INTERNATIONAL

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Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases)[1]

This standard is issued under the fixed designation E681; 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 test method covers the determination of the lower and upper concentration limits of flammability of chemicals having sufficient vapor pressure to form flammable mixtures in air at atmospheric pressure at the test temperature. This test method may be used to determine these limits in the presence of inert dilution gases. No oxidant stronger than air should be used.

NOTE 1—The lower flammability limit (LFL) and upper flammability limit (UFL) are sometimes referred to as the lower explosive limit (LEL) and the upper explosive limit (UEL), respectively. However, since the terms LEL and UEL are also used to denote concentrations other than the limits defined in this test method, one must examine the definitions closely when LEL and UEL values are reported or used.

1.2 This test method is based on electrical ignition and visual observations of flame propagation. Users may experience problems if the flames are difficult to observe (for example, irregular propagation or insufficient luminescence in the visible spectrum), if the test material requires large ignition energy, or if the material has large quenching distances.

1.3 Annex A1 provides a modified test method for materials (such as certain amines, halogenated materials, and the like) with large quenching distances which may be difficult to ignite.

1.4 In other situations where strong ignition sources (such as direct flame ignition) is considered credible, the use of a test method employing higher energy ignition source in a sufficiently large pressure chamber (analogous, for example, to the methods in Test Method E2079 for measuring limiting oxygen concentration) may be more appropriate. In this case, expert advice may be necessary.

1.5 The flammability limits depend on the test temperature and pressure. This test method is limited to an initial pressure of the local ambient or less, with a practical lower pressure limit of approximately 13 kPa (100 mm Hg). The maximum practical operating temperature of this equipment is approximately 150 °C.

1.6 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 This test method should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test method may be used as elements of a fire risk assessment that takes into account all of the factors pertinent to an assessment of the fire hazard of a particular end use.

1.8 This standard may involve hazardous materials, operations, and equipment. *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Section 8.

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E171 Practice for Conditioning and Testing Flexible Barrier Packaging
E582 Test Method for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures
E1445 Terminology Relating to Hazard Potential of Chemicals
E1515 Test Method for Minimum Explosible Concentration of Combustible Dusts

[1] This test method is under the jurisdiction of ASTM Committee E27 on Hazard Potential of Chemicals and is the direct responsibility of Subcommittee E27.04 on Flammability and Ignitability of Chemicals.

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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.

E2079 Test Methods for Limiting Oxygen (Oxidant) Concentration in Gases and Vapors

2.2 *NFPA Standard:*[3]

NFPA 69 Standard on Explosion Prevention Systems

3. Terminology

3.1 *Definitions:*

3.1.1 *lower limit of flammability or lower flammable limit (LFL)*—the minimum concentration of a combustible substance that is capable of propagating a flame in a homogeneous mixture of the combustible and a gaseous oxidizer under the specified conditions of test.

3.1.2 *propagation of flame—as used in this test method*, the upward and outward movement of the flame front from the ignition source to the vessel walls or at least to within 13 mm (½ in.) of the wall, which is determined by visual observation. By outward, it is meant a flame front that has a horizontal component to the movement away from the ignition source.

3.1.3 *upper limit of flammability or upper flammable limit (UFL)*—the maximum concentration of a combustible substance that is capable of propagating a flame in a homogeneous mixture of the combustible and a gaseous oxidizer under the specified conditions of test.

3.2 Additional terms can be found in Terminology E1445.

4. Summary of Test Method

4.1 A uniform mixture of a gas or vapor with air is ignited in a closed vessel, and the upward and outward propagation of the flame away from the ignition source is noted by visual observation. The concentration of the flammable component is varied between trials until the composition that will just sustain propagation of the flame is determined.

5. Significance and Use

5.1 The LFL and UFL of gases and vapors define the range of flammable concentrations in air.

5.2 This method measures the LFL and UFL for upward (and partially outward) flame propagation. The limits for downward flame propagation are narrower.

5.3 Limits of flammability may be used to determine guidelines for the safe handling of volatile chemicals. They are used particularly in assessing ventilation requirements for the handling of gases and vapors. NFPA 69 provides guidance for the practical use of flammability limit data, including the appropriate safety margins to use.

5.4 As discussed in Brandes and Ural,[4] there is a fundamental difference between the ASTM and European methods for flammability determination. The ASTM methods aim to produce the best representation of flammability parameters, and rely upon the safety margins imposed by the application standards, such as NFPA 69. On the other hand, European test methods aim to result in a conservative representation of flammability parameters. For example, in this standard, LFL is the calculated average of the lowest go and highest no-go concentrations while the European test methods report the LFL as the minimum of the five highest no-go concentrations.

NOTE 2—For hydrocarbons, the break point between nonflammability and flammability occurs over a narrow concentration range at the lower flammability limit, but the break point is less distinct at the upper limit. For materials found to be non-reproducible per 13.1.1 that are likely to have large quenching distances and may be difficult to ignite, such as ammonia and certain halogenated hydrocarbon, the lower and upper limits of these materials may both be less distinct. That is, a wider range exists between flammable and nonflammable concentrations (see Annex A1).

6. Interferences

6.1 This test method is not applicable to certain readily oxidized chemicals. If significant oxidation takes place when the vapors are mixed with air, unreliable results may be obtained. Flow systems designed to minimize hold-up time may be required for such materials.

6.2 Measured flammable limits are influenced by flame quenching effects of the test vessel walls. The test vessel employed in this test method is of sufficient size to eliminate the effects of the flame quenching for most materials (and conditions).

NOTE 3—There may be quenching effects, particularly on tests run at subambient pressures. For materials that may be difficult to ignite (see Note 2), tests in a larger vessel or different ignition sources (see Annex A1, 12 L flask) may show flame propagation that is not seen in the 5 L flask with spark or exploding wire igniters. This test method is a small scale test and this possible limitation must be considered in hazard assessments.

6.3 The oxygen concentration in the air has an important effect on the UFL. Typically, room air is used. If cylinder air is used to simulate room air it must have an oxygen concentration of 20.94 % ± 0.1 %. Reconstituted air in cylinders has variability in the oxygen concentration and must be verified for oxygen concentration.

7. Apparatus

7.1 Fig. 1 is a schematic diagram of the apparatus; details and dimensions are presented in Appendix X1. The apparatus consists of a glass test vessel, an insulated chamber equipped with a source of controlled-temperature air, an ignition device with an appropriate power supply, a magnetic stirrer, and a cover equipped with the necessary operating connections and components.

7.2 If tests are to be conducted at an elevated temperature, the test vessel may be heated as described in Appendix X1. The heating system must be capable of controlling the gas temperature inside the test vessel to within ±3 °C both temporally and spatially. An appropriate device such as a thermocouple must be used to monitor the gas temperature within the test vessel. Active (connected) volumes beyond the test vessel itself should be held above the condensation temperature of all components in the material being tested. Electrical heating tapes must be employed for heating components to the desired temperature.

NOTE 4—Certain bare wire thermocouples may cause catalytic oxidation of test vapors, as evidenced by a persistent high-temperature

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

[4] Brandes, E., and Erdem, A. U., "Towards a Global Standard for Flammability Determination," 42nd Annual Loss Prevention Symposium, New Orleans, LA, April 2008.