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An American National Standard

# Standard Test Method for Measuring Smoke Toxicity for Use in Fire Hazard Analysis[1]

This standard is issued under the fixed designation E1678; 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.

## INTRODUCTION

The pyrolysis or combustion of every combustible material or product produces smoke that is toxic. It is, therefore, desirable to establish a test method for the development of data characterizing smoke toxicity as an element of fire hazard analyses for both pre-flashover and post-flashover fires. The test method includes quantification of the toxicity of the smoke and ascertain whether the observed toxicity can be attributed to the major common toxicants.

## 1. Scope*

1.1 This fire-test-response standard covers a means for determining the lethal toxic potency of smoke produced from a material or product ignited while exposed to a radiant heat flux of 50 kW/m$^2$ for 15 min.

1.2 This test method is limited to test specimens no larger than 76 mm by 127 mm (3 in. by 5 in.), with a thickness no greater than 51 mm (2 in.). Specimens are intended to be representative of finished materials or products, including composite and combination systems.

1.3 Lethal toxic potency values associated with 30-min exposures are predicted using calculations that use combustion atmosphere analytical data for carbon monoxide, carbon dioxide, oxygen (vitiation) and, if present, hydrogen cyanide, hydrogen chloride, and hydrogen bromide. The predictive equations are therefore limited to those materials and products whose smoke toxicity can be attributed to these toxicants. An animal check determines the extent to which additional toxicants contribute to the lethal toxic potency of the smoke.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.5 This standard measures and describes the response of materials, products, or assemblies in response to heat under controlled conditions, but does not by itself incorporate all factors required for fire hazard of fire risk assessment of the materials, products, or assemblies under actual fire conditions.

1.6 *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 (particularly with regard to the care and use of experimental animals) prior to use.* For specific hazards statements, see Section 7 and Note X1.1.

1.7 *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]

E176 Terminology of Fire Standards

E800 Guide for Measurement of Gases Present or Generated During Fires

2.2 *ISO Documents:*[3]

ISO 19701 Methods for Sampling and Analysis of Fire Effluents

ISO 19702 Guidance for Sampling and Analysis of Toxic Gases and Vapours in Fire Effluents Using Fourier Transform Infrared (FTIR) Spectroscopy

2.3 *NFPA Standard:*[4]

NFPA 269-2017 Standard Test Method for Developing Toxic Potency Data for Use in Fire Hazard Modeling

[1] This test method is under the jurisdiction of ASTM Committee E05 on Fire Standards and is the direct responsibility of Subcommittee E05.21 on Smoke and Combustion Products.

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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.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org..

[4] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269, http://www.nfpa.org.

***A Summary of Changes section appears at the end of this standard**

## 3. Terminology

3.1 *Definitions*—For definitions of general terms used in this test method, refer to Terminology E176.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *carboxyhemoglobin saturation, n*—the percent of blood hemoglobin predominately converted to carboxyhemoglobin from reaction with inhaled carbon monoxide.

3.2.1.1 *Discussion*—The chemical reaction between carbon monoxide and hemoglobin in blood is reversible. The effect of carbon monoxide on the exposed person may not be reversible.

3.2.2 *concentration-time curve, n*—a plot of the concentration of a gaseous toxicant as a function of time.

3.2.2.1 *Discussion*—The concentration-time curve can also be used to represent the sum total of all combustion products instead of just a single one.

3.2.3 *Ct product, n*—the concentration-time product in (µL/L)·min obtained by integration of the area under a concentration-time curve.

3.2.3.1 *Discussion*—Values expressed using this unit are numerically equal to those using the previously cited unit, ppm, a term whose use is discouraged.

3.2.4 *fractional exposure dose (FED), n*—the ratio of the integrated area under the concentration-time curve for a gaseous toxicant or the sum of all combustion products produced in a given test to that integrated C(t) area which has been determined statistically from independent experimental data to produce lethality in 50 % of test animals within a specified exposure and postexposure time.

3.2.4.1 *Discussion*—When C is nearly constant over time, the time values in this ratio numerically cancel, and the FED is simply the ratio of the average concentration of a gaseous toxicant to its $LC_{50}$ value for the same exposure time. When only a single measurement of C is made during a test, the accuracy of this simplification is not known. When not used with reference to a specific toxicant, the term FED represents the summation of FEDs for individual toxicants in a combustion atmosphere.

3.2.5 *$LC_{50}$, n*—a measure of lethal toxic potency; the concentration of gas or smoke calculated statistically from concentration-response data to produce lethality in 50 % of test animals within a specified exposure and postexposure time, expressed in µL/L.

3.2.5.1 *Discussion*—Values expressed using this unit are numerically equal to those using the previously cited unit, ppm, a term whose use is discouraged.

3.2.6 *mass loss concentration, n*—the mass loss of a test specimen per unit exposure chamber volume in $g·m^{-3}$.

3.2.7 *post-flashover, n and adj*—referring to the state of a fire after flashover.

## 4. Summary of Test Method

4.1 In this test method, a test specimen is subjected to ignition while it is exposed for 15 min to a radiant heat flux of 50 $kW/m^2$. (See X1.2.2.) The smoke produced is collected for 30 min within a 200-L chamber communicating with the combustion assembly through a connecting chimney. Concentrations of the major gaseous toxicants are monitored over the 30-min period, with Ct products for each being determined from integration of the areas under the respective concentration-time plots. The Ct product data, along with the mass loss of the test specimen during the test, are then used in calculations to predict the 30-min $LC_{50}$ of the test specimen.

4.2 The predicted $LC_{50}$ is then confirmed in comparable tests by exposing six rats, restrained for head-only exposure, for 30 min to the smoke produced from that mass of the test specimen whose mass loss concentration during the 30-min period is approximately (±10 %) equivalent to 70 % and to 130 % of its estimated $LC_{50}$. If no more than one rat dies during the 30-min exposure, or within 14-days post-exposure to the mass loss concentration corresponding to 70 % of the $LC_{50}$, and at least five rats die during the 30-min exposure, or within 14-days post-exposure, to the mass loss concentration corresponding to 130 % of the $LC_{50}$, the predicted $LC_{50}$ is considered to be confirmed. Confirmation ensures that the monitored toxicants account for the observed toxic effects.

4.3 An animal test result that does not confirm the prediction indicates the presence of one or more additional toxicants or toxicological antagonists, and the degree of disagreement indicates the importance of the unmeasured factors.

4.4 For calculation of hazard from pre-flashover, flaming fires, the toxicant gas yields and $LC_{50}$ values are to be used as experimentally determined. For calculation of hazard from post-flashover fires, the yields of carbon monoxide are augmented to reflect the higher yields produced in such fires. The experimental $LC_{50}$ values are then adjusted using a specified calculation to produce $LC_{50}$ (post-flashover) values.

## 5. Significance and Use

5.1 This test method has been designed to provide data for the mathematical modeling of fire hazard as a means for the evaluation of materials and products and to assist in their research and development.

5.1.1 Test Method E1678 is functionally equivalent to NFPA 269-2017.

5.2 This test method is used to predict, and subsequently confirm, the lethal toxic potency of smoke produced upon the exposure of a material or product to specific fire test conditions. Confirmation determines whether certain major gaseous toxicants account for the observed toxic effects and lethal toxic potency. If a predicted lethal toxic potency value is not confirmed adequately, indicating a potential for unusual or unexplained toxicity, the lethal toxic potency will need to be investigated using other methodology, such as conducting an experimental determination of the $LC_{50}$ using the apparatus described. (See X1.3.1 and X1.3.2.)

5.3 This test method produces lethal toxic potency values that are appropriate for use in the modeling of both pre-flashover and post-flashover fires. Most fire deaths due to smoke inhalation in the U.S. occur in areas other than the room of fire origin and are caused by fires that have proceeded beyond the room of fire origin. It is assumed that these are flashover fires. Therefore, the principal emphasis is placed on