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Standard Terminology Relating to the Compatibility and Sensitivity of Materials in Oxygen Enriched Atmospheres[1]

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1. Scope

1.1 This terminology defines terms related to the compatibility and sensitivity of materials in oxygen enriched atmospheres. It includes those standards under the jurisdiction of ASTM Committee G04.

1.2 The terminology concentrates on terms commonly encountered in and specific to practices and methods used to evaluate the compatibility and sensitivity of materials in oxygen. This evaluation is usually performed in a laboratory environment, and this terminology does not attempt to include laboratory terms.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

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

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

G114 Practices for Evaluating the Age Resistance of Polymeric Materials Used in Oxygen Service

G120 Practice for Determination of Soluble Residual Contamination by Soxhlet Extraction

G121 Practice for Preparation of Contaminated Test Coupons for the Evaluation of Cleaning Agents

G122 Test Method for Evaluating the Effectiveness of Cleaning Agents

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

G125 Test Method for Measuring Liquid and Solid Material Fire Limits in Gaseous Oxidants

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

G131 Practice for Cleaning of Materials and Components by Ultrasonic Techniques

G136 Practice for Determination of Soluble Residual Contaminants in Materials by Ultrasonic Extraction

G144 Test Method for Determination of Residual Contamination of Materials and Components by Total Carbon Analysis Using a High Temperature Combustion Analyzer

G145 Guide for Studying Fire Incidents in Oxygen Systems

3. Terminology

3.1 *Definitions:*

aging, *n*—the exposure of a material to stress, such stress of which may include time, pressure, temperature, abrasion, ionizing radiation, light, impact with gas or particles, tensile or compressive force (either static or cyclic), or any other feature that may be present individually or in combination. **G114**

accelerated aging, *n*—a type of artificial aging whereby the effect of prolonged exposure during service is stimulated by aging at elevated temperature. **G114**

artificial aging, *n*—aging in which a stress variable is outside the domain of exposure that a material might see in a component for oxygen service or in which an alternative mechanism is used to produce an effect that simulates the results of natural aging.

[1] This terminology 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] 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.

DISCUSSION—The degree of artificiality may vary on a large scale. An example of mild artificiality is exposure of a material to a greater pressure than it experiences in the use condition. An example of extreme artificiality is the use of sandpaper to increase a material's surface roughness to simulate particle-impact abrasion that occurs in the use condition. A high degree of artificiality affects the strength of conclusion that can be drawn, because it may be difficult to relate the results to the use condition. Artificial aging that accelerates natural aging but does not alter the resulting effect is preferred. **G114**

autoignition temperature (AIT), *n*—the lowest temperature at which a material will spontaneously ignite in an oxygen-enriched atmosphere under specific test conditions. **G63, G72, G94, G128**

average regression rate (*Regression Rate of the Melting Interface [RRMI]***),** *n*—the average rate at which the melting interface advances along the test sample length as melting of the test sample occurs. **G124**

blank, *n*—the contamination level of a fluid when the test coupon is omitted.

DISCUSSION—Sometimes referred to as the "background level." **G121**

burn length, *n*—the burn length is the length of the sample that has been consumed by burning.

DISCUSSION—The burn length is determined by subtracting the post-test sample length from the pretest sample length (which does not include the promoter length or the region used by the test sample support). **G124**

characteristic elements, *n*—those factors that must be present for an ignition mechanism to be active in an oxygen-enriched atmosphere. The more characteristic elements present for a particular ignition mechanism, the more active that mechanism is. **G88**

cleaning effectiveness factor (CEF), *n*—the fraction of contaminant removed from an initially contaminated test coupon as determined by gravimetric techniques. **G122**

cleanliness, *n*—the degree to which an oxygen system is free of contaminant.

DISCUSSION—Cleanliness and contamination are opposing properties: increasing cleanliness implies decreasing contamination. **G93**

contaminant (contamination), *n*—unwanted molecular, non-volatile residue (NVR), or particulate matter, or combinations thereof, that could adversely affect or degrade the operation, life, or reliability of the systems or components upon which it resides.

DISCUSSION—Contamination and cleanliness are opposing properties: increasing cleanliness implies decreasing contamination. **G93, G120, G121, G131, G136, G144, G145**

contaminate, *v*—a process of applying contaminant. (non-volatile residue (NVR) and/or particulate matter). **G131, G136, G120, G121**

control coupon (*witness coupon***) ,** *n*—a coupon made from the same material and prepared in exactly the same way as the test coupons which is used to verify the validity of the method or part thereof.

DISCUSSION—In practice, the control coupon is contaminated in the same manner as the test coupons and is subjected to the identical cleaning procedure. **G120, G121, G131**

degas, *v*—the process of removing gases from a liquid. **G131, G136**

direct incident cause, *n*—the mechanical or thermodynamic event (such as breakage of a component or near-adiabatic compression), the physicochemical property (such as heat of combustion), the procedure (such as a valve opening rate), or any departure(s) from the intended state of any of these items, that leads directly to ignition, or fire, or both. **G145**

direct oxygen service, *n*—service in contact with oxygen-enriched atmosphere during normal operations.

DISCUSSION—Examples are oxygen compressor piston rings or control valve seats. **G63, G88, G94**

energy threshold, *n*—the highest impact energy level at a given pressure for which the passing criteria have been met. **G86**

exemption pressure, *n*—the maximum pressure for an engineering alloy at which there are no oxygen velocity restrictions (from CGA 4.4 and EIGA doc IGC13). **G94**

fibers, *n*—particulate matter with a length of 100 µm or greater and a length-to-width ratio of 10 to 1 or greater. **G93**

fire limit, *n*—the threshold limit conditions that will just support self-sustained burning of a material under a combination of specified conditions and at least one variable parameter. (Typically oxidant concentration, diluent nature, pressure, temperature, geometry, flow or flame parameters etc.) **G125**

flammable material, *n*—a material that is able to ignite and demonstrate self-sustained burning per specific test method criteria considering configurational, environmental, and promoter energy conditions (example: Oxidizer%, P, T, etc.).

DISCUSSION—It is noteworthy that a material's flammability in oxygen is highly-dependent on multiple factors (configuration, environment, promoter energy, etc.) and caution is advised to consider these factors when evaluating a material's flammability in a given oxygen application. **G124**

fractional evaporation, *n*—the continuous evaporation of the quantity of liquid that results in a progressive concentration of a less-volatile constituent(s). **G145**

galling, *n*—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. **G88**

gaseous fluid impact-igintion resistance, *n*—the resistance of a material to ignition when struck by rapidly compressed high pressure gas in an oxygen enriched atmosphere under a specific test procedure. **G63**

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

DISCUSSION—The magnitude of a hazard relates to the severity of the harm it could cause. **G128**

highest no-burn pressure, *n*—the highest gas pressure tested (at a specified oxygen concentration and fixed sample temperature) at which a material does not burn more than specific test method criteria. **G124**

highest no-burn temperature, *n*—the maximum sample temperature (at a specified oxygen concentration and pressure) at which a material does not burn more than specific test method criteria. **G124**

igniter, *n*—a material used to ignite the promoter that can burn under an electrical influence, such as a small-diameter wire. **G124**

ignition temperature, *n*—the temperature at which a material will ignite in an oxidant under specific test or system conditions.

DISCUSSION—The ignition temperature of a material in a system is related to the temperature measured by Test Method G72 (AIT), but is also a function of system pressure, configuration and operation, and thermal history of the material. **G88, G128**

ignition mechanisms, *n*—specific factors (physical attributes such as system materials, system design, component design, component performance factors, contamination, etc. as well as system conditions such as temperature, pressure, flow velocities, oxygen concentration, etc.) that cause the initial fire within a system.

DISCUSSION—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 compression heating. **G88, G128**

incident, *n*—an ignition or fire, or both, that is both undesired and unanticipated, or an undesired and unanticipated consequence of an ignition or fire that was anticipated. **G145**

indirect oxygen service, *n*—service that is not normally in contact with oxygen but which might be as a result of a foreseeable malfunction (single fault), operator error, or process upset. Examples: liquid oxygen tank insulation or liquid oxygen pump motor bearings. **G63, G88, G94**

lowest burn pressure, *n*—the minimum tested gas pressure (at a specified oxygen concentration and fixed sample temperature) at which a material burns more than specific test method criteria. **G124**

lowest burn temperature, *n*—the minimum tested sample temperature (at a specified oxygen concentration and pressure) at which a material burns more than specific test method criteria. **G124**

maximum use pressure, *n*—the greatest pressure to which a material can be subjected as a result of a reasonably foreseeable malfunction, operator error or process upset. **G63, G94**

maximum use temperature, *n*—the greatest temperature to which a material can be subjected as a result of a reasonably foreseeable malfunction, operator error, or process upset. **G63, G94**

mechanical impact, *n*—a blow delivered by a plummet that has been dropped from a pre-established height onto a striker pin, in contact with a sample. **G86**

mechanical 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. **G63, G94, G128**

molecular contaminant (non-particulate contamination), *n*—molecular contaminants that may exist in a gaseous, liquid, or solid state and may be uniformly or nonuniformly disturbed.

DISCUSSION—Molecular contaminant may be found as a solution, an emulsion, or in the form of droplets. Molecular contaminants account for most of what constitutes Non-Volatile Residue (NVR). **G120, G121, G136, G144**

natural aging, *n*—aging in which a material is exposed to conditions replicating those that are present in actual service in a component for oxygen service. **G114**

nonmetal, *n*—any material other than a metal, non-polymeric alloy, or any composite in which the metallic component is not the most easily ignited component and for which the individual constituents cannot be evaluated independently, including ceramics (such as glass), synthetic polymers (such as most rubbers), thermoplastics, thermosets, and natural polymers (such as naturally occurring rubber, wood, and cloth.) **Nonmetallic is the adjective form of this term.** **G63, G93, G94, G128**

nonvolatile residue (NVR), *n*—molecular or particulate matter remaining following the filtration and controlled evaporation of a solvent containing contaminants.

DISCUSSION—The size of a particle is usually defined by its greatest dimension and is specified in micrometers. NVR may be uniformly or non-uniformly distributed as a solution, an emulsion or in the form of droplets. Molecular contaminants account for most of the Non-volatile Residue NVR. **G120, G121, G131, G136, G144**

operating pressure, *n*—the pressure expected under normal operating conditions. **G63, G94**

operating temperature, *n*—the temperature expected under normal operating conditions. **G63, G94**

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. **G125, G128**

oxidant index, *n*—the minimum concentration of an oxidant, such as oxygen, nitrous oxide, or fluorine, expressed as a volume percent, in a mixture of the oxidant with a diluent, such as nitrogen, helium, or carbon dioxide, that will just support sustained burning of a material initially as given in its specific configuration (width and shape) and at given conditions of temperature, pressure, flow conditions, and propagation direction, etc. (see *oxygen index*).

DISCUSSION—The oxidant index (or limit) may be more specifically identified by naming the oxidant, such as oxygen index (or limit), nitrous oxide index (or limit), or fluorine index (or limit). Unless specified otherwise, the typical oxidant is taken to be oxygen, the typical diluent is taken to be nitrogen, and the typical temperature is taken as room temperature. **G125**

oxidative degradation, *n*—physical or mechanical property changes occurring as a result of exposure to oxygen. **G114**

oxygen compatibility (*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. **G93, G125, G128, G145**

oxygen-enriched (oxygen-enriched atmosphere), *adj*—afluid (gas or liquid) mixture containing more than 25 mole percent oxygen.

DISCUSSION—This definition has been historically used within ASTM Committee G04 standards related to materials testing and pressurized piping systems. For these applications this definition has been shown to be effective and continues to be reasonable. However, different applications may require a more conservative definition considering oxygen concentration or partial oxygen pressure or both. For example, some CGA standards use 23.5% oxygen to define oxygen-enrichment for industrial applications (CGA G-4.1, CGA PS-13), and at least one ISO standard incorporates an oxygen partial pressure of >30 bar (435 psi) as part of its definition of oxygen enrichment (ISO 14456) to acknowledge the increase in availability of oxidizing gas beyond ambient-pressure air that may affect the flammability and/or ignitability of materials. **G63, G88, G94, G128, G145**

oxygen index, *n*—the minimum concentration of oxygen, expressed as a volume percent, in a mixture of oxygen and nitrogen that will just support sustained burning of a material initially in its specific configuration (width and shape) and at room temperature under the conditions of Test Method D2863 (see Test Method D2863). **G125**

oxygen resistance, *n*—resistance of a material to ignite spontaneously, propagate by sustained combustions, or undergo oxidative degradation. **G114**

oxygen service, *n*—applications involving the production, storage, transportation, distribution, use of oxygen-containing media. **G114**

particle (*particulate contaminant*), *n*—a general term used to describe a finely divided solid of organic or inorganic matter with observable length, width, and thickness.

DISCUSSION—A molecular contaminant may be in a gaseous, liquid, or solid state and may be uniformly or non-uniformly distributed. Molecular contaminants account for most of the NVR. The solids are usually reported as the amount of contaminant by the population of a specific micrometer size, usually defined by its greatest dimension. See methods described in Methods F312 or ARP 598 for particle size and population determination. **G93, G120, G121, G131, G136, G144**

physical aging, *n*—aging that occurs during normal storage which is a function of time after production. **G114**

pressure limit, *n*—the minimum pressure of an oxidant (or oxidant mixture) that will just support sustained burning of a material initially at given conditions of oxidant concentration, temperature, flow condition, and propagation direction, etc.

DISCUSSION—The pressure limit may be more specifically identified by naming the oxidant: oxygen pressure limit, nitrous oxide pressure limit, or fluorine pressure limit, etc. **G125**

pressure threshold, *n*—the highest pressure at a given impact energy level for which the passing criteria have been met. **G86**

promoter, *n*—an optional material that can add supplemental heat and increase the temperature (that is, melt the end of the test sample) to start burning of the metallic material being tested. **G124**

qualified technical personnel, *n*—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 oxidants and other materials. **G63, G88, G94, G128, G145**

reaction, *n*—a chemical change or transformation in the sample initiated by a mechanical or gaseous fluid impact.

DISCUSSION—A reaction from ambient pressure, LOX mechanical impact may be determined by an audible report, and electronically or visually detected flash, obvious charring of the sample, cup, or striker pin. Reactions in pressurized LOX or GOX are typically indicated by an abrupt increase in test sample temperature, chamber pressure, and light levels and may be supplemented by obvious changes in odor, color, or material appearance as a result of thermal decompositions observed during examination after the test. **G74, G86**

reaction effect, *n*—the personnel injury, facility damage, system damage, component damage, product loss, downtime, or mission loss that could occur as the result of an ignition or fire. **G63, G94**

regression rate of the melting interface, *n*—the average rate at which the solid-liquid metal (melting) interface advances along the test sample length during a test. The regression rate may be related to the burning rate of the test sample through a specific assumption about the extent of reaction. **G124**

residual contamination, R_c, *n*—the absolute mass of contaminant remaining after a cleaning process, expressed in milligrams per square centimeter of area or optionally as milligrams per square meter. **G122**

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

DISCUSSION—The magnitude of a risk relates to how likely a hazard is to cause harm. **G128**

sample temperature, *n*—the initial temperature of the test sample being evaluated.

DISCUSSION—Various methods of measuring sample temperatures can be used. The method selected must be reported with test data. **G124**

self-sustained burning, *n*—burning of a material that is self-supporting without the influence of an external heat source or igniter. In standard testing, burning that consumes the material past a specified burn criteria which is beyond the influence of a promoter, or sample holder in its specific configuration (width and shape), assuming sufficient oxidizer. **G124**

standard rod sample—a 3.2 mm (0.125 in.) diameter rod with a minimum length of 101.6 mm (4 in.) (which does not include the promoter length or region used by the test sample support). **G124**

surface roughness, R_a, *n*—the arithmetic average deviation of the surface profile from the centerline, normally reported in micrometers. **G121, G122**

system conditions—the physical parameters of a specific system. These can include local and system-wide pressure, temperature, flow, oxygen concentration, and others. G128

temperature limit, *n*—the minimum temperature of an oxidant (or oxidant mixture) in temperature equilibrium with the material or of the directly heated material that will just support self-sustained burning of a material initially at given conditions of oxidant concentration, temperature, pressure, flow condition, and propagation direction, etc.

DISCUSSION—The temperature limit may be more specifically identified by naming the oxidant: oxygen temperature limit, nitrous oxide temperature limit, or fluorine temperature limit. G125

threshold pressure, *n—(Legacy Reference: This legacy term was historically used to represent various thresholds; now referenced more specifically as either lowest burn pressure and highest no-burn pressure, or as lowest reaction pressure or highest no-reaction pressure as defined by each standard's burn criteria)* the minimum gas pressure (at a specified oxygen concentration and ambient temperature) that supports self-sustained combustion of the entire standard sample or until the sample holder influences burning. Legacy reference to G124.

valid test, *n*—a test in which the igniter and/or promoter combination has melted the bottom section of the test sample where the igniter and/or promoter is located. G124

wetted material—any component of a fluid system that comes into direct contact with the system fluid. G128

4. Symbols

R_c = residual contamination
R_a = surface roughness

5. Acronyms

AIT = autogenous ignition temperature or autoignition temperature
CEF = cleaning effectiveness factor
GOX, *n,* = gaseous oxygen
LOX, *n,* = liquid oxygen
NVR = nonvolatile residue

6. Keywords

6.1 atmospheres; definitions; material compatibility; material sensitivity; oxygen-enriched; terminology