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Standard Guide for Development of Fire-Risk-Assessment Standards[1]

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1. Scope

1.1 This guide covers the development of fire-risk-assessment standards.

1.2 This guide is directed toward development of standards that will provide procedures for assessing fire risks harmful to people, property, or the environment.

2. Referenced Documents

2.1 *ASTM Standards:*

[1] This guide is under the jurisdiction of ASTM Committee E-5 E05 on Fire Standards and is the direct responsibility of Subcommittee E05.33 on Fire Safety Engineering. Current edition approved Feb. October 10, 1996. 2001. Published Ap January 2002. Originally published as E 1776–96. Last previous edition E 1776–96.

E 176 Terminology of Fire Standards[2]
E 603 Guide for Room Fire Experiments[2]
E 1546 Guide for Development of Fire-Hazard-Assessment Standards[2]

2.2 *Other ASTM Documents:*

SFPE Engineering Guide to Performance-Based Fire Protection, Society of Fire Protection Engineers and Style for ASTM Standards[3] NFPA, Quincy, MA, 2000[3]

3. Terminology

3.1 *Definitions*—See Terminology E 176.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *fire-test-response-characteristic index, n*—a single quantitative measure that combines two or more fire-test-response characteristics for a material, product, or assembly, all developed under test conditions compatible with a common fire scenario, addressing collectively the corresponding threat. See also *fire-test-response-characteristic profile, fire hazard, fire risk, fire-test-response characteristic*.

3.2.2 *fire-test-response-characteristic profile, n*—array of fire-test-response characteristics for a material, product, or assembly, all developed under test conditions compatible with a common fire scenario, addressing collectively the corresponding threat. See also *fire hazard, fire risk, fire-test-response characteristic*.

4. Significance and Use

4.1 This guide is intended for use by those undertaking the development of fire-risk-assessment standards. Such standards are expected to be useful to manufacturers, architects, specification writers, and authorities having jurisdiction.

4.2 As a guide, this document provides information on an approach to the development of a fire-risk-assessment standard; fixed procedures are not established. Limitations of data, available tests and models, and scientific knowledge may can constitute significant constraints on the fire-risk-assessment procedure and associated standard.

4.3 While the focus of this guide is on developing fire-risk-assessment standards for products, the general concepts presented also may apply can be applied to processes, activities, occupancies, and buildings.

5. Key Elements

5.1 This guide uses as its key elements the following:

5.1.1 The purpose of a fire-risk-assessment standard is to provide a standardized procedure for assembling a compilation of information relevant to the fire risk of a product under specific conditions of use.

5.1.2 The information assembled should shall be relevant to the purpose of assessing the fire risk of the specific designated product within the range of all relevant fire scenarios.

5.1.3 The information assembled should shall be explicit and quantitative. It should shall provide a sufficiently thorough examination of the product's fire risk under the conditions defined by the scope of the specific standard so as to permit valid choices and decisions with respect to the fire risk of that product.

5.1.4 A persuasive scientific case must be made in the documentation of a specific fire-risk-assessment standard that the procedures, data, and risk measures specified by the standard will address questions about a product's fire risk with sufficient accuracy and validity that a more thorough assessment procedure would not materially alter any decisions that might are to be made based on the standard. If such a case cannot be made for all products to be addressed, then the risk assessment should shall specify those conditions under which a more thorough fire-risk-assessment procedure should is to be used.

5.1.5 The absence of a data source, test method, or calculation procedure of sufficient scope and proven validity to support the needs of a particular fire-risk-assessment procedure may not be does not, by itself, provide a sufficient reason to justification for the use of a data source, test method, or calculation procedure of lesser scope or unproven validity. It is recognized that fire-risk assessments of such products may need to be performed in any event, using relevant nonstandardized procedures. When such nonstandardized or unvalidated procedures are used, the details shall be included to such an extent that the procedures become standardized only for use within the specified fire-risk-assessment procedure through final publication of the fire-risk-assessment standard document.

5.1.6 Among the possible significant outcomes of a fire-risk assessment would be the are a revelation that a product produces either an increase, no increase, or a decrease in fire risk on some or all risk measures and for all or some of the scenarios specified by the standard relative to another product or relative to baseline risk values for those measures and scenarios. These baseline values may or may not be derived from fire-risk assessment of products already in use. However, when the product is proposed for an existing use, it should be compared to an the appropriate baseline for comparison is existing products having the same use. For example, if a product's risk is uniformly rated greater than the reference values on all comparisons specified by the standard, then the overall fire-risk assessment of the product will be greater than the fire risk of the baseline (or product in use).

[2] *Annual Book of ASTM Standards*, Vol 04.07.

[3] Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428. NFPA, 1 Batterymarch Park, Quincy, MA 02269–9101.

5.1.7 If the assessment shows that the product is not uniformly rated higher than, equivalent to, or less than the other product(s) or the baseline for all risk measures, and reflecting all scenarios specified by the standard, then decision rules may the implications of the fire risk assessment for product evaluation will not be n clear without the development of appropriate decision rules. Such rules would determine the overall risk, giving appropriate weighting to each risk measure.

6. Relationship Between Fire Hazard and Fire Risk

6.1 It is important to differentiate between *fire hazard* and *fire risk*. The relationship is as follows:

6.1.1 A fire-hazard measure addresses the expected performance of a product for a particular fire scenario, including designated conditions of use. A fire-risk measure incorporates fire-hazard measures but also incorporates the probability of occurrence of each fire scenario and addresses all relevant fire scenarios.

6.1.2 Because the number of distinguishable relevant fire scenarios in any fire-risk assessment is usually unmanageably large, it will normally be necessary for fire scenarios to be grouped into classes for purposes of analysis. This may make the fire-risk assessment less product-specific or less specific to specific conditions of use than would be true of a fire-hazard assessment.

6.1.3 Some existing fire-risk-assessment models and calculation procedures define fire risk as the sum over all fire scenario classes of the probability-weighted fire hazard for that fire scenario class. In such an approach:

6.1.3.1 The fire scenarios in each fire scenario class shall be very similar with respect to those characteristics that determine fire hazard.

6.1.3.2 Each fire scenario class will have a probability (P_i) that represents the likelihood of a fire corresponding to a scenario in that class.

6.1.3.3 For each fire scenario class, a specific fire scenario shall be chosen as representative of the class, so that the fire hazard for that specific fire scenario can be used as a valid estimate of H_i, the fire hazard of the fire scenario class. This is defined as the probability-weighted mean fire hazard for all the specific fire scenarios in the fire scenario class, a quantity that cannot be directly calculated.

6.1.3.4 If this structure is adopted, then the relationship between fire risk measure and fire hazard measure is given by the following formula:

$$Risk = \Sigma_i \left(P_i \times H_i\right) \quad (1)$$

where:

H_i = hazard for representative scenario of scenario class i, i = 1, ..., n and
P_i = probability of scenario class i, i = 1, ..., n.

6.1.4 For a fire-risk-assessment standard, this formula shows that a fire-risk-assessment procedure may be constructed from a fire-hazard-assessment procedure, a valid structure of fire scenario class and representative fire scenarios by class, and valid sources for fire scenario class probability data.

7. Fire Risk-Assessment Standards

7.1 Fire-risk-assessment standards shall conform in style and content to the *ASTM Form and Style Manual*[4].

7.2 Fire-risk-assessment standards shall include sections entitled: Scope, Significance and Use, Terminology, and Procedure. The sections should shall be numbered and arranged in that order.

7.2.1 *Scope*—The statement in the Scope should clearly state:

7.2.1.1 The product or class of products of interest,

7.2.1.2 The fire scenario(s) included in the standard,

7.2.1.3 The assumptions used in the standard,

7.2.1.4 The structure of the fire-risk-assessment procedure, including test methods, models, other calculation procedures, data sources, fire hazard measures, fire risk measures, and any other evaluation criteria or procedures used, and

7.2.1.5 Any limitations on the application of the standard, such as the manner, form, or orientation in which the product is incorporated within an assembly, geometric restrictions essential to use of the product, the quantity of product in use, the end use of the product, and the type of occupancy to which the standard is applicable.

7.2.2 *Significance and Use*:

7.2.2.1 The major uses and any limitations of the standard fire-risk-assessment procedure should shall be clearly described, including an explicit description of the extent to which the included fire scenarios, in 7.2.1.2, constitute all the relevant fire scenarios for the product (class) and occupancy type addressed by the standard.

7.2.2.2 The significance of the assessment to users should shall be clearly stated.

7.2.3 *Terminology*—Terms unique to the fire-risk-assessment standard should shall be clearly defined. Standard terms as defined in Terminology E 176 shall be used.

7.2.4 *Procedure*:

7.2.4.1 This section should shall include detailed descriptions of the fire-risk-assessment procedure and its component parts, including test methods, calculation procedures, scenario description, data sources, and evaluation criteria or procedures.

[4] Available from ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

7.2.4.2 Where sources for data on fire experience or expert judgment are cited, the procedures for assembling the data and the accuracy, precision, and reliability of the data should shall be documented. The data should shall be accessible to personnel conducting or reviewing the fire-risk assessment.

7.2.4.3 If calculation procedures include models, the versions used should shall be carefully identified and referenced, and major assumptions and limitations of the models shall be noted. Validation information, or lack thereof, should shall also be noted.

7.2.4.4 If calculation procedures are used, it will be especially helpful if sample calculations should be are included.

7.2.4.5 Standard test methods should shall be carefully identified and referenced. If a test method not yet adopted as a national standard is used, its descriptions should shall provide all the information that would be included if it were being submitted separately for consideration as a standard test method. Data on reproducibility and validation of nonstandardized methods should shall be included or its unavailability shall be explicitly noted. Engineering Guide to Performance-Based Fire Protection, Society of Fire Protection Engineers and NFPA, Quinc. If a standard test method has been modified for the standard, all details of the modification and evidence of the effects of the modification on results should shall be included. These guidelines also apply to any large-scale test protocols.

8. Fire-Risk-Assessment Procedure

8.1 *Overview of Elements of Fire Risk*:

8.1.1 HPossible sources of harm to people may result, people, directly or indirectly, from include toxic (narcotic or irritant) substances produced by a fire, thermal insults (heat stress and burns) due to convected and radiant flux, obscuration of vision by smoke (which may interfere with the ability to escape), oxygen depletion, or and structural damage leading to traumatic injury.

8.1.2 HPossible sources of harm to property may result directly include direct damage from heat, corrosive smoke, soot or firefighting, or indirectly as and indirect damage as a consequence of business interruption or other adverse effects on the ability of the property to be used for its designed purposes.

8.1.3 Harm to the environment includes direct harm to animals or plant life located outside the property of origin, and indirect harm to people, animals, plant life, or property as a result of contamination of air, water, or adjacent land.

8.1.4 The fire risk of a product depends on its properties, how it is used, and the environment in which it is used, including the number and characteristics of people potentially exposed and the value and fragility of property exposed to a fire involving the product. Therefore, a fire-risk-assessment procedure for a particular product shall describe the product, how it is used, and its environment.

8.2 *Development of a Fire-Risk-Assessment Standard*—The steps to follow in developing a fire-risk-assessment standard are as follows:

8.2.1 Define the scope (for example, the product(s) or product class of interest, and where and how the products are used),

8.2.2 Identify the measure of fire effect to be used in defining fire hazard and fire risk (for example, deaths, injuries, business loss, property loss),

8.2.3 Identify the measure of fire risk as a function of the measures of fire effect and fire hazard (for example, if fire hazard is defined as fire effect for a specific scenario, then fire risk may be defined by the formula given in 6.1.3.4),

8.2.4 Identify the structure for the fire scenarios of concern, including, if needed by the selected measure of fire risk, scenario class definitions and representative scenarios (for example, geometry, ventilation, and other spacial characteristics of environment; initial heat source; initial fuel source if not the product; locations and burning properties of secondary fuel sources; occupant characteristics),

8.2.5 Using Guide E 1546, identify the fire-hazard estimation procedure to be used to calculate the fire hazard for each representative fire scenario,

8.2.6 Identify the necessary data sources to support the procedures and measures identified in 8.2.2-8.2.5, including calculation of probabilities, and

8.2.7 Identify the necessary safety factors, sensitivity analyses, or other elements required to permit valid interpretation of the fire-risk estimates, in light of the uncertainties and biases of data or calculation methods, which shall have been previously documented in 8.2.2-8.2.6.

8.3 *Define the Scope*—The first step involves defining the products or class of products to which the fire-risk-assessment standard is to apply (that is, scope) and examining the points of variability and commonality in the product or product class and in product usage that define parameters of the fire-risk-assessment procedure.

8.4 *Identify the Measure of Fire Effect*—There are several—The candidate measures that may be used to calculate for calculation of fire risk, each with has its advantages and disadvantages.

8.4.1 *Measures of End Outcomes*, such as deaths, injuries, or property damage, are the most directly related to the ultimate concerns of fire impact on people, property, or the environment. However, these measures require more extensive and elaborate estimation procedures than do some other measures, which may not require so much information on the entire building or occupancy or on its occupants. As the analysis goes beyond the product's immediate environment, it may become becomes more difficult to isolate differences between products, but t such dis efferences are stisll real and potentially important.

8.4.2 *Measures of Physical Fire Effects*, such as extent of flame or smoke damage or whether flashover occurs, are less directly and reliably related to the ultimate concerns of fire impact on people, property, or the environment. However, most of these measures can be calculated with less elaborate estimation procedures, including procedures that do not characterize occupants or spaces beyond the first room or area involved in fire. This ~~may reduce uncertainties~~ eliminates some sources of uncertainty and makes it easier to isolate effects of product differences, although the ultimate significance, to the end outcomes that are ultimately of concern, of the risk differences so identified may be less clear.

8.5 *Identify Measure of Fire Risk*:

8.5.1 *Mean Fire Hazard*—The formula given in 6.1.3.4 defines fire risk as the mean value of fire hazard and is the fire-risk measure to be used in most circumstances.

8.5.2 *Probability of Hazard*—An alternative measure defines fire risk as the probability that a specified level of fire hazard will be met or exceeded. This measure can be used if a focus on high-severity outcomes is considered appropriate or in circumstances where the measure of fire effect is not scalar (for example, flashover occurs), which prevents the use of a mean fire hazard definition of fire risk.

8.5.3 *Absolute Versus Relative Risk*—For any measure of fire risk, it ~~may be~~ is possible to substitute a dimensionless measure that provides only the proportional change in fire risk from some baseline. This choice ~~may permit less elaborate~~ removes some parts of the estimation procedures, such as ~~no~~ the need for estimates of the absolute probability that fire will occur or for controversial assumptions such as a dollar equivalent for a lost human life. However, this reduction in information and in the difficulty of estimation also will make the result more difficult to interpret and therefore less useful.

8.6 *Identify Fire Scenario Structure*:

8.6.1 A scenario description provides all the characteristics required to select and specify test methods, fire model or calculation procedure, and data, to produce one or more fire-hazard measures. Apart from those characteristics that identify the product(s) or product class, its usage, and the occupancy type as being within the specified scope, all possible values of all other characteristics ~~should be taken to~~ presumptively describe relevant fire scenarios. Any additional limitations on scenarios shall be carefully documented and justified.

8.6.2 Scenario classes are groups of scenarios. The rules for grouping are normally such that some characteristics are specified as common to all scenarios in the class, some characteristics are allowed to vary but only within specified ranges, and some characteristics are allowed to vary without limit (for example, if scenarios are defined by the physical details of ignition, fires involving Class III B combustible liquids constitute a scenario class in which the type of material is precisely specified as a liquid, the flashpoint is specified to within a range, and other characteristics, such as the heat source, are allowed to vary over all possibilities).

8.6.3 As described in the SFPE Engineering Guide to Performance-Based Fire Protection, the identification of fire scenarios and the characterization and selection of design fire scenarios can be initiated through an examination of data on fires that have occurred, using failure analysis and appropriate fire incident databases, and an examination of what could occur, using Failure Modes and Effects Analysis (FMEA), What-if analysis, and hazards and operability studies (HAZOPS), among other common tools.

8.6.4 Techniques used to identify and select scenarios for fire risk assessment of a building design can be modified for the purpose of defining a fire risk assessment procedure for use in evaluating burnable products or materials.

8.6.5 For assessments within the scope of E 1776, scenario definition will depend primarily upon the location of the product to be evaluated and the location of the point of fire origin, as well as the heat source igniting the product (either an initiating heat source igniting the product as the first item ignited or the compartment fire igniting the product secondarily). Characterization of the building and occupant characteristics will be necessary if the hazard estimation methods selected require such data.

8.6.6 Evidence shall be provided for each scenario class to support the implicit claim that all scenarios included within that scenario class can be accurately represented by a single design fire scenario. Evidence also shall be provided that the scenarios and scenario classes addressed by the fire risk assessment method collectively represent all scenarios in which the product can be involved in fire with significant probability or significant consequence.

8.6.7 Identify Fire-Hazard-Estimation Procedure—As described in Guide E 1546, the fire-hazard-estimation procedure shall be a set of calculation procedures and assumptions capable of estimating fire-hazard values in the form specified from specifications of scenario, occupancy type, product, and product use characteristics. This will normally include calculation methods to estimate the magnitude and severity of fire effects as a function of location and time, the locations and statuses of occupants as a function of time, and the timing of certain key events (for example, flashover, detector or sprinkler actuation).

8.7 *Identify Fire-Hazard-Estimation Procedure*—As described in Guide E 1546, the fire-hazard-estimation procedure shall be a set of calculation procedures and assumptions capable of estimating fire-hazard values in the form specified from specifications of scenario, occupancy type, product, and product use characteristics. This will normally include calculation methods to estimate the magnitude and severity of fire effects as a function of location and time, the locations and statuses of occupants as a function of time, and the timing of certain key events (for example, flashover, detector or sprinkler actuation).

8.8 *Identify Necessary Data Sources*:

8.8.1 Scenarios and scenario classes need to be compatible with the selected fire-hazard-estimation procedure and its associated data sources, as well as with the data sources used for estimating probabilities.

8.8.2 Probabilities will typically be estimated as ratios where the numerator is a measure of fire experience (for example, fires) and the denominator is a measure of exposure (for example, a building of the specified occupancy type for a year).

8.8.3 Data bases on fire experience ~~may~~ can be assembled nationally or by some association linked to the selected occupancy type or product. Detailed estimates of fire experience normally use data from the United States Fire Administration's (USFA) National Fire Incident Reporting System (NFIRS) calibrated by the National Fire Protection Association's (NFPA) annual fire experience survey. More detailed statistics may be available from for some purposes exist in special data bases or special studies conducted by industry groups, the insurance industry, individual fire departments or state fire marshals, or other federal government agencies, such as the National Transportation Safety Board (NTSB), the Consumer Product Safety Commission (CPSC), and the National Center for Health Statistics (NCHS).

8.8.4 Data bases on exposure may can be assembled nationally, typically from the United States Census Bureau or other federal government agency data, or by some association linked to the selected occupancy type or product.

8.8.5 Records of fire experience or current usage can only address existing products. The corresponding characteristics for new products shall be estimated from their performance in fire tests and from other observable characteristics. Numerical models based in the physical sciences are only limited by the level of understanding of the processes included and the assumptions made within them. characteristics.

8.8.6 Data requirements for the fire-hazard-estimation procedure are likely to rely on fire-test-response characteristics for which the fire test specifications should are to be matched as closely as possible to the characteristics of the fire scenario(s) to which the data will be applied. For example, a test for the rate of heat release of a burning product will require specification of the incident heat flux. The scenario specifications may provide instead the type of first item ignited in fire from which it may be possible to infer or estimate the object's mass, burning characteristics, and distance to the product, which in turn can be used to calculate the incident heat flux such a fire will impose on the product.

8.9 *Identify Other Elements for Valid Interpretation*—Most databases have uncertainties and biases. Most fire-risk- and fire-hazard-estimation procedures introduce assumptions with additional uncertainties. These uncertainties will themselves be difficult to quantify. Safety factors and sensitivity analyses are among the traditional elements used to permit valid interpretation and use of the analyses despite these limitations. The fire-risk-assessment procedure shall specify these elements and provide evidence for their adequacy.

9. Keywords

9.1 fire; fire hazard; fire risk