NFPA®

53

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

2021

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This edition of NFPA 53, *Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres*, was prepared by the Technical Committee on Oxygen-Enriched Atmospheres. It was issued by the Standards Council on October 5, 2020, with an effective date of October 25, 2020, and supersedes all previous editions.

This edition of NFPA 53 was approved as an American National Standard on October 25, 2020.

Origin and Development of NFPA 53

Development of NFPA 53 was initiated in 1965 largely as a result of interest in the area of oxygen-enriched atmospheres by the aerospace industry and medical personnel/researchers, who expressed a need for a single source of general data on the hazards of oxygen-enriched atmospheres.

The first edition was published in 1969 under NFPA procedures that did not require Association meeting action for NFPA documents. A second edition was formally adopted under NFPA procedures at the NFPA Annual Meeting in 1974. Subsequent editions were adopted in 1979, 1985, 1990, and 1994.

The 1994 edition reflected a complete review of the contents of the document and incorporated new information gained by research at the National Aeronautics and Space Administration from 1984 to 1994.

The 1999 edition changed the document from a guide to a recommended practice. Also, some minor changes were made to the definitions of *oxygen-enriched atmosphere* and *ignition temperature*.

The 2004 edition of the recommended practice underwent editorial revisions to meet the NFPA *Manual of Style* and included only minor editorial changes.

The 2011 edition reconfirmed the provisions as they were written in the 2004 edition.

The 2016 edition added heat of combustion and autoignition temperature data to the expanded table of nonmetallic materials for oxygen service. In addition, new fire experience reports were added to Annex D.

The 2021 edition has provided annex material to explain the differences in oxygen-enriched atmosphere thresholds between various standards and organizations, and revisions have been made to ensure that SI/US unit conversions are available throughout the recommended practice.

Technical Committee on Oxygen-Enriched Atmospheres

Committee Scope: This Committee shall have primary responsibility for documents on the fire and explosion hazards that may exist in oxygen-enriched atmospheres. The Committee will correlate its work with the Committee on Health Care Facilities and other related NFPA committees as required.

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text should be sent to the technical committee responsible for the source document.

Information on referenced and extracted publications can be found in Chapter 2 and Annex G.

Chapter 1 Administration

1.1 Scope. This document establishes recommended minimum criteria for the safe use of oxygen (liquid/gaseous) and the design of systems for use in oxygen and oxygen-enriched atmospheres (OEAs).

1.2 Purpose. The purpose of this recommended practice is to provide information for the selection of materials, components, and design criteria that can be used safely in oxygen and OEAs.

1.3 Application. This recommended practice is applicable to the selection of materials and components, and to the design of new systems associated with OEAs. Such applications include, but are not limited to, gas and compressed air supplies, spaceflight operations, industrial processes, welding applications, self-contained breathing apparatus (SCBA), self-contained underwater breathing apparatus (SCUBA), medical applications (including home assisted-breathing apparatus), underwater tunneling and caisson work, and commercial and military aviation.

1.4 Interpretations. The National Fire Protection Association does not approve, inspect, or certify any installation, procedure, equipment, or material. With respect to this recommended practice, and to fire and associated hazards in OEAs, its role is limited solely to an advisory capacity. The acceptability of a particular material, component, or system for use in an OEA is solely a matter between the user and the provider. However, to assist in the determination of such acceptability, the National Fire Protection Association has established interpretation procedures. These procedures are outlined in NFPA's "Regulations Governing the Development of NFPA Standards."

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this recommended practice and should be considered part of the recommendations of this document.

Δ 2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 51, *Standard for the Design and Installation of Oxygen–Fuel Gas Systems for Welding, Cutting, and Allied Processes,* 2018 edition.

NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* 2020 edition.

NFPA 70®, National Electrical Code®, 2020 edition.

NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems,* 2021 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids,* 2020 edition.

NFPA 99, *Health Care Facilities Code,* 2021 edition.

NFPA 99B, *Standard for Hypobaric Facilities,* 2021 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment,* 2021 edition.

2.3 Other Publications.

2.3.1 API Publications. American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005-4070.

API STD. 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks,* 2013, Addendum 2, 2018.

2.3.2 ASME Publications. American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990.

ASME B31.3, *Process Piping,* 2016.

ASME B31.5, *Refrigeration Piping and Heat Transfer Components,* 2016.

ASME B31.8, *Gas Transmission and Distribution Piping Systems,* 2016.

ASME Boiler and Pressure Vessel Code, 2017.

Δ 2.3.3 CGA Publications. Compressed Gas Association, 14501 George Carter Way, Suite 103, Chantilly, VA 20151.

CGA G-4, *Oxygen,* 2015.

CGA P-1, *Safe Handling of Compressed Gases in Containers,* 2015.

CGA S-1.1, *Pressure Relief Device Standards — Part 1 — Cylinders for Compressed Gases,* 2011.

CGA S-1.2, *Pressure Relief Device Standards — Part 2 — Cargo and Portable Tanks for Compressed Gases,* 2009.

CGA S-1.3, *Pressure Relief Device Standards — Part 3 — Stationary Storage Containers for Compressed Gases*, 2008.

2.3.4 U.S. Government Publications. U.S. Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

Title 49, Code of Federal Regulations, Part 173.301, "General Requirements for Shipment of Compressed Gases in Cylinders and Spherical Pressure Vessels," 2019.

Title 49, Code of Federal Regulations, Part 173.302, "Charging of Cylinders with Non-Liquefied Compressed Gases," 2019.

Title 49, Code of Federal Regulations, Part 173.337, "Nitric Oxide," 2019.

Title 49, Code of Federal Regulations, Part 178.37, "Specification 3AA and 3AAX Seamless Steel Cylinders," 2019.

Title 49, Code of Federal Regulations, Part 178.45, "Specification 3T Seamless Steel Cylinders," 2019.

Δ **2.3.5 Other Publications.** *Merriam-Webster's Collegiate Dictionary*, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

Phillips, B.R., "Resonance Tube Ignition of Metals," Ph.D. Thesis, University of Toledo, Toledo, OH, 1975.

Pressure-Relieving Systems for Marine Cargo Bulk Liquid Containers, National Academy of Sciences, Washington, DC, 1973.

Schmidt, H. W.; and Forney, D. F. "ASRDI Oxygen Technology Survey, Volume IX: Oxygen Systems Engineering Review." NASA SP 3090, NASA, Washington, DC, 1975.

Δ **2.4 References for Extracts in Recommendations Sections.**

NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* 2018 edition.

NFPA 921, *Guide for Fire and Explosion Investigations,* 2017 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter apply to the terms used in this recommended practice. Where terms are not defined in this chapter or within another chapter, they should be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary,* 11th edition, is the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3* Code. A standard that is an extensive compilation of provisions covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.

3.2.4 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.5* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.6 Recommended Practice. A document that is similar in content and structure to a code or standard but that contains only nonmandatory provisions using the word "should" to indicate recommendations in the body of the text.

3.2.7 Should. Indicates a recommendation or that which is advised but not required.

3.2.8 Standard. An NFPA Standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase "standards development process" or "standards development activities," the term "standards" includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

3.3 General Definitions.

3.3.1 Activation Energy. The minimum energy that colliding fuel and oxygen molecules must possess to permit chemical interaction.

3.3.2 Autoignition or Autogenous Ignition Temperature. See 3.3.18, Ignition Temperature.

3.3.3 Combustible Material. A material capable of undergoing combustion.

3.3.4 Combustion. A chemical process of oxidation that occurs at a rate fast enough to produce heat and usually light in the form of either a glow or flame.

3.3.5 Concentration. The ratio of the amount of one constituent of a homogeneous mixture to the total amount of all constituents in the mixture.

3.3.6 Contaminant. A foreign or unwanted substance that can have deleterious effects on system operation, life, or reliability.

3.3.7 Deflagration. Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium. [**68,** 2018]

3.3.8 Detonation. Propagation of a combustion zone at a velocity that is greater than the speed of sound in the unreacted medium. [**68,** 2018]

3.3.9 Diluent. A gas used to dilute or reduce the concentration of oxygen.

3.3.10 Fire. A rapid oxidation process, which is a chemical reaction resulting in the evolution of light and heat in varying intensities. [**921,** 2017]

3.3.11 Flame Propagation Rate. The velocity with which the combustion front travels through a body of gas, measured as the highest gas velocity at which stable combustion can be maintained, and the velocity at which combustion travels over the surface of a solid or liquid.

3.3.12 Flammable. A combustible that is capable of easily being ignited and rapidly consumed by fire. Flammables may be solids, liquids, or gases exhibiting these qualities.

3.3.13 Flammable Limits. The minimum and maximum concentration of fuel vapor or gas in a fuel vapor or gas/gaseous oxidant mixture (usually expressed as percent by volume) defining the concentration range (flammable or explosive range) over which propagation of flame will occur on contact with an ignition source. The minimum concentration is known as the lower flammable limit (LFL) or the lower explosive limit (LEL). The maximum concentration is known as the upper flammable limit (UFL) or the upper explosive limit (UEL).

3.3.14 Flash Point. The minimum temperature of a liquid or solid at which it gives off vapor sufficient to form an ignitible mixture with a gaseous oxidant (i.e., oxygen) near the surface of the liquid or solid under specified environmental conditions.

3.3.15 Fuel. Any material that will maintain combustion under specified environmental conditions.

3.3.16 Hyperbaric. Pressure greater than ambient.

3.3.17 Hypobaric. Pressure less than ambient.

3.3.18* Ignition Temperature. The minimum temperature required to initiate or cause self-sustaining combustion independently of the heating or heated element under specified environmental conditions. Ignition temperatures are commonly reported as the autogenous ignition temperature, autoignition temperature (AIT), or spontaneous ignition temperature (SIT).

3.3.19 Lower Flammable Limit or Lower Explosive Limit. See 3.3.13, Flammable Limits.

3.3.20* Minimum Ignition Energy. The minimum energy required to ignite a flammable mixture; usually the minimum energy of an electric spark or arc expressed in joules.

3.3.21 Mixture.

3.3.21.1 ***Lean Mixture.*** A fuel and oxidizer mixture having less than the stoichiometric concentration of fuel.

3.3.21.2 ***Rich Mixture.*** A fuel and oxidizer mixture having more than the stoichiometric concentration of fuel.

3.3.21.3 ***Stoichiometric Mixture.*** A balanced mixture of fuel and oxidizer such that no excess of either remains after combustion.

3.3.22* Oxidant. An oxygen-bearing chemical compound that supports combustion.

3.3.23 Oxidation. Reaction with oxygen either in the form of the element or in the form of one of its compounds.

3.3.24 Oxygen. A chemical element that, at normal atmospheric temperatures and pressures, exists as a colorless, odorless, and tasteless gas and comprises about 21 percent by volume of the earth's atmosphere.

3.3.25* Oxygen-Enriched Atmosphere (OEA). An atmosphere in which the concentration of oxygen exceeds 21 percent by volume or its partial pressure exceeds 21.3 kPa (160 torr).

3.3.26* Pressure. The force per unit of area. Values in this recommended practice are based on the unit of pressure derived from the International System of Units (SI), which is the pascal (Pa) or newton per square meter (N/m^2).

3.3.26.1 ***Absolute Pressure.*** The total pressure being measured that equals gauge pressure plus atmospheric pressure.

3.3.26.2 ***Gauge Pressure.*** Pressure measured with reference to atmospheric pressure that equals absolute pressure minus atmospheric pressure.

3.3.27 Spontaneous Ignition Temperature. See 3.3.18, Ignition Temperature.

3.3.28 Upper Flammable Limit or Upper Explosive Limit. See 3.3.13, Flammable Limits.

3.3.29 Worst-Case. The maximum concentration, pressure, temperature, or flow-rate that can occur with a reasonable single-point failure or upset.

Chapter 4 Types of Systems Used in Oxygen-Enriched Atmospheres

4.1 General. Mechanical and electrical systems that can be found in oxygen-enriched atmospheres (OEAs) include the following:

(1) Air conditioning: Heating, cooling, humidity control, purification, filtering, fresh air supply, and forced circulation
(2) Hydraulic services (water and hydraulic fluids): Acceptable hydraulic fluids (chemically inert in oxygen), water supply and waste piping, valves, temperature controls, pressure regulators, fire extinguishment
(3) Compressed air supply: Compressor, cylinder manifold for emergency use, pressure controls, and piping system from supply source to use location
(4) Gas supply: Uses of gas in OEAs are as follows:
    (a) Cylinders of compressed gases, such as oxygen, nitrous oxide, nitrogen, helium, and natural air, for human breathing
    (b) Anesthetic vaporizers such as halothane, enflurane, and isoflurane
    (c) Cylinder storage, cylinder fastenings in storage or in manifold assemblies, piping and fittings with check valves, flow valves, pressure regulators as required for safe transmission of gas from cylinder to terminal at use site, and hose and hose connections at use site for attaching dispensing equipment
    (d) Inhalation devices, such as face masks and endotracheal tubes, for connecting to dispensing equipment and for supplying air or gaseous mixtures to humans or animals for breathing
(5) Suction apparatus: Vacuum pump with controls, piping system from pump to use site, pickup hose, and attachments and shutoff valves