubbing motion during operation, friction ignition is considered to be remote. Though the valve can be opened rapidly, the maximum velocity of the seat during closure would be negligible, hence mechanical impact ignition is also rated remote. Since the system is both clean and dry, neither particle impact nor static electricity is felt considered to be likely. There is no electrical apparatus in the equipment, so that arc ignition is thought to be almost impossible. Since sudden pressurization of the system to 5000 psig (34.5 MPa) might occur, the theoretical temperature achievable from heat of compression (Eq 1) would be very high, and adiabatic compression ignition is thought to be a highly probable ignition source. No other ignition sources are identified, but their absence cannot be assumed. The summary of ignition probability ratings is:

Friction	1
Heat of Compression	4
Mechanical Impact	1
Particle Impact	2
Static Electricity	2
Electric Arc	0
Other	1

7.8.1.3 *Prospective Material Evaluations (see 7.3)*—Nonmetallic seat materials are reviewed, and polytetrafluoroethylene (PTFE) is found to be highly rated with regard to resistance to ignition (it has one of the highest ignition temperatures for plastics). A well-documented material, it has a very low heat of combustion of 1700 cal/g and impressive Liquid Oxygen (LOX) impact results of passing at a 10 kg-m energy level. Hence, PTFE is considered the best available plastic.

7.8.1.4 *Post-Ignition Property Evaluation (see 7.4)*—Though PTFE is found to have a low heat of combustion, the size of the seat required is quite large. Beyond this, PTFE is found to be a rather dense material. In a relatively dense polymer. As a consequence, ignition of the seat would be expected to release a small to moderate quantity of heat.

7.8.1.5 *Reaction Effect Assessment (see 7.5)*—Ignition of the seat might, in turn, ignite the stainless steel valve components and possibly release fire to the surroundings. Since such ignition would most likely occur while personnel are in the immediate area and since barricading is not feasible, the effect on personnel safety is rated high. Ignition would result in damage to the valve alone, which could be readily and inexpensively replaced. Interruption of the system for the required repair time is acceptable. Hence the following reaction assessment ratings are assigned:

Effect of Personnel Safety	D
Effect on System Objectives	B
Effect on Function Capability	B

Because of the importance of personnel safety, the overall rating is concluded to be a worst case D.

7.8.1.6 *Final Selection (see 7.6)*—In view of the overall Catastrophic Reaction Assessment Rating catastrophic reaction effect severity (Code D), only a valve seat that is very able to function successfully is concluded to be acceptable. Since there is a high probability (rating 3) that a PTFE seat would be exposed to temperatures due to heat of compression approaching the ignition point, evenpoint (x °F (y °C) predicted using Eq 1), PTFE is concluded to be unacceptable in this application. As a result, a metal seat is selected instead (refer to X1.1).

7.8.2 *Pipeline Control Valve:*

7.8.2.1 *Application Description*—Automatic flow control is required in an 8-in. (20.3-cm), 650-psig (4.6-MPa) carbon steel above-ground pipeline at ambient temperature. High flow and tight shutoff are also required. The control valve is unattended in normal operation. The line was previously blast cleaned, and a strainer will be immediately upstream of the valve. A bronze-body globe valve is under consideration. A10 diameter length of Monel pipe is present downstream to comply with CGA Pamphlet G-4.4 (6). A soft seat is under consideration.

7.8.2.2 *Ignition Probability Assessment (see 7.2)*—Friction is negligible between the plug and seat. Also, the operational speed and load are low; frictional heating is unlikely. Rapid opening is likely to produce nearly some adiabatic compression heating downstream of the valves and affect materials there. Rapid closure could produce inertial ram pressurization against the valve by the large upstream mass; adiabatic compression ignition isposes a significant prospect.risk. There can be only a low velocity impact of the plug on the seat during closure, and the presence of a strainer renders remote chances of mechanical impact or particle impact ignition. Since the pipeline is clean, dry, and remote from electrical equipment, arc and spark from associated equipment or static discharge are unlikely. The pipeline is grounded and subject to lightning strikes. However, strikes, however, in the event of so intense an ignition event, the role of valve seat would be relatively unimportant. No other ignition mechanisms are identified, but their absence cannot be assumed. The summary of ignition probability ratings is:

Friction	1
Heat of Compression	3
Mechanical Impact	1
Particle Impact	1
Static Electricity	1
Electric Arc	0
Other	1

7.8.2.3 *Prospective Material Evaluations (see 7.3)*—The probable exposure to heat of compression ignition requires a material with a high ignition temperature; PTFE has one of the highest autoignition temperatures capable of withstanding predictable temperatures. the predicted high heat of compression. PTFE also has a low heat of combustion, and excellent mechanical impact test results. PTFE is also readily available and superior to the alternative of nylon. Hence aliphatic polymamides (PA, eg., nylon 66). Hence, PTFE is taken under consideration.

7.8.2.4 *Post-Ignition Property Assessment (see 7.4)*—Though PTFE has a low heat of combustion, the mass of PTFE present in the seat is large and PTFE is rather dense; complete combustion would represent a large heat release. In contrast, the PTFE is in excellent intimate contact with a massive bronze body and the gas-wetted area is modest. As a result, the very compatible brass body should resist ignition and remain intact. Ignition of the downstream carbon steel piping is rated unlikely because of the 10 diameter isolation section of monel Monel pipe.

7.8.2.5 *Reaction Effect Assessment (see 7.5)*—Ignition of the seat would be unlikely to produce a major release of fire nor or to ignite the pipeline. Since the valve and neighboring pipeline are unattended, the effect of on personnel safety is rated negligible (A). Combustion of the seat in the absence of penetration would not interrupt oxygen supply to the pipeline, nor would the combustion products force a long-term process problem. Combustion of the seat, when the valve is closed would supply oxygen to the pipeline, but the system can safely control this flow. Hence the effect on system objectives is rated negligible (A). Finally, since only the valve seat is expected to react, the effect on functional capability is rated marginal (B). The overall reaction effect rating is therefore the marginal (B) rating of the effect on functional capability.

7.8.2.6 *Final Selection (see 7.6)*—Among the materials available for valve seats, only PTFE ~~rated~~ had an acceptable rating relative to the probable exposure to heat of compression. The destructive potential of PTFE is acceptable and yields an acceptable reaction effect. As a result, PTFE is selected for the seat application.

7.8.3 *Reactor Butterfly Valve:*

7.8.3.1 *Application Description*—Several 12-in. (30-cm) remotely operated butterfly valves are required for controlling flow to a reactor. The piping is stainless steel. The temperature is ~~essentially~~ ambient. The operating pressure is 2 psig (13.8 kPa ~~gage~~ gauge). The gas velocity is 40 ft/s (12.2 m/s). ~~Elastomer~~ Elastomeric linings for use as seats in cast steel valves with bronze disks are under consideration.

7.8.3.2 *Ignition Probability Assessment (see 7.2)*—A review of the operating conditions and the system indicates that no ignition mechanism is likely to be present. Valve breakaway and sealing torque are low, and the valve is slow-operating, so disk-to-seat friction and mechanical impact are rated as remote probabilities. The relatively low gas velocity and the cleanness of the stainless steel line minimize particulate impact and static electricity, which are rated unlikely and remote, respectively. Heat of compression is almost impossible at the low pressures involved. There is no electrical apparatus that could produce ignition, and therefore a remote rating is assigned. No other mechanisms of ignition are foreseen, but their absence cannot be assumed. Therefore, a summary of the ignition probability assessment is:

Friction	1
Heat of Compression	0
Mechanical Impact	1
Particle Impact	2
Static Electricity	1
Electric Arc	1
Other	1

7.8.3.3 *Prospective Material Evaluations (see 7.3)*—For economy, it is desirable to use the manufacturer’s standard CR ~~elastomer liner (chloroprene rubber); (chloroprene rubber) elastomeric liner,~~ which also functions as a seat. Oxygen compatibility tests on the liner material give the following results:

Autoignition temperature in 2000 psig (13.8 MPa) O ₂ , °C	200
Impact, minimum drop height, in. (mm)	27 (680)
Heat of Combustion, cal/g (MJ/kg)	5800 (24.3)

7.8.3.4 *Post-Ignition Property Evaluation (see 7.4)*—The relatively high total heat release potential (5.8 kcal/g × 8.8 kg per liner = 51 000 kcal per liner) is substantial but is expected to be released at a fairly low rate in 2 psi (13.8 kPa ~~gage~~ gauge) oxygen.

7.8.3.5 *Reaction Effect Assessment (see 7.5)*—Ignition of the seat would not likely ignite the cast steel valve body or the stainless steel piping; a release of flame would also be unlikely. Also, the valves are located on top of the reactor, isolated from personnel or other equipment. As a result, the effect on personnel safety is rated negligible. Damage in the event of an ignition would likely be ~~less than \$1000 minimal~~ and the process ~~upset~~ disruption would be minimal due to parallel manifolding. For these reasons, the effect on system objectives is rated negligible, and the effect on functional capability is rated marginal. The summary of the ~~Reaction Effect Assessment~~ reaction effect assessment is:

Effect on Personnel Safety	A
Effect on System Objectives	A
Effect on Functional Capability	B

The overall assessment is a marginal B rating.

7.8.3.6 *Final Selection (see 7.6)*—In view of the ~~rather mild~~ marginal rating resulting from modest repair costs alone, the CR elastomer with a medium resistance to ignition is justified, consistent with 7.6.1.2. The judgment is ~~buttressed~~ reinforced by reference to Table ~~X1-1~~ X1.1, which indicates successful use of this material in a nearly identical situation.

7.8.4 *Pipeline Gasket:*

7.8.4.1 *Application Description*—A gasket is required for use between flanges in a 900-psig (6.2-MPa) centrifugal compressor discharge to a carbon steel pipeline. Gas temperatures of 150°C are possible. The flange is unattended and remotely located.

7.8.4.2 *Ignition Probability Assessment (see 7.2)*—There is no friction source in a flange system, therefore friction ignition is essentially impossible. Due to the inherent volume in the pipeline, pressure relieving devices, limited flow rate of the compressor, and the fact that the flange is not at a dead end, rapid pressurization is a remote possibility. In addition, there are no mechanical motions that might produce impact of the gasket. Particles might be produced and might be accelerated to the gas velocity, however, direct impact on the gasket is unlikely since the gasket will be installed by qualified mechanics and will, therefore, be properly and completely isolated between the steel flanges. The absence of associated electrical equipment and shielding indicate a remote chance of static electricity or electric arc ignition. No other sources are foreseen, but their absence cannot be assumed. The summary of ignition probability ratings is: