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

This standard is issued under the fixed designation E1546; 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 guide covers the development of fire-hazard-assessment standards.

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

1.3 Fire-hazard assessment and fire-risk assessment are both procedures for assessing the potential for harm caused by something–the subject of the assessment–when it is involved in fire, where the involvement in fire is assessed relative to a number of defined fire scenarios.

1.4 Both fire-hazard assessment and fire-risk assessment provide information that can be used to address a larger group of fire scenarios. Fire-hazard assessment provides information on the maximum potential for harm that can be caused by the fire scenarios that are analyzed or by any less severe fire scenarios. Fire-risk assessment uses information on the relative likelihood of the fire scenarios that are analyzed and the additional fire scenarios that each analyzed scenario represents. In these two ways, fire-hazard assessment and fire-risk assessment allow the user to support certain statements about the potential for harm caused by something when it is involved in fire, generally.

1.5 Fire-hazard assessment is appropriate when the goal is to characterize maximum potential for harm under worst-case conditions. Fire-risk assessment is appropriate when the goal is to characterize overall risk (average severity) or to characterize the likelihood of worst-case outcomes. It is important that the user select the appropriate type of assessment procedure for the statements the user wants to support.

1.6 Fire-hazard assessment is addressed in this guide and fire-risk assessment is addressed in Guide E1776.

1.7 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

1.8 This fire standard cannot be used to provide quantitative measures.

1.9 This standard is used to predict or provide a quantitative measure of the fire hazard from a specified set of fire conditions involving specific materials, products, or assemblies. This assessment does not necessarily predict the hazard of actual fires which involve conditions other than those assumed in the analysis.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D2859 Test Method for Ignition Characteristics of Finished Textile Floor Covering Materials

E176 Terminology of Fire Standards

E603 Guide for Room Fire Experiments

E648 Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source

E1354 Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter

E1678 Test Method for Measuring Smoke Toxicity for Use in Fire Hazard Analysis

E1776 Guide for Development of Fire-Risk-Assessment Standards

2.2 *ISO Standards:*[3]

ISO 13943 Fire Safety – Vocabulary

2.3 *NFPA Standards:*[4]

NFPA 101 Code for Safety to Life from Fire in Buildings and Structures

NFPA 901 Uniform Coding for Fire Protection

2.4 *SFPE Standards:*[5]

SFPE Engineering Guide to Performance-Based Fire Protection

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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 02169-7471, http://www.nfpa.org.

[5] Available from Society of Fire Protection Engineers (SFPE), 7315 Wisconsin Ave., Suite 620E, Bethesda, MD 20814, http://www.sfpe.org.

3. Terminology

3.1 *Definitions of Terms*—See Terminology E176 and ISO 13943. In case of conflict the definitions in Terminology E176 shall prevail.

3.2 *Definitions:*

3.2.1 *environment, n—as related to fire*, the conditions and surroundings that may influence the behavior of a material, product, or assembly when it is exposed to ignition sources of fire.

3.2.2 *fire-characteristic profile, n*—an array of fire-test-response characteristics, all measured using tests relevant to the same fire scenario, for a material, product, or assembly, to address, collectively, the corresponding fire hazard. See also *fire hazard*, *fire risk*and *fire-test response characteristic*.

3.2.2.1 *Discussion*—An array of fire-test-response characteristics in a set of data relevant to the assessment of fire hazard in a particular fire sceanrio. In other words, all the fire tests used would have a demonstrated validity for the fire scenario in question, for example, by having comparable fire intensities. The fire-characteristic profile is intended as a collective guide to the potential fire hazard from a material, product, or assembly involved in a fire that could be represented by the laboratory test conditions.

3.2.3 *fire hazard, n*—the potential for harm associated with fire.

3.2.3.1 *Discussion*—A fire may pose one or more types of hazard to people, animals, or property. These hazards are associated with the environment and with a number of fire-test-response characteristics of materials, products, or assemblies including, but not limited to, ease of ignition, flame spread, rate of heat release, smoke generation and obscuration, toxicity of combustion products, and ease of extinguishment.

3.2.4 *fire risk, n*—an estimation of expected fire loss that combines the potential for harm in various scenarios that can occur with the probabilities of occurrence of those scenarios.

3.2.4.1 *Discussion*—Risk may be defined as the probability of having a certain type of fire, where the type of fire may be defined in whole or part by the degree of potential harm associated with it, or as potential for harm weighted by associated probabilities. However, it is defined, no risk scale implies a single value of acceptable risk. Different individuals presented with the same risk situation may have different opinions on its acceptability.

3.2.5 *fire scenario, n*—a detailed description of conditions, including environmental, of one or more of the stages from before ignition to the completion of combustion in an actual fire, or in a full scale simulation.

3.2.5.1 *Discussion*—The conditions describing a fire scenario, or a group of fire scenarios, are those required for the testing, analysis, or assessment that is of interest. Typically, they are those conditions that can create significant variation in the results. The degree of detail necessary will depend upon the intended use of the fire scenario. Environmental conditions may be included in a scenario definition but are not required in all cases. Fire scenarios often define conditions in the early stages of a fire while allowing analysis to calculate conditions in later stages.

3.2.6 *fire test response characteristic, n*—a response characteristic of a material, product, or assembly to a prescribed source of heat or flame, under controlled fire conditions; such response characteristics may include, but are not limited to, ease of ignition, flame spread, heat release, mass loss, smoke generation, fire endurance, and toxic potency of smoke.

3.2.6.1 *Discussion*—A fire-test-response characteristic can be influenced by variable characteristics of the heat source, such as it intensity, or of the burning environment, such as ventilation, geometry of item or enclosure, humidity, or oxygen concentration. It is not an intrinsic property such as specific heat, thermal conductivity, or heat of combustion, where the value is independent of test variables. A fire-test-response characteristic may be described in one of several terms. Smoke generation, for example, may be described as smoke opacity, change of opacity with time, or smoke weight. No quantitative correlation need exist between values of a fire-test-response characteristic for different materials, product, or assemblies, as measured by different methods or tested under different sets of conditions for a given method.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *fire 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-characteristics profile*, *fire hazard*, *fire risk*, *fire-test-response characteristic*.

3.3.2 *fire hazard assessment, n*—a process for measuring or calculating the potential for harm created by the presence of a material, product, or assembly in the relevant fire scenarios.

3.3.3 *fire risk assessment, n*—a means for computing the probability of fire loss within a specified period in a defined occupancy or situation.

4. Significance and Use

4.1 This guide is intended for use by those undertaking the development of fire-hazard-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 hazard standard; fixed procedures are not established. Limitations of data, available tests and models, and scientific knowledge may constitute significant constraints on the fire-hazard-assessment procedure.

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

4.4 When developing fire-risk-assessment standards, use Guide E1776. The present guide also contains some of the guidance to develop such a fire-risk assessment standard.

5. Key Elements

5.1 This guide uses as its key elements the following:

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

5.1.2 The information assembled by using a fire-hazard-assessment standard should be relevant to the purpose of assessing the fire hazard of the specific designated product within the range of designated fire scenarios. The information assembled by using a fire-risk-assessment standard (see Guide E1776) should be relevant to the purpose of assessing the fire risk of the specific designated product within the range of all relevant scenarios.

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

5.1.4 A persuasive scientific case must be made in the documentation of a specific fire-hazard-assessment standard that the procedures, data, and hazard measures specified by the standard will address questions about a product's fire hazard with sufficient accuracy and validity that a more thorough assessment procedure would not materially alter any decisions that might be made based on the standard. If such a case cannot be made for all products to be addressed, then the hazard assessment should specify those conditions under which a more thorough fire-hazard-assessment procedure should be used. In some cases, the more thorough assessment procedure identified by a fire-hazard-assessment standard can be considered to be a fire-risk-assessment procedure, but this must be confirmed via Guide E1776.

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-hazard-assessment procedure may not be a sufficient reason to use a data source, test method, or calculation procedure of lesser scope or unproven validity. It is recognized that fire-hazard assessments of such products may need to be performed in any event, using relevant non-standardized procedures. When such non-standardized 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-hazard-assessment or fire-risk-assessment procedure through final publication of the fire-hazard-assessment or fire-risk-assessment standard document.

5.1.5.1 The concepts discussed in 5.1.5 apply both to fire-hazard assessments, conducted in accordance with this guide, and to fire-risk assessments, conducted in accordance with Guide E1776.

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

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 hazard measures and reflecting all scenarios specified by the standard, then the implications of the fire-risk assessment for product evaluation (in accordance with Guide E1776) will not be clear without the development of appropriate decision rules. Such rules would combine the fire hazard or fire risk measures, giving appropriate weighting to each fire-hazard or fire-risk measure, and, if necessary, would combine measures for different scenarios, giving appropriate weighting to each scenario. Decision rules for combining measures need not be simple weighted sums of the component measures. Decision rules for combining scenarios normally use weights reflecting the relative likelihood of different scenarios. Fire-risk-assessment standards normally include procedures for combining scenarios, but fire-hazard-assessment standards normally do not. Note that the scenario may affect not only the value of individual fire hazard or fire risk measures but also the decision rules for combining fire hazard or fire risk measures (in the latter case by using Guide E1776).

6. Relationship Between Fire Hazard and Fire Risk

6.1 It is important to differentiate between *fire hazard* and *fire risk* (see 3.1 for the definitions). 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 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 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 the fire risk measure and fire hazard measure is given by the following formula:

$$Risk = \sum_i (P_i \times H_i) \quad (1)$$

where:

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

H_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.

6.1.5 The principal differences between a fire-hazard assessment and a fire-risk assessment are (a) a fire-risk assessment incorporates relative scenario likelihood into the information provided in the assessment, whereas a fire-hazard assessment normally does not do so; and (b) the scenarios in a fire-risk assessment need to be chosen so that they collectively represent all relevant fire scenarios, whereas the scenarios in a fire-hazard assessment need only be chosen so that a more thorough assessment would not materially alter any decisions made based on the assessment and the standard.

6.1.6 A fire-risk assessment may be most appropriate when it is not possible to demonstrate that use of a fire-hazard assessment will not materially alter any decisions made based on the assessment and the standard, relative to decisions that would have been made using a fire-risk assessment. A fire-hazard assessment may be acceptable and more efficient when the purpose is only to demonstrate that consequences are acceptably small for each scenario analyzed.

7. Fire-Hazard-Assessment Standards

7.1 Fire-hazard-assessment standards shall conform in style and content to the *ASTM Form and Style Manual*.[6]

7.2 Fire-hazard-assessment standards shall include sections labeled: Scope, Significance and Use, Terminology, and Detailed Procedure; the sections should be numbered and arranged in that order.

7.2.1 *Scope*—the Scope statement 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, and, for a fire-risk assessment, in accordance with Guide E1776, the scenario class represented by each fire scenario,

7.2.1.3 The assumptions used in the standard,

7.2.1.4 The structure of the fire-hazard-assessment procedure, including test methods, models, other calculation procedures, data sources, hazard measures, and 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-hazard-assessment procedure should be clearly described. For fire-risk-assessment procedures, in accordance with Guide E1776, this should include an explicit description of the extent to which the included fire scenario classes and representative fire scenarios, in 7.2.1.2, constitute all the relevant fire scenario classes and representative 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 be clearly stated.

7.2.3 *Terminology*—Terms unique to the fire-hazard-assessment standard should be clearly defined. Standard terms as defined in Terminology E176 shall be used. Terms not included in Terminology E176 but useful for this guide are included in 3.3.

7.2.4 *Detailed Procedure:*

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

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

7.2.4.3 If calculation procedures are used, sample calculations should be included.

7.2.4.4 Standard test methods should be carefully identified and referenced. If a test method not yet adopted as a national standard is used, its descriptions should 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 non-standardized methods should be included. 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 be included. These guidelines also apply to any large-scale test protocols.

7.2.4.5 If 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 be documented. The data should be accessible to personnel conducting or reviewing the fire-hazard assessment.

8. Fire-Hazard-Assessment Procedures

8.1 *Overview of Elements of Fire Hazard:*

8.1.1 Possible sources of harm to people or animals, directly or indirectly, 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, and structural damage leading to traumatic injury.

8.1.2 Possible sources of harm to property include direct damage to contents, furnishings, structure, or other installed or moveable combustibles, from heat, corrosive smoke, soot or

[6] Available from ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428–2959. http://www.astm.org.

firefighting, 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 for 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, adjacent land.

8.1.4 The fire hazard or risk of a product depends on its properties, how it is used, and the context 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-hazard-assessment or fire-risk-assessment procedure for a particular product should describe the product, how it is used, and its context of use.

8.2 *Development of a Fire-Hazard-Assessment Standard*—The seven basic steps to follow in developing a fire-hazard-assessment standard are the following:

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

8.2.2 Identify the measure of harm to be assessed (for example, deaths, injuries, business loss, property loss),

8.2.3 Identify and describe the fire scenarios to be analyzed (for example, geometry, ventilation, and other special characteristics of environment; initial heat source; initial fuel source if not the product; locations and burning properties of secondary fuel sources; occupant characteristics), and for fire-risk assessment (in accordance with Guide E1776), including the scenario classes represented by each scenario selected for analysis,

8.2.4 Identify the test methods or calculation procedures needed to produce the measures of fire hazard (note that, when assessing fire risk in accordance with Guide E1776, probability assessments will be needed),

8.2.5 Use the scenarios to define key parameters of the test methods or calculation procedures,

8.2.6 Identify the types and sources of data required to support the selected test methods and calculation procedures, identified in 8.2.2 – 8.2.5 (note also that, when assessing fire risk, in accordance with Guide E1776, it will be necessary to identify the types and sources of data required for calculation of needed probabilities), and

8.2.7 Identify the criteria or procedures for evaluating the fire hazard measures relative to the degree of harm.

8.2.8 Identify the necessary safety factors, sensitivity analyses, or other elements required to permit valid interpretation of the fire-hazard in light of the uncertainties and biases of data or calculation methods, which should have been previously documented in 8.2.2 – 8.2.7

8.2.9 Fig. 1 graphically displays the steps in 8.2.1 – 8.2.8, where the left side shows steps for fire-hazard assessment and the right side shows steps for fire-risk assessment, in accordance with Guide E1776.

8.3 *Define the Scope and Context*—The first step involves defining the products or class of products to which the fire-hazard-assessment standard is to apply (that is, scope) and defining the general and specific environments in which the products will be used (that is, context), including implications of those environments for test conditions or model parameters in the fire-hazard-assessment calculation procedure. This may be accomplished by answering the following questions:

8.3.1 *Product or Class*—What is the product or product class to be covered? Is the definition clear enough that one can always determine whether a product is covered by the standard? Is the definition broad enough that all products capable of substituting for covered products are also included? Is the definition sufficiently specific that it does not invite invalid comparisons, such as comparisons of products that have very dissimilar uses and do not satisfy all the assumptions of the standard?

8.3.2 *Product Involvement in Fire*—When and how does the product tend to become involved in fire? Is there a particular role in fire that tends to be the only point of concern for this product class in a specific use (for example, initial heat source, initial fuel source, principal or largest fuel source, high severity per unit of product, major avenue of fire spread, major part of value at risk)? Based on this information, is there a subset of the following fire-test-response and other characteristics that can validly be isolated as the only ones providing significant variation in fire hazard for this product class? Consider the following:

8.3.2.1 Ignitability,

8.3.2.2 Flame-spread rate,

8.3.2.3 Heat release—peak rate, rate of rise in rate (fire growth rate), total heat released,

8.3.2.4 Mass loss or smoke-generation rate,

8.3.2.5 Opacity of smoke produced (also described as smoke obscuration),

8.3.2.6 Corrosivity of smoke produced,

8.3.2.7 Profile of toxic (irritant and asphyxiant) species produced—rate, total, toxic potency,

8.3.2.8 Thermal-decomposition rates,

8.3.2.9 Fire resistance—structural integrity, thermal conductivity, mechanical response (for example, melting, collapsing),

8.3.2.10 Ease of extinguishment, and

8.3.2.11 Quantity of product in use relative to size and type of occupancy.

8.3.3 *Environment:*

8.3.3.1 What are the environments in which the product will be used? Environment characteristics of interest typically include those that define the manner of use of the product and those that define nearby heat sources and other fuel items, nearby occupants and their characteristics or behaviors, and the dimensions and characteristics of the spaces in which fire can develop. In practical terms, the general-environment characteristics of interest will generally be those that can be translated into fire test specifications or variables in calculations. Typically, most or all of these environment characteristics can be inferred from the (property) use groups or occupancy classifications where the product is to be used. Use groups and occupancy classifications suitable for this purpose can be found in many codes and in coding rules for fire incident databases.

8.3.3.2 What does this information and other information on the product's environment indicate about the number of persons or quantity and value of property that potentially could

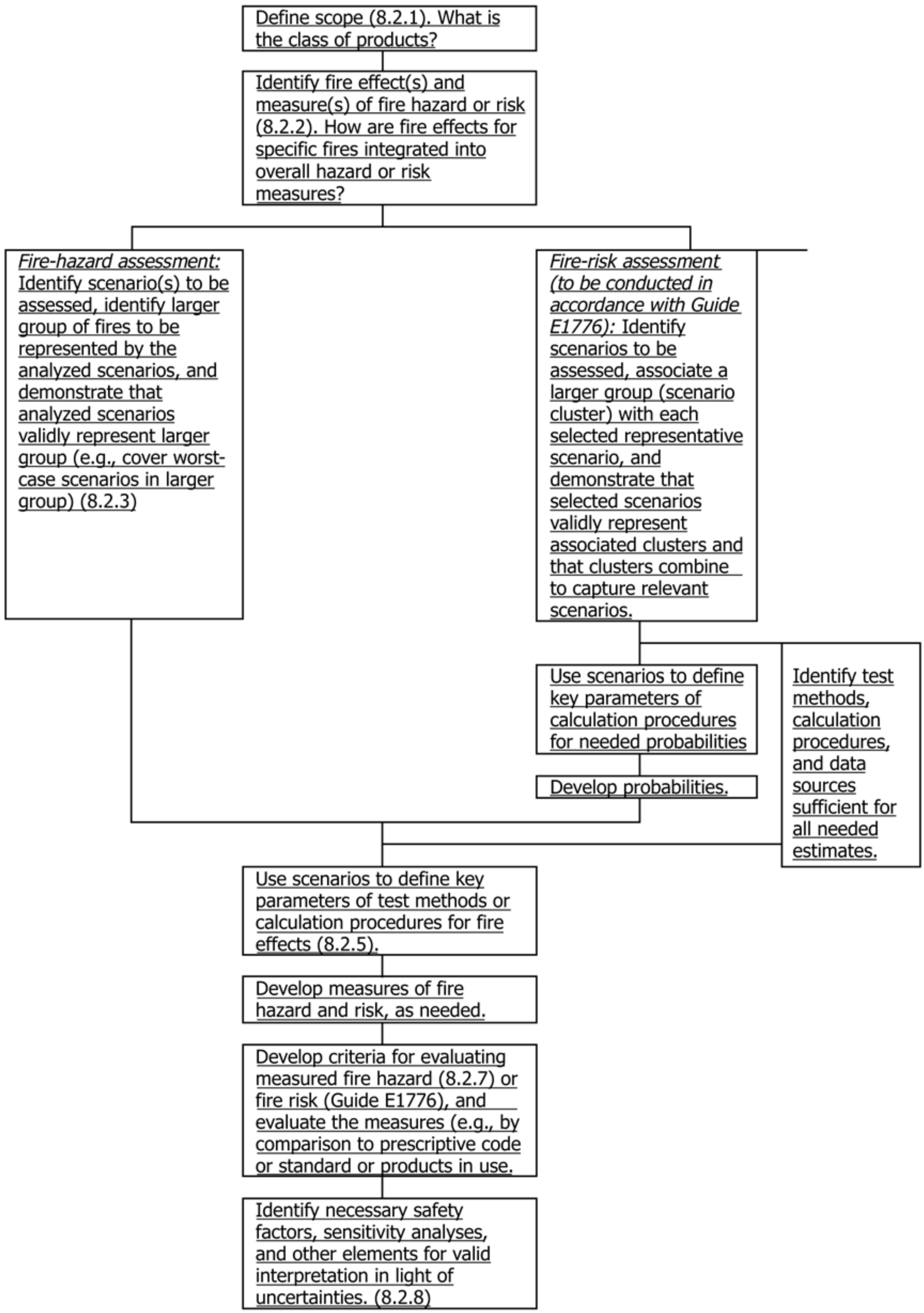

FIG. 1 Flow Chart Showing Steps in Fire-Hazard or Fire-Risk Assessment

be exposed to a fire involving the product, the special capabilities or limitations of the occupants, and the special characteristics or vulnerabilities of the property? What does this information indicate about the relative importance to overall fire hazard of the particular fire-test response and other characteristics selected in 8.3.2?

(1) For example, for a product used in a small property, such as, dwelling or store, the most important measures of its

involvement in a fire might include its ability to start a fire (ignitability) and the speed with which it produces hazardous conditions (heat release, smoke-generation rate, profile of toxic species produced). For a product used in a large property, like a high-rise hotel or office building, other measures of involvement in fire might also be of interest, such as its ability to produce hazardous conditions over a large area (flame-spread rate, quantity of product in use, total heat released, total toxic product produced).

(2) As another example, for a product used in a densely populated property (for example, multifamily residential, public assembly) the measures of fire involvement of greatest concern might emphasize the product's ability to produce conditions hazardous to occupants (heat release, toxic species) while for a product used in an industrial property, the measures of greatest interest might emphasize the product's ability to produce fire effects that damage property that is either expensive to replace or repair or critical to operation of the facility (endurance under fire conditions, smoke corrosivity).

8.3.3.3 *Environment*—What is known about the immediate environment of the product as it affects the likely conditions of the product's involvement in fire? Is the product always located in an exposed or enclosed space? What types of fire barriers separate the product from other spaces (for example, an ordinary wall, a fire-rated wall, an ordinary door that may be open, or a fire-rated door with automatic closing device)? Is the product used in areas where building systems or other features such as, air-handling systems or open stairways, could contribute to transport of the product's fire effects to remote parts of the property? Is the product typically used as a single unit or as a component of an assembly? Are there other products normally associated with the product in question (for example, a carpet and its pad) or installation procedures that may affect the fire-hazard development of the product? Is more, or less, humidity likely to affect performance of the product?

8.3.3.4 What is the range of conditions of the product in use? Are there patterns of age, use, or abuse that will affect its fire performance? Based on answers to questions like these, how should the product specimen and its environment be prepared for testing?

8.4 *Identify Measures Used to Calculate Fire Hazard*—There are several measures that may be used to calculate fire hazard (or fire risk, in accordance with Guide E1776). Each type of measure has advantages and disadvantages.

8.4.1 *Measures of End Outcomes,* Such measures, including deaths, injuries, or property damage, are the most directly related to the ultimate concerns of fire impact on people and property. This direct relationship is an advantage. However, these measures require the use of scenarios that specify not only the product and its immediate environment but also the entire building or occupancy and its occupants. As the analysis goes beyond the product's immediate environment, it may become more difficult to isolate differences between products, but this effect is real.

8.4.1.1 An intermediate approach measures the arrival of a particular fire condition, such as, reduced visibility, flashover, or insufficient oxygen, that may affect occupants and property. This approach lacks the rigor required to perform a direct death or damage analysis. However, it does set meaningful general criteria by which to judge products. When this intermediate approach is used, the standard should clearly state that the hazard assessment determines the arrival of particular fire conditions that do not necessarily relate to deaths and damage.

8.4.2 *Measures of Physical Fire Effects*—Such measures, including 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 a fire. This 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.

8.4.3 *Measures of Fire-Test-Response Characteristics*—Such measures may be used individually or as elements in a fire-characteristic profile. These measures come directly from test methods, which may reduce their uncertainty, and tend to be based on tests involving only the product, which may simplify the process of isolating differences between products. These are advantages of such profiles. However, the relative importance, interaction, and relevance of the fire-test-response characteristics, individually and collectively, to the hazard posed by the product in real fires must be established by comparison to more thorough assessments. The need for such comparisons exists for all fire-hazard measures, but is greatest for measures of fire-test-response characteristics, because they are farthest removed from end-outcome measures; this is a disadvantage of this approach.

8.4.4 *A Fire-Characteristic Index* is a measure that is calculated from component fire-test-response characteristics or intrinsic fire properties. Such an index may make it easier to distinguish product differences, and because it integrates several fire-test-response characteristics, it may permit identification of simple evaluation criteria. These are advantages to this approach. Disadvantages include the need to demonstrate that the index validly integrates the component characteristics, which are likely to include the need for comparison of the index with results from large-scale tests and analyses of real fires.

8.4.5 *Calculated Measures of End Outcomes* are developed using equations to calculate measures of the type described in 8.4.1 and 8.4.1.1 from input variables consisting of measures of the type described in 8.4.3. A fire model is an example of a set of equations to perform such a calculation.

8.4.6 *Measures of Fire Risk (to be assessed by means of Guide E1776):*

8.4.6.1 *Mean of 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 used in most circumstances.

8.4.6.2 *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.

8.4.6.3 *Absolute versus Relative Risk*—For any measure of fire risk, it is possible to substitute a dimensionless measure that provides only the proportional change in fire risk from some baseline. This choice removes some parts of the estimation procedures, such as the need for estimates of the absolute probability that fire will occur or for controversial assumptions such as dollar equivalent for a lost human life. If the threshold for acceptable risk is defined by the risk associated with current products for the existing use or with products compliant with current codes, then relative risk measures are likely to be sufficient.

8.5 *Identify and Describe Scenarios:*

8.5.1 A scenario is a detailed description of conditions, including environmental, of one or more of the stages from before ignition to the completion of combustion in an actual fire. A fire scenario includes a set of details required to select and specify test methods, fire model, or calculation procedure to produce one or more fire-hazard measures. The fire-hazard-assessment standard includes procedures to identify and describe scenarios, including procedures for selecting the scenarios to be used in the calculation. The standard can also identify specific scenarios to include or represent in the calculation. Typical characteristics used to define scenarios include the following:

8.5.1.1 The location of the initial fuel for the fire, its fire-test-response characteristics, and its intrinsic fire properties;

8.5.1.2 The location of the ignition heat source and its heat-release characteristics;

8.5.1.3 Proximities and characteristics of other items near the first item ignited;

8.5.1.4 Layout of the building or other environment, including the number of rooms and floors, room and other area dimensions, and openings and vents between rooms and areas and between rooms and the outside;

8.5.1.5 Thermal properties of all room linings, fuel loads of rooms and spaces other than the first room or area involved, properties and quantities of contents and finishes providing avenues of flame spread, and properties of barriers (doors, walls) and conditions required to breach them;

8.5.1.6 Number of persons, quantities and values of property, and the locations and characteristics of people and property as they affect vulnerability and reaction to fire.

8.5.2 For fire-risk assessments, in accordance with Guide E1776, each scenario selected for analysis is linked to a scenario class which it represents. 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). Probabilities can be estimated for scenario classes but are not meaningful when calculated for fully specified scenarios. Because fire hazard is calculated for a scenario while probability is calculated for the linked scenario class, it is important that the scenario be a representative scenario for its scenario class. A representative scenario is an average scenario which may not be the same as a typical scenario. Evidence should 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 should 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 for significant consequence.

8.5.3 Because the focus of the assessment is a product, the most important scenario dimensions typically will be those that either define the fire conditions that cause the product to become involved in fire or indicate the point in the fire when the product's contribution will have the greatest consequence for hazard. To determine this, it is necessary to answer questions like these:

8.5.3.1 *Is the product a likely first item ignited?* This may be determined through analysis of historical fire experience if the product has been in use in the same manner for some time. If the answer is yes, the same analysis can indicate the relative importance of various types of initial heat sources such as:

(1) Glowing hot object (lighted tobacco product, fireplace ember or spark, overloaded electrical wire).

(2) Radiant-heat source (appliance designed to, or known to, produce heat).

(3) Open-flame source (match or lighter, torch, gas fueled burner or pilot light, fireplace fire, trash fire).

(4) Accelerant-fed fire (arson fire set on the product with use of accelerants).

8.5.3.2 *Is the product a potential major fuel source even if not the first item ignited?* This may be estimated by the relative quantity and total heat release of the product available for fire involvement in rooms and areas where fire typically begins. If the answer is yes, then one might develop parameters for the heat source exposure to the product.

8.5.3.3 *Is the product a potential avenue of flame spread?* This may be estimated from a review of large historical fires. If the answer is yes, then one might specify testing of the product using a heat source considered to be representative of fire conditions for a well-developed fire that has not yet filled a large room or a floor.

8.5.3.4 *How close is the exposed population (or the most critical property) to the fire, and what does this imply about the most critical stage of the product's fire involvement?* Consider the following possible spatial relationships:

(1) Population is in the same room as fire.

(2) Population is in other rooms on the same floor or on an adjacent floor connected by an open stairway or air-handling system.

(3) Population is in building but remote from fire (several floors away or separated from fire by rated fire barriers, enclosed stairway, or considerable distance).

(4) Population is exposed by fighting the fire, whether as fire department, facility fire brigade, employees, etc.

(5) Population is exposed after the fire (for example, during overhaul or cleanup).

8.5.3.5 *What are the mental, physical, and age characteristics of the population?*

(1) Is escape hindered due to age, physical infirmity, or mental capacity?

(2) How much escape time is likely to be needed?

8.5.3.6 *Are special installation or structural requirements necessary to mitigate the hazard?*

(1) If the product is being compared to other products in the same class, is the data used relevant under the same installation requirements?

(2) Is it clear in reporting on the assessment what mitigating or protective features are necessary for the hazard measure to be viable?

8.5.4 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.

8.5.5 If one of the areas listed in 8.5.3 can be identified as the greatest concern, that may mean that one product fire performance characteristic is of greatest importance, such as the product's ability to generate a significant hazard quickly, its total hazard capacity (for example, quantity in use), or the persistence of its hazard during and after suppression operations. Such determinations can then be used to define test methods or calculation procedures that will measure the product's contribution to fire hazard at those stages of the fire.

8.5.6 In particular, if the greatest concern with a product is its ability to initiate fire or to produce by itself a rapid onset of hazardous conditions, then it is most likely that test methods and calculation procedures need not explicitly address the product beyond its immediate environment or the specifics of the population and property at risk. Thus, the analysis can be cut off at the immediate environment in this case, with little loss in validity and with reduced computation, if appropriate checks are incorporated. Conversely, if the greatest concerns with the product are with its contribution to large fires exposing remote populations or concentrations of value relatively late in the fire, then it may be impossible to define a valid fire-hazard-assessment procedure without explicitly addressing all the scenario dimensions that define the building.

8.5.7 In each case, the procedure is to use what is known of the scope and context to identify appropriate parameters for selection and specification of a test method, model, or calculation procedure. No algorithms or heuristics exist to fully specify this process. However, it is common practice in a fire-hazard assessment to develop one or more scenarios of the most-common-serious-fire type (for example, leading causes of fatal fires involving the product class) and one or more scenarios of the most-severe-credible-fire type (for example, characteristics of the deadliest fire involving the product in the past decade). Use of this most-likely versus most-severe approach has advantages since this permits substantial use of historical fire experience, provides a readily understandable context for experts to provide estimates of key scenarios, and is likely to produce very diverse scenarios, which provide some assurance that the product's fire potential will be fully exercised and that no surprises are likely to come up.

8.6 *Identify Test Methods or Calculation Procedures for Fire-Hazard Assessment:*

8.6.1 It is likely that in completing the preceding steps in 8.2 – 8.5, the developers of a fire-hazard-assessment standard will have been led to identify appropriate test methods and calculation procedures capable of producing the designated hazard measures. The steps in Section 7 should help in translating occupancy type, product, and product use characteristics into parameter specifications for those test methods and calculation procedures.

8.6.2 The following steps should help in translating specifications of scenario into parameter specifications for those test methods and calculation procedures.

8.6.2.1 A test method or calculation procedure will require a number of specifications or input values. For example, a test for the rate of heat release of a burning product will require specification of the circumstances of ignition (for example, piloted ignition), the level of incident heat flux, and any requirements for control of oxygen or humidity levels in the combustion atmosphere. A calculation procedure for estimating the development of a fire involving a product may require input data on the first item ignited in fire, its mass and burning characteristics, and the distance from the first item to the product.

8.6.2.2 Each of the specifications and input values required by the test methods or calculation procedures should be set on the basis of inference from the characteristics of the scenario already selected. This is likely to require use of statistics on characteristics of relevant historical fires and some documented judgments by experts. It may also require some iteration, in which the process of defining key parameters identifies ambiguities in the definition of the relevant scenarios, leading to clarification or even redefinition, and finally to completion of the process of defining key parameters. The scenarios and the test methods and calculation procedures need to be defined compatibly, and iterative modification of all three is likely to be required to make them fit.

8.6.2.3 This exercise also may indicate that the chosen scenario is consistent with a range of values for a particular key parameter. In such a circumstance, the specific value chosen should be representative of the range.

8.6.2.4 The process of defining key parameters by inference from scenario characteristics typically will not follow a unique course but will be influenced by the quantity and quality of available information. For that reason, the assumptions made and the evidence to support them must be clearly documented as part of the documentation of the fire-hazard-assessment standard.

8.6.3 At this point, the standard developer should be most concerned about either the possibility that full specification of all scenarios selected for analysis will require parameters in combinations that no existing test method of calculation procedure can provide, or the possibility that the tests on and experience with the selected test methods or calculation procedures are not sufficient to establish that they will produce hazard measures properly representative of end-outcome hazards in real fires. Therefore, the developer should carefully review and document the evidentiary base on the selected test methods and calculation procedures. If that evidentiary base is insufficient or indicates important deficiencies in the methods or procedures, then the developer should address them through some combination of further research, redesign of the procedure, or limitation of the scope of the standard.

8.7 *Identify and Show Relevance, Validity, and Appropriateness of Sources of Data for Fire-Hazard or Fire-Likelihood Estimation*—Data available for use in the fire-hazard estimation step of a fire-hazard assessment (or the fire-likelihood estimation step of a fire-risk assessment in accordance with Guide E1776) may be of any of these types: test-response results, based on application of small-scale test methods or large-scale test protocols: measurements of or statistics on characteristics of historical fires: or documented judgments by experts. In selecting data, the following points should be observed:

8.7.1 The adequacy of the data and data sources should be assessed relative to basic standards of precision and accuracy and relative to the calculation procedure's assumptions as to what the data represent.

8.7.2 Fire experience data (measurements of or statistics on characteristics of historical fires) must be shown to have sufficient precision and level of detail for the use made of it. Other types of data must be shown to be sufficiently representative of the real fire situations to which they are meant to apply. No data source is superior to any other in all respects.

8.7.3 Well-devised large-scale experiments can provide detailed data on full-scale fires. Some fire phenomena may not manifest themselves in small-scale experiments as they do in large-scale experiments and real fires, and these phenomena may not be measurable after the fact in real fires. Therefore, any fire-hazard-assessment procedure that does not use large-scale experiments as a data source should be checked against data from large-scale experiments to establish that relevant phenomena are being properly captured. If room-scale fire tests are used, Guide E603 should apply.

8.7.4 Small-scale experiments offer the greatest potential for control and therefore may produce very detailed data with greater repeatability than other data sources. Where possible, tests shall be standard test methods approved by ASTM committees. Where appropriate ASTM standards are not available, other standards that have been developed through a consensus process should be used.

8.7.5 If data on fire effects on people are estimated or calculated rather than measured, they should be checked against fire-experience data to establish that key assumptions of the estimation or calculation procedure (for example, calculation procedure formulas or parameters, animal model used in tests) produce results consistent with relevant fire experience.

8.7.6 Likelihoods of ignition 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). Relative probabilities of occurrence for different scenario classes will typically be estimated as ratios where both numerator and denominator are measures of fire experience, resulting in a ratio equal to the fraction of all relevant fires that satisfy the defining characteristics of the specific scenario class.

8.7.6.1 Fire-experience data is based on historical fires and so cannot provide data on new products or new uses of existing products. Therefore, it is unlikely that any fire-hazard-assessment procedure based solely on fire-experience data will have enough scope of application to be useful.

8.7.6.2 Major sources of U.S. fire-experience data include the U.S. Fire Administration's (USFA) National Fire Incident Reporting System (NFIRS) files of reported fire incidents, statistics on all U.S. reported fires based on projections from NFIRS files,[7] the National Fire Protection Association's (NFPA)[4] major fire investigation reports, the vehicle accident reports of the National Transportation Safety Board (NTSB),[8] and the field-study investigations of the Consumer Product Safety Commission (CPSC).[9]

8.7.6.3 It should be recognized that each of these sources of fire experience data necessarily contain limitations in accuracy and specific detail and should not be taken as absolute.

8.7.7 Data on products, buildings, people, behavior, or any other element in the fire-hazard assessement (or fire risk assessment in accordance with Guide E1776) should be collected with an awareness that those involved in fires, or in serious fires, may differ in important aspects from the larger class of products, buildings, people, behavior, etc.

8.7.8 Databases on exposure 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. If relative risk measures are used and absolute risk measures are not used, it may not be necessary to use measures of exposure.

8.7.9 Records of fire experience or current usage can only address existing products. The corresponding characteristics for new products can be estimated from their performance in fire tests and from other observable characteristics.

8.7.10 Data requirements for the fire-hazard-estimation procedure are likely to rely on fire-test-response characteristics for which the fire test specifications 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

[7] Available from US Fire Administration (USFA), 16825 S. Seton Ave. Emmitsburg, MD 21727, http://www.usfa.dhs.gov.

[8] Available from NTSB, 490 L'Enfant Plaza East S.W., Washington, DC 20594, http://ntsb.gov/alj/gc_org.htm.

[9] Available from U.S. Consumer Product Safety Commission (CPSC), 4330 East West Hwy., Bethesda, MD 20814, http://www.cpsc.gov.

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.

8.7.11 In addition to describing appropriate types and sources of data, a fire-hazard-assessment standard can include compilations of data. Normally, such compilations are included in non-mandatory appendixes.

8.8 *Identify Other Elements for Valid Interpretation:*

8.8.1 Most databases have uncertainties and biases. Most fire-risk- and fire-hazard-estimation procedures introduce assumptions with additional uncertainties. These uncertainties themselves are typically 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. A fire-hazard-assessment procedure, or a fire-risk-assessment procedure in accordance with Guide E1776, should specify these elements and provide evidence for their adequacy.

8.8.2 If more than one fire-test-response characteristic or intrinsic fire property is to be used to determine hazard, the standard should specify the procedure to be used in calculating an overall fire-hazard comparison between the product and a baseline or between the product and another product or products. This procedure might be a formula for calculating one overall hazard measure from several characteristics, in which case a scientific rationale should be presented for the formula. The procedure could be a set of decision rules, such as a rule that one product is better than another only if it is better in all measures, or better in a measure identified as that of greatest concern. In using this rule, it may not be strong enough in a specific case of two products to provide for a definitive comparison as to the overall hazard, in which case a definitive comparison may require a fire-risk assessment in accordance with Guide E1776.

8.8.3 If the end-outcome measures, such as number of deaths, injuries, or monetary loss, are not used directly in the assessment, then the fire-hazard assessement standard should provide guidance on the implications of the particular values or ranges of the measures (such as smoke production, temperature, or CO content) used.

8.8.4 The standard should not attempt to set a safety threshold or other pass/fail criterion but should specify all steps required to determine fire-hazard measures for which safety thresholds or pass/fail criteria can be meaningfully set by responsible officials who may use the standard.

APPENDIXES

(Nonmandatory Information)

X1. AN APPLICATION OF E1546 GUIDE FOR THE DEVELOPMENT OF FIRE-HAZARD-ASSESSMENT STANDARDS (FLOOR COVERINGS IN SPECIFIED HEALTH CARE OCCUPANCIES)

X1.1. Scope

X1.1.1 This is an example of a fire hazard assessment standard written in accordance with Guide E1546. It is intended solely for the purpose of illustrating the application of Guide E1546 and so assisting in the development of fire-hazard-assessment standards. It is not to be used as a fire-hazard-assessment standard itself.

X1.1.1.1 As an example of a standard developed in accordance with Guide E1546, this document is itself a more detailed guide to the format and content of a fire-hazard-assessment standard. For this reason, this document will refer to itself as both an "example standard" and a "guide." The term "example standard" will be used in any passage where a free-standing standard would refer to itself as a "standard."

X1.1.1.2 A fire-hazard-assessment standard, or any other performance-based standard, is useful if there are new technologies or unusual designs whose associated fire hazards cannot be adequately measured by existing test-method-based standards; or if the goals of existing codes, standards, and regulations can be met more flexibly or less expensively by new technologies or designs that would not be acceptable under existing codes, standards, or regulations but could be shown to achieve the goals. Because existing codes, standards, and regulations typically do not state their goals in measureable form, suitable for engineering analysis, suitable goals that express the intent of the code, standard, or regulation must be developed by those responsible for safety. Those individuals have not controlled the specification of goals and associated evaluation criteria in this example standard, which is the principal reason that it is to be used as a guide and example and not as a standard for the subject product.

X1.1.1.3 Because this is an example and not a finished standard for use, the evaluation criteria, scenarios, assumptions, and models proposed must be regarded only as plausible, workable candidates that illustrate the structure and content of a fire-hazard-assessment standard. They do not all have consensus support as final choices for a standard ready for use.

X1.1.2 This example standard addresses fire-hazard assessment of floor coverings installed on the floor areas of buildings used as health-care occupancies. Paragraph X1.2.3.1 defines health-care occupancies, and Paragraphs X1.2.3.2 and X1.2.3.3 specify the types of health care occupancies addressed by this example standard. This example standard does not address floor coverings installed on walls, ceilings, stairs, or in occupancies other than health care.

X1.1.3 Floor coverings include carpets, carpet tiles, wood flooring, resilient flooring, and cast-in-place materials. Underlayments and previously installed floor coverings are included in the analysis as part of the floor covering.

X1.1.4 Floor coverings may be formed in place, attached by adhesive, adhesive tape, mechanical devices such as nails, or be unattached to the subfloor.

X1.1.5 This example standard addresses fire hazard, defined as loss of life at the fire scene, which is the measure of harm to be used. Section 6 identifies evaluation criteria to be used in determining that occupants are not exposed to fire effects sufficient to cause death.

X1.1.6 This example standard addresses fire hazards resulting from involvement of floor coverings in fires. The fire scenarios of concern, defined in detail in a later section, have been chosen to represent both common and severe scenarios in which floor coverings play a significant role in the development of a fire hazard to life, either as the first combustible item ignited or as a major factor in the growth or spread of fire. Each scenario description includes a discussion of the reasons for inclusion of the scenario.

X1.1.6.1 Reported fires involving significant contribution from floor coverings in health-care occupancies have been extremely rare for many years, and their associated losses are a small share of the total fire losses in health-care occupancies, which are themselves a small share of the total fire problem. Therefore, the assessment procedures described here are not to be used to supplement existing codes, standards, and regulations, which have proven fully adequate to provide safety from fire for floor coverings in health-care occupancies. A fire hazard assessment is to be used only to establish equivalency with the existing codes, standards, and regulation.

X1.1.7 For each scenario, this example standard provides examples of test methods or calculation procedures which can be used to assess the evaluation criteria for the floor-covering product.

X1.2. Terminology

X1.2.1 For terms related to fire used in this guide, refer to Terminology E176 and ISO 13943. In case of conflict, the definitions in Terminology E176 shall prevail.

X1.2.2 Terms specific to this standard and not provided in the Terminology E176 and ISO 13943 are the following, the first three of which are taken from the 1976 edition of NFPA 901, which is the basis for U.S. reporting of fire incidents:

X1.2.3 *Definitions:*

X1.2.3.1 *health-care occupancies*—occupancies used for purposes such as medical or other treatment or care of persons suffering from physical or mental illness, disease, or infirmity. Such facilities ordinarily, but not always, provide sleeping facilities for occupants. Health-care occupancies include those used for nursing care, limited health care, medical care, and ambulatory health care.

X1.2.3.2 *facilities that care for the aged*—these facilities include facilities with or without nursing staff.

X1.2.3.3 *facilities that care for the sick or injured*—these facilities include hospitals, infirmaries, clinics, sanatoriums, sanitariums, facilities for care of post-operative patients, and separate clinic buildings for maternity and other uses. They do not include medical office buildings, outpatient clinics, mental institutions, or institutions for the mentally retarded, all of which may be considered health-care occupancies for some purposes but are not included in this document.

X1.2.3.4 *lethal fire effects*—a shorthand expression for any quantifiable, physical effects of fire, including toxicity, anoxia, and heat, on exposed people such that sufficient exposure will lead to death at the fire scene. This term refers to the effects but is not intended to incorporate any assumptions regarding lethal thresholds or levels required to cause death or other adverse health effects. Where thresholds are necessary to the assessment, they are specifically and directly addressed in the appropriate passage of the example standard.

X1.3. Significance and Use

X1.3.1 The hazard, or potential for loss of life in fire, posed by floor-covering products is assessed relative to typical combustibles, ignition heat sources, and occupant characteristics in the selected health-care occupancies.

X1.3.2 The selection of floor coverings for a particular facility through the use of a fire-hazard assessment will need to reflect the specific characteristics of the facility. Floor coverings that would be found acceptable in a fire-hazard assessment using values typically found in facilities can prove unacceptably hazardous if the other combustibles, ignition heat sources, or occupant characteristics proposed for the particular facility are atypical.

X1.4. Detailed Procedure

X1.4.1 Section X1.5 describes in detail the scenarios of concern. Section X1.5 also translates the overall life safety objective of preventing deaths due to fire hazards of floor coverings into evaluation criteria for each scenario.

X1.4.2 Section X1.6 describes in detail the assumptions regarding the building and the occupants.

X1.4.3 Section X1.7 describes the test methods cited as examples of those which can be used and indicates the scenarios to which each test method applies.

X1.4.4 Section X1.8 describes the calculation methods to be used and indicates the scenarios to which each calculation method applies.

X1.4.5 Section X1.9 describes the procedure for using the test methods and calculations to produce a hazard measure for each scenario.

X1.4.6 Analysis of uncertainty and use of safety factors in all tests and calculations are not provided in this example standard.

X1.5 Scenarios of Concern

X1.5.1 This section describes fire scenarios to be used in the fire-hazard assessment. The scenarios are listed in order of likely increasing severity. The life safety objective of preventing deaths due to fire hazards of floor coverings is met only if it is met for all of the chosen scenarios.

X1.5.1.1 A product can play an instrumental role in creating a threat to life through fire by being the first item ignited. This is addressed in Scenarios 1 and 2, which address open-flame and other ignition heat sources, respectively. A product can also play an instrumental role as a secondary ignited item that provides the critical fuel load required for the total room fire to grow large enough to create a threat to life. This is addressed in Scenario 3. Finally, a product can play an instrumental role as a secondary ignited item in a fire that creates a threat to life in a room other than the room of origin, either by contributing a significant share of the lethal fire effects in that other room, which is addressed by Scenario 4, or by providing the principal avenue of flame spread to that other room, which is addressed by Scenario 5.

X1.5.1.2 Of the reported 1980-1992 U.S. structure fires in health-care facilities, defined as facilities that care for the sick or the aged, 69.0 % of fires and 26.9 % of associated deaths occurred in scenarios where the first item ignited was not a floor covering and flame spread did not occur beyond the first item ignited. Therefore, these fires did not involve any ignition of floor coverings and are not reflected in any of the selected scenarios.

X1.5.1.3 Another 9.3 % of fires and 24.7 % of deaths occurred in scenarios that did not begin with ignition of floor coverings and in which fire spread beyond the first item ignited but not beyond the immediate area. These fires probably did not involve the ignition of floor coverings.

X1.5.2 Scenario 1 is a fire beginning with the direct impingement of a small open-flame ignition source, such as a match, lighter, or candle, on floor covering. It is not necessary for the calculation, but Scenario 1 is assumed to occur in an occupied room, and if further detail is required for calculations, assume it is an occupied patient room.

X1.5.2.1 The evaluation criterion for Scenario 1 is that the floor covering shall not ignite under exposure conditions representative of Scenario 1, as assessed using an appropriate fire test. For purposes of this evaluation, "ignition" requires a fire that continues to burn and to increase the fire-involved area for at least 2 min after the initiating heat source is removed.

X1.5.3 Scenario 2 is a fire beginning with direct exposure of floor covering to a common heat source other than an open flame, such as a radiant heater. It is not necessary for the calculation, but Scenario 2 is assumed to occur in an occupied room, and if further detail is required for calculations, assume it is an occupied patient room.

X1.5.3.1 The evaluation criterion for Scenario 2 is that the floor covering shall not ignite under exposure conditions representative of Scenario 2, as assessed using an appropriate fire test. For purposes of evaluation, "ignition" requires a fire that continues to burn and to increase the fire-involved area for at least 2 min after the initiating heat source is removed.

X1.5.4 Scenarios 1 and 2 are part, but not all, of the health-care facility fires involving ignition of floor coverings as the first item ignited. Fires beginning with ignition of floor coverings accounted for 0.5 % of fires and 0.7 % of deaths in reported 1980-1992 U.S. structure fires in those facilities. Of these, the small open-flame heat sources (Scenario 1) accounted for roughly half the fires and none of the deaths.

X1.5.5 Scenario 3 is a pre-flashover fire beginning with ignition by any common heat source of an item other than floor covering. Scenario 3 is an occupied patient room but is also intended to represent any occupied room intended for use by patients, such as a lounge or dining room.

X1.5.5.1 The evaluation criterion for Scenario 3 is that the presence of the floor covering shall not be the additional fuel that causes a fire that otherwise would never have created a hazard to life, to grow large enough to create such a hazard.

X1.5.5.2 If the burnable item first ignited is too small a fuel load, then Scenario 3 adds nothing to Scenario 1, in which a small open-flame source is applied to floor covering. If the burnable item first ignited is too large a fuel load, then Scenario 3 adds nothing because the first item ignited will by itself create a hazard to life. Therefore, it is necessary to specify the first item ignited to produce standardized results. In this example, the first item ignited is a chair, as specified in X1.6.8.2.

X1.5.5.3 It also is necessary to specify that in this scenario, flame spread from the first ignited item does not occur to any second fuel item except floor covering. This may be unlikely in practice, but for certain geometric arrangements and inter-item separations in a room, it is not impossible. In the absence of this assumption, it is likely that the first two involved fuel packages, excluding floor coverings, would be sufficient to create a hazard to life, thereby rendering the question of floor covering contributions moot.

X1.5.6 Scenario 4 is a fire beginning with ignition of items other than floor covering and leading to ignition of the floor covering at room flashover. The effect of the fire on occupants is assessed only for rooms other than the room of origin; this is equivalent to assuming that Scenario 4 occurs in an unoccupied room with floor covering.

X1.5.6.1 The evaluation criterion for Scenario 4 is based on the burning floor covering's share of the lethal fire effects from the room fire as measured in a second, adjacent patient room, where fire effects travel along a corridor connecting the two rooms.

X1.5.6.2 The criterion will be satisfied if the floor covering share of the lethal fire effects never exceeds the floor covering share of total exposed combustible area, where lethal fire effects are measured as quantity of toxic gases expressed in fractional effective dose form, as described in Test Method E1678, and the threshold is evaluated when the fractional effective dose reaches 1.0 in the second patient room, as measured at a height level with the top of the entrance door.

X1.5.7 Scenario 5 is a fire where the hazard of concern occurs if flame spread over the floor covering of interest provides the avenue by which a fire in an unoccupied room leads to ignition in a second, occupied room.

X1.5.7.1 The evaluation criterion for Scenario 5 is that the floor covering shall not be the first avenue of travel by which flame spread reaches a room that is down the corridor from the room of fire ignition. It is thereby assumed that if flame spreads to the second room, ignition in the second room will follow.

X1.5.7.2 In Scenario 5, the floor covering is in the corridor adjacent to the room of fire origin, but not in the room of fire origin. The floor covering is ignited by exposure to a fully developed fire in the room of fire origin. It is further assumed that the floor covering is the only combustible material in the corridor, which means that the only avenues for fire to spread to the occupied second room are by means of the floor covering or by means of the hot layer in the corridor produced by the fire in the room of fire origin.

X1.5.7.3 In order for fire to spread by means of the floor covering ahead of the hot layer, flame spread over the floor covering must be a result of heat flux from floor covering that is already burning.

X1.5.7.4 For purposes of calculation in this example standard, it is assumed that the hot layer spread rate is at least 10 ft/s. That is, flame spread by means of the floor covering must be at least that fast in order to provide the avenue by which fire reaches the second room, and it is assumed that flame spread by means of the floor covering of more than 10 ft/s. will be the avenue for fire spread to the second room in some fires. Therefore, the evaluation criterion for Scenario 5 will be met if the flame spread rate for the floor covering is less than 10 ft/s.

X1.5.7.5 For purposes of calculation in this example standard, it is assumed that the initially ignited section of corridor floor covering, which was ignited by exposure from the fully involved room of origin, will itself produce a heat flux on the adjacent, unignited floor covering no higher than 50 kW/m^2. If this were a standard complete for practical use rather than an example, this example heat flux value would be replaced by either a more empirically based value, reflecting appropriate, current test results and research, or a test procedure for calculating the heat flux produced by a fully involved section of the candidate floor covering with dimensions equal to the width of a standard corridor and the width of a standard doorway.

X1.5.7.6 Therefore, the evaluation criterion for Scenario 5 will be met if the flame spread rate for the floor covering is less than 10 ft/s at the heat flux specified in X1.5.7.5. Flame spread rate for a floor covering under a known heat flux can be calculated using equations given in the technical literature, including (**1**)[10], and the measured time to ignition for the product under a known heat flux. If this were a standard complete for practical use rather than an example, the calculation method would be fully specified and would incorporate, or at least consider, the effect on heat flux of the growth in burning floor covering area due to flame spread and the reduction in burning floor covering area due to burnout.

X1.5.7.7 Scenario 5 is included to provide completeness for this example standard, despite the fact that the type of threat to be assessed is not associated with any commercially available floor covering and is extremely unlikely to be associated with any future floor covering. The analogous scenario to Scenario 5, however, will be important and nontrivial for some other products, and it is important that this example standard show where every relevant scenario fits into the overall fire-hazard assessment.

X1.5.8 Scenarios 3–5 are part, but not all, of the group of fires that do not begin with ignition of floor coverings but have fire spread beyond the area of origin and so could involve floor coverings as secondary fuels. As implied by the statistics cited in X1.5.1.1, X1.5.1.2, and X1.5.4, fires beginning with something other than floor covering and not having flame spread confined to object or area of origin accounted for 21.2 % of fires and 47.7 % of deaths among 1980-1992 reported U.S. structure fires in health-care facilities. Of these, 9.9 % of fires and 2.4 % of deaths involved unknown extent of flame and so cannot be further classified. This leaves 11.3 % of fires and 45.3 % of deaths that can be further sorted into Scenarios 3–5.

X1.5.9 The user of this example standard shall consider the possibility that other scenarios need to be analyzed to adequately assess the fire hazard posed by floor coverings due to unusual design, occupancy, or other circumstances. Documentation shall address the need, or absence of need, for analysis of additional fire scenarios, based on any special intended conditions of application for the floor-covering product.

X1.5.10 Each of the five scenarios is described in category terms, and they collectively represent all the common and severe fire scenarios in health-care facilities in which floor coverings may be a factor.

X1.5.10.1 More specific scenario specification is needed in order to permit analysis and assessment. Specifications are done as part of the selection of test methods and test conditions, which affect the analysis of floor covering ignitability and early fire growth for Scenarios 3–5.

X1.5.10.2 Scenario specifications are indicated in Section X1.6 on assumptions if the specifications are the same for all scenarios analyzed; this avoids needless repetition of identical specifications. Scenario-specific conditions are specified in Section X1.5 on scenarios.

X1.5.10.3 All specifications involve value judgments as to the appropriateness of using typical or more challenging conditions in specifying the fire challenge to the floor coverings. A fire-hazard assessment done to a standard shall be required to indicate whether, and if so where, any specifications in the standard should be made more challenging to properly reflect characteristics of a particular facility.

X1.5.10.4 Specifications shall be considered more challenging if they result in more rapid onset of conditions hazardous to people or more severity in any conditions hazardous to people, such as more rapid growth in rate of heat release or higher rate of heat release, respectively, for burning items excluding floor coverings. Specifications are considered more challenging if they involve the absence of, reduced coverage of, or less capability of any fire-protection systems. Specifications are also more severe if they involve more occupants, occupants being closer to the fire, or occupants being less capable of self- or assisted rescue. Composite specifications, not representing any particular room in the facility but representing the most challenging conditions, item by item, in the facility, should be used.

X1.6 Assumptions

X1.6.1 If the application is to a particular facility, then facility-specific measurements are to be used for room height, width, and length for a two-patient room; door opening height and length for a two-patient room; similar dimensions for a utility room; wall and ceiling covering thermal properties; any

[10] The boldface numbers in parentheses refer to the list of references at the end of this standard.

special geometries of ceilings; smoke detector and sprinkler presence and location; and room-to-room (measured from door opening to door opening) distances for a patient room to an adjacent patient room and to a utility room three rooms away.

X1.6.1.1 Burning properties of products and materials are permitted to be estimated from published test and calculation data, if relevant data are available. The *SFPE Handbook for Fire Protection Engineering* (**2**) and the *Fire Protection Handbook* (**3**) are general sources for such data. Less available but often appropriate are the publications of national fire laboratories, such as the National Institute of Standards and Technology's Building and Fire Research Laboratory. If these sources do not provide needed data, the user will need to perform tests on the products and materials, as described in Sections X1.7 and X1.8.

X1.6.2 If facility-specific measurements are not available or not appropriate, then default values must be used, and they would need to be set in order for this example guide to be a complete standard.

X1.6.2.1 If the application is to a particular facility, then both default and facility-specific values are to be used for heat-release rate time curves for patient beds and associated bedside furniture in two-patient rooms; effective heat of combustion for patient room combustibles; distances from floor coverings to furniture and between pieces of furniture; and ease of ignition for pieces of furniture. All of the latter values involve conditions that can be altered after occupancy, and the floor covering must be one that will be safe in the range of conditions the facility may experience during its lifetime.

X1.6.3 Paragraphs X1.6.4 – X1.6.9 provide a set of default values of spatial dimensions and fire properties of materials other than floor coverings. Paragraphs X1.6.10 and X1.6.11 provide a set of values for occupant-related assumptions. Occupant-related assumptions need to be set conservatively to reflect community values. Therefore, such assumptions would not be adjusted by the user for a particular facility and only default values are to be used.

X1.6.3.1 The various default values are considered realistic for illustrative purposes in this example standard but have not been proven as the most appropriate conditions for practical use. Such verification must be provided if this example standard is to be used as more than an example.

X1.6.4 Patient rooms are for two patients and have a width of 3.8 m, a height of 2.4 m, and a length of 9.0 m. Patient room door openings have a height of 2.0 m and a width of 1.0 m.

X1.6.5 Utility rooms have a width of 2.5 m, a height of 2.4 m, and a length of 2.5 m. Utility room door openings have a height of 2.0 m and a width of 1.0 m.

X1.6.6 Wall coverings throughout are gypsum with wallpaper, having thermal properties of k = 0.14 W/m K, density = 700 kg/m^3, and specific heat = 900 J/kg K. Ceiling coverings throughout are gypsum, with the same thermal properties as the wall coverings. Ceilings are horizontal, not sloping or beamed.

X1.6.7 Fire protection systems are assumed to be those required for new health-care facilities in NFPA 101. Smoke alarms are assumed to be present in patient rooms and corridors and to be operational when fire occurs. As a challenging, conservative assumption, sprinklers are assumed not to be operational when fire occurs.

X1.6.8 Each patient room bed has a heat-release rate time-curve as shown in Table X1.1. All patient room combustibles are assumed to have an effective heat of combustion of 15 MJ/kg (**4**).

X1.6.8.1 There is a bedside table adjacent to each bed, each with a heat-release rate time-curve as shown in Table X1.1. Bedside tables are ignited by adjacent burning beds and become involved when the heat-release rate of the adjacent bed reaches 0.5 MW.

X1.6.8.2 Each patient room bed has an associated chair, located immediately adjacent to the bed and 0.5 m from the center point of ignition of the floor covering when the floor covering is the first item ignited. Chairs have a heat-release rate time-curve as shown in Table X1.1.

X1.6.9 Room-to-room (or door-to-door) distances required for calculations of spread of fire effects are assumed to be equal

TABLE X1.1 Assumed Time Curves for Rate of Heat Release, kW[A]

Time, s	Chair[B]	Bed Table	Mattress[C]
0	0	0	0
20	12	14	20
40	20	16	105
60	65	36	200
80	120	64	320
100	270	100	455
110	295	150	510
120	310	200	465
140	400	500	435
160	390	500	500
180	340	400	745
200	250	350	695
220	220	300	520
240	160	250	430
260	100	200	300
280	50	150	125
300	20	100	30
320	20	50	6
340	0	30	0
360	0	20	0
370	0	0	0
380	0	0	0
390	0	0	0
450	0	0	0
510	0	0	0
540	0	0	0
570	0	0	0
720	0	0	0
900	0	0	0

[A]The data in Table X1.1 was assembled from tests whose results have not previously been published but are considered realistic for illustrative purposes in this example standard. *They have not been proven as the most appropriate conditions for practical use. Such verification must be provided if this example standard is to be used as more than an example.*

[B]The illustrative chair values are based on tests on three different chairs – a vinyl covered armless 16.0-kg chair, an 18.2-kg chair with bent wooden arms, and an 18.5-kg left-facing chair from a modular group with treated heavy nylon fabric.

[C]The illustrative mattress values are based on tests on three different mattresses – a treated vinyl-covered 17.6-kg innerspring mattress consisting of decubitus pad directly under the cover and on top of an 18-mm conventional foam insulator pad hog-ringed to the innerspring, followed by a polyester shoddy insulator sheet, the innerspring unit, another polyester shoddy insulator sheet, and another 18-mm foam pad before the fabric; an 18.3-kg mattress of similar construction except for a 25-mm thickness of polyurethane foam; and a mattress like the first one but with foam designed to meet the *California Technical Bulletin 117 Test.*

to one patient room width in Scenario 4 and three patient room widths in Scenario 5. The latter assumption reflects the fact that nearly all patient rooms have another patient room adjacent to them, while most patient rooms do not have a utility room immediately adjacent to them.

X1.6.10 Of the two patients, both are assumed to be asleep in bed at time of ignition. One is assumed to be able to walk at 0.5 m/s, while the other is assumed to need assistance. It is assumed that assistance arrives 30 s after the smoke alarm sounds and the patient can be removed from the room in 3 min after assistance arrives.

X1.6.11 The occupant assumptions affect only Scenario 3. The evaluation criteria for Scenario 1–2 require prevention of ignition, the evaluation criterion for Scenario 5 refers to the floor-covering role in allowing ignition of a remote room, and the evaluation criterion for Scenario 4 refers to the floor-covering share of lethal fire effects in an adjacent room, regardless of when those effects are created. The net effect of the assumptions in X1.6.7 is to require that floor covering not lead to lethal effects in the room of fire origin within 4.5 min of the activation of the room smoke detector.

X1.6.12 Default assumptions regarding ventilation are to be taken from the documentation of CFAST (see X1.8.1) or other model used to calculate the spread of fire effects.

X1.7 Test Methods and Test Conditions

X1.7.1 The various ignition sources and exposure conditions selected for Scenarios 1 through 5 are considered realistic for illustrative purposes in this example standard but have not been proven as the most appropriate conditions for practical use. Such verification must be provided if this example standard is to be used as more than an example.

X1.7.1.1 In setting test methods and test conditions, the intent is to properly reflect the selected fire scenarios, take advantage of existing test methods recognized in ASTM Standards, and provide a procedure that will aid in selecting among real floor coverings. Existing test-result-based standards for floor-covering products have the same purpose, and the test conditions they use have consensus support, which should be recognized in this procedure where appropriate.

X1.7.2 The assessment of floor-covering ignitability under small open-flame impingement called for in Scenario 1 shall be accomplished by testing with a methenamine tablet using the apparatus and procedures of Test Method D2859, except where conditions have been specifically modified in this document. The apparatus and specifications from Test Method D2859 are to be used on any type of floor covering, not just the textile floor coverings addressed by the standard. In accordance with X1.5.2.1, floor-covering ignitability is assessed by determining whether the floor covering will continue to burn and to spread flame after removal of the ignition heat source. This evaluation criterion is similar to, but not identical to, the evaluation criterion of Test Method D2859, which assesses the area of flame spread.

X1.7.2.1 Scenario 1 is intended to address ignition resistance of the floor covering to a potential ignition heat source that is an open flame. This is essentially the same purpose as that of Test Method D2859 in its existing scope, except that here, the method is being used as part of a larger hazard assessment and is applied to a wider range of floor-covering products.

X1.7.3 The assessment of floor-covering ignitability called for in Scenario 2 shall be accomplished by testing using unpiloted ignition, reflecting that Scenario 2 does not involve an open flame, and the apparatus and procedures of Test Method E1354, except where conditions have been specifically modified in this document. The heat source specified in Scenario 2 shall be represented by heat-flux test conditions of 10 kW/m^2 (**5**).

X1.7.3.1 Scenario 2 is intended to address ignition resistance of the floor covering to radiant heat from a potential ignition heat source that is not an open flame. Therefore, heat flux values that properly reflect this scenario will be less than those associated with flashover, which can be as low as 20 kW/m^2.

X1.7.4 To determine the time when the floor covering will be ignited by heat flux from the burning chair and the rate of heat-release time curve for the burning floor covering, as required for Scenario 3, use Test Method E1354 with spark ignition and heat-flux test conditions of 20 kW/m^2 (**6,7**).

X1.7.4.1 Assessment of the evaluation criterion for Scenario 3 requires calculation in addition to data directly from the test method. Section X1.8 describes the calculation required. If the product does not ignite under these conditions, it has met the evaluation criteria for this scenario; it is not necessary to perform the calculations described in Section X1.8.

X1.7.5 To determine the fire conditions at the point of ignition of the floor coverings in the flashover fire beginning with items other than floor coverings in Scenario 4, use Test Method E1354 with spark ignition and heat-flux test conditions of 25 kW/m^2 (**8**).

X1.7.5.1 Assessment of the evaluation criterion for Scenario 3 requires calculation in addition to data directly from the test method. Section X1.8 describes the calculation required.

X1.7.6 To determine the time to ignition value needed in Scenario 5, use Test Method E648 or E1354. Results for 50 kW/m^2, which are required for the evaluation, can be calculated from test results at lower heat-flux values. If this were a complete standard for practical use, rather than an example, this section would choose between the two test methods and would indicate the methods to be used for the calculation of required results from test results at lower heat-flux values.

X1.8. Calculation

X1.8.1 The evaluation criteria for Scenarios 3 and 4 will require three of the four components of the HAZARD model or equivalent: CFAST, a model that translates heat-release rate time-curves for burning items into time curves for fire effects in a multi-room building; TENAB, a model that translates time-curves for fire effects into assessments of the onset of lethal conditions; and DETACT, a model that translates time-curves for fire effects into assessments of the activation time of fire detectors. DETACT is designed for use with heat detectors but can be used with additional calculation rules to estimate activation times for smoke alarms (**9**).

X1.8.2 The key floor-covering fire-test-response characteristics to be obtained from the test methods in Section X1.7 and needed by the fire-hazard estimation procedure in Section X1.4 are as follows:

X1.8.2.1 Rate of heat release under an external radiant exposure by Test Method E1354. This parameter will need to be measured under at least two heat flux levels, in accordance with Section X1.7.

X1.8.2.2 Smoke and toxic gas release rates and toxic potency of gases released under an external radiant exposure. Smoke and toxic gas contribution of the floor covering relative to the overall contribution of the room is the evaluation criterion for Scenario 3. Test Methods E1354 and E1678 can be used to develop needed data on smoke generation and toxic gas release rates and toxic potency, respectively.

X1.8.3 The evaluation criteria for Scenarios 1, 2, and 5 can be developed directly from test data, as previously indicated.

X1.8.4 Assessment of the evaluation criterion for Scenario 3 requires the user to calculate the time line for the room fire, combining the rate of heat-release time-curve for the chair that is the first item ignited, taken from Table X1.1, and the rate of heat-release time-curve for the floor covering, using the results from testing as specified in X1.7.4, which will also be used to calculate when the floor covering will be ignited.

X1.8.4.1 Use CFAST to translate the time line of the rate of heat release, with associated time lines for toxic product release rates, for the combined room fire into a time line of toxic gas concentrations and other fire effects in the room of origin, and use DETACT to calculate when the nearest smoke alarm will activate.

X1.8.4.2 Use the occupant characteristics specified in X1.6.10 to calculate when occupants will have been removed from the room of origin, and use TENAB to calculate whether they will have received a fatal injury from fire effects prior to that time.

X1.8.5 Assessment of the evaluation criterion for Scenario 4 requires the user to calculate the time line for the room fire, combining the rate of heat release time curve for the first item(s) ignited, taken from Table X1.1, and the rate of heat release time curve for the floor covering, using the results from testing as specified in X1.7.4.

X1.8.5.1 Assume the mattress from Table X1.1 is the first item ignited and is the fuel package that produces flashover in the room of origin. Assume ignition of the floor coverings at flashover.

X1.8.5.2 Use CFAST to translate the time line of the rate of heat release for the room fire into a time line of toxic gas concentrations and other fire effects in the room of origin, the adjacent corridor, and the second exposed room, with layouts and dimensions as specified in Section X1.6. Express all fire effects in Fractional Effective Dose form, using TENAB, and calculate the share contributed by the burning floor covering in each room, as a function of time.

X1.8.5.3 After the Fractional Effective Dose in the second occupied room reaches 1, determine whether the floor-covering share of the Fractional Effective Dose ever exceeds the evaluation criterion specified in X1.5.6.2.

X1.9. Fire-Hazard-Assessment Report

X1.9.1 The report must identify the scenarios, building layout(s), furnishings, and occupancy(s) used in each calculation.

X1.9.2 The report must identify any reference data used and the source of that data.

X1.9.3 The report must identify the evaluation criteria, calculation methods, and assumptions used for each scenario, and provide references or other evidence for the validity and appropriateness of the calculation methods and assumptions used in the assessment. Limits on the valid ranges for use of the models shall be explicitly addressed.

X1.9.4 The report must identify the results of the evaluation, in terms of success in meeting the objective of preventing loss of life, for each scenario.

X2. FLOW CHARTS

X2.1 The seven basic steps in Section 8 are intended first to identify a class of products and circumstances of product use and then to express in quantitative terms the fire hazard to which this class of products gives rise in a specific scenario. In practice the steps are closely related and even intertwined. The makeup of the class of products to which the assessment applies is often influenced by the scenario and by the details of the methods identified or developed to measure the product characteristics to be controlled. The scope of the final document may therefore reflect limitations that become apparent only during scenario analysis or the development of test methods. Candidate test or calculation methods in turn may require redesign or even rejection because they are unsuitable for some members of the product class. Thus, the steps are rarely entirely sequential and, especially in Steps 1, 4 and 5, an iterative process is usually required.

X2.1.1 One way to begin is to describe a single fire incident, real or hypothetical and to relate the outcome of this incident to the properties of one member of the product class. This becomes the "benchmark" product and the particulars of the incident become the rudiments of the scenario. As more detail is added and other potential examples are considered, both the product class and the final shape of the scenario gain definition.

X2.2 *Flow Charts 1*—Flow Chart 1 (Fig. X2.1), and sub-charts 1-A, -B and -C (Figs. X2.2-X2.4), are designed to aid in relating the particulars of the scenario and circumstances of product use to the measurable or calculable fire and smoke properties of the product. In effect, this carries the analysis through the first three steps (8.3 – 8.5), which results in the list of tests and/or calculations on which the assessment will be based and implicitly describes the benchmark product's involvement in the fire (8.3.2).

X2.2.1 It is usually possible to break up the fire response parameters listed in 8.3.2 into: (1) those which can readily be classified, either as important contributors to hazard or with no effect on it; and (2) those whose contribution is uncertain. For example, if the incident would not have occurred without ignition of the product, then product ignitability is certainly important. If, in the same incident, the product has burned out or contributes very little by the time the fire has reached a threatening size, then the product's heat release rate is probably of little importance. Finally, the significance of some responses, such as flame spread, may be difficult to estimate in advance of a detailed analysis.

X2.2.2 As suggested in 8.5.3, fire experience may help in deciding whether a given scenario is the most appropriate or significant mechanism by which the product influences the fire outcome. Since the objective is to identify and design scenarios in which the mechanism can be used to best effect, the initial incident can be modified if it does not do so.

X2.3 *Flow Chart 2*—Flow Chart 2 (Fig. X2.5) is intended to help in broadening the definition of the product class after the first four steps (8.3 – 8.6) have been carried out for the benchmark product. At this point, a list can be formulated of candidate products for inclusion in the class to which the hazard assessment may pertain. The product class is then broadened one example at a time by responding to the questions which appear in 8.3.1. A new candidate may fit easily into the existing definition of the product class; it may be inappropriate for inclusion; or its inclusion may require that the definition of the product class, which originally included only the benchmark, be modified. It is important to capture any reasons for excluding candidates from the product class and to record them in the section on scope and limitations in the hazard assessment document.

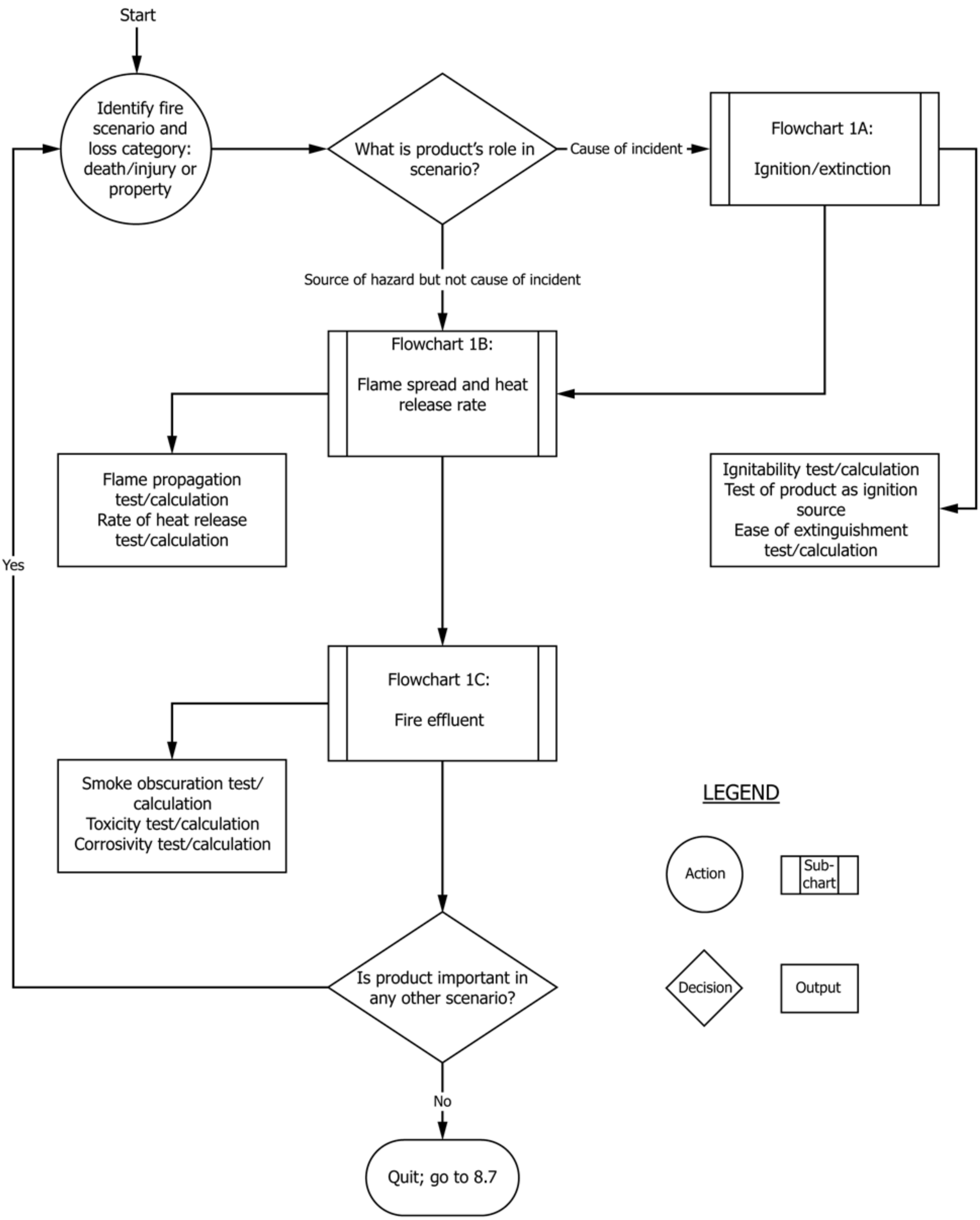

FIG. X2.1 Flow Chart 1 Using Fire Scenarios to Identify Test or Calculation Procedures (Steps 1-4)

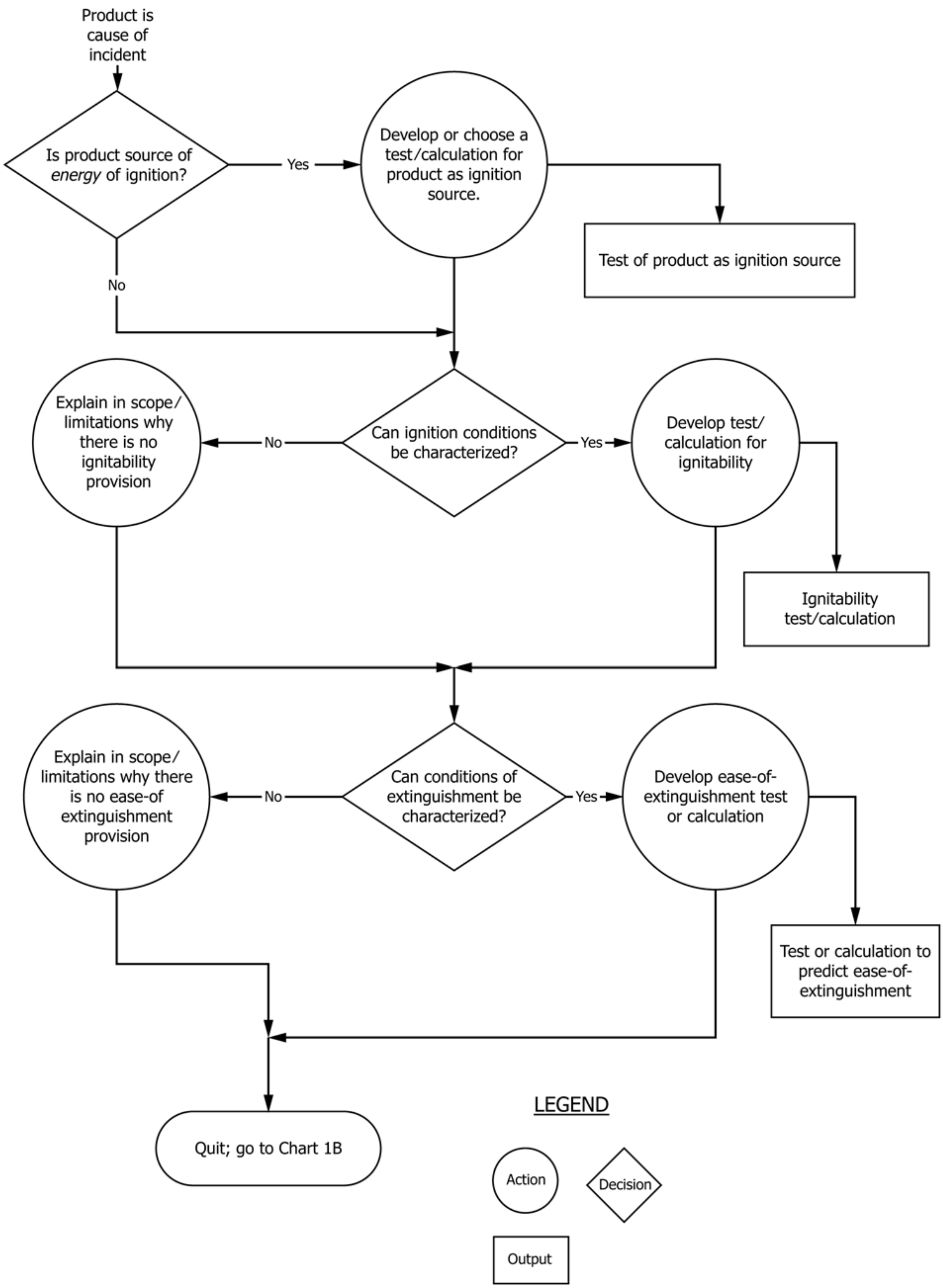

FIG. X2.2 Flow Chart 1A Ignition and Extinction Ref: 8.5.3.1

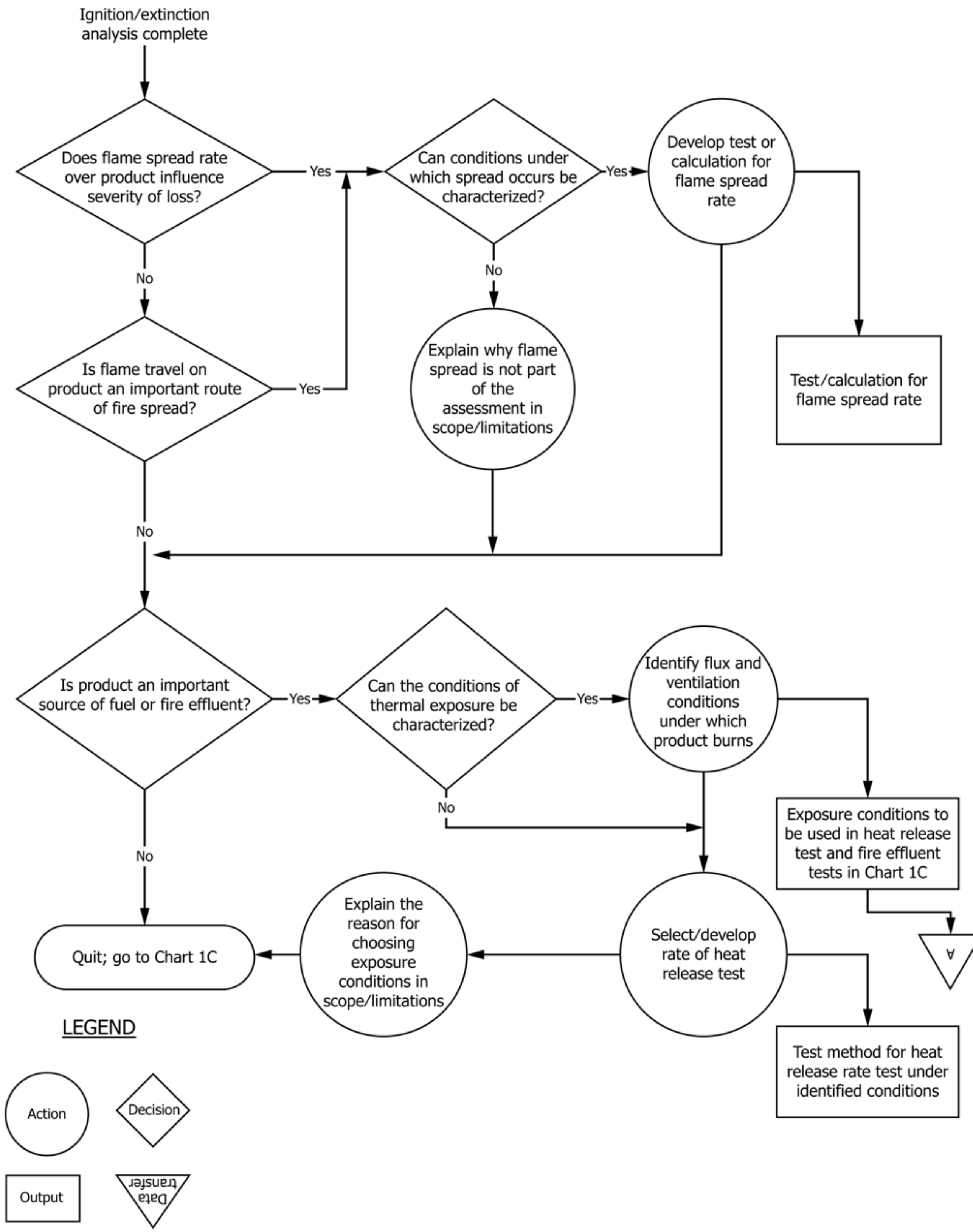

FIG. X2.3 Flow Chart 1B Flame Spread and Heat Release Ref: 8.5.3.2

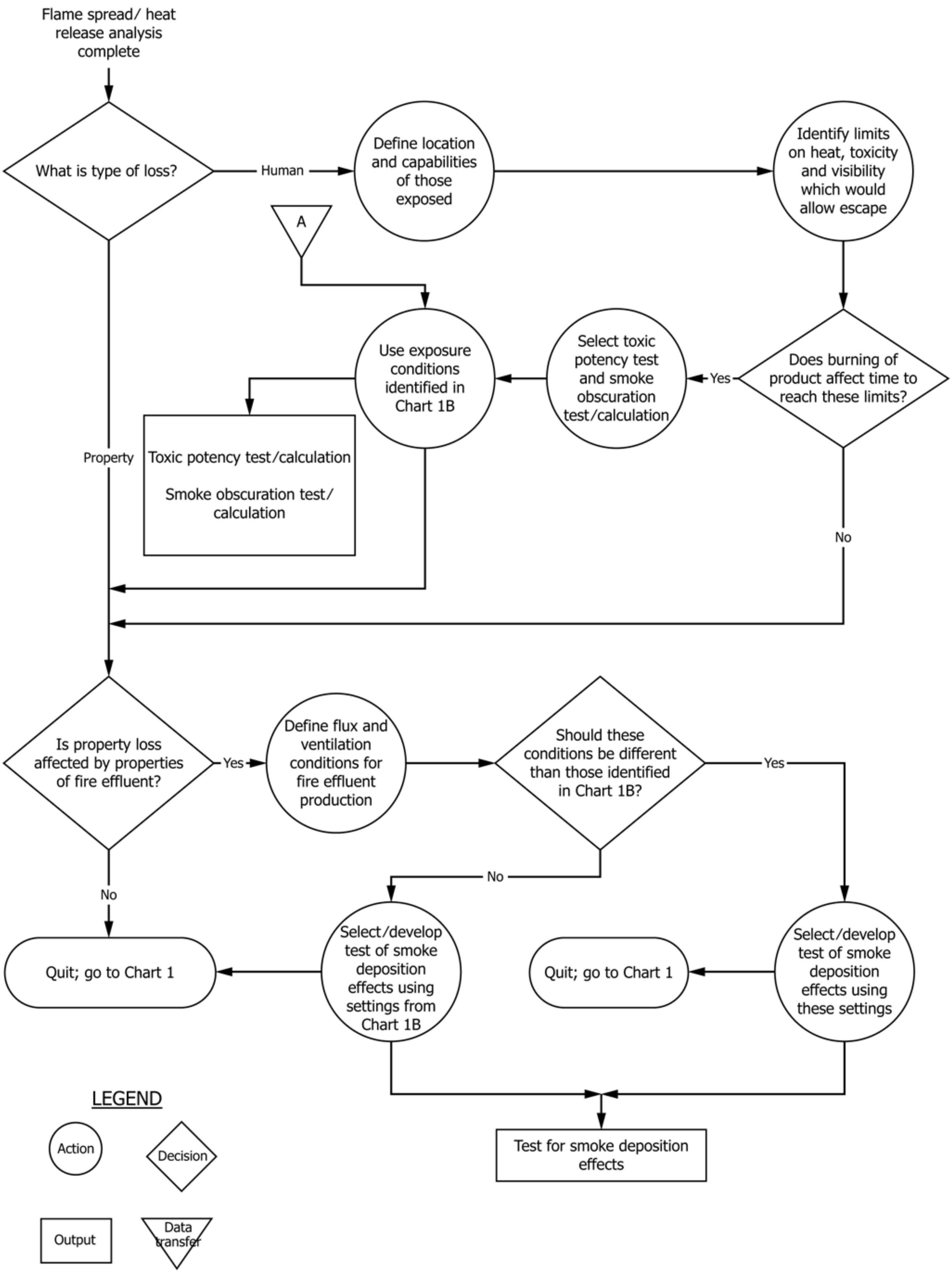

FIG. X2.4 Flow Chart 1C Fire Effluent Ref: 8.5.3.4 and 8.5.3.5

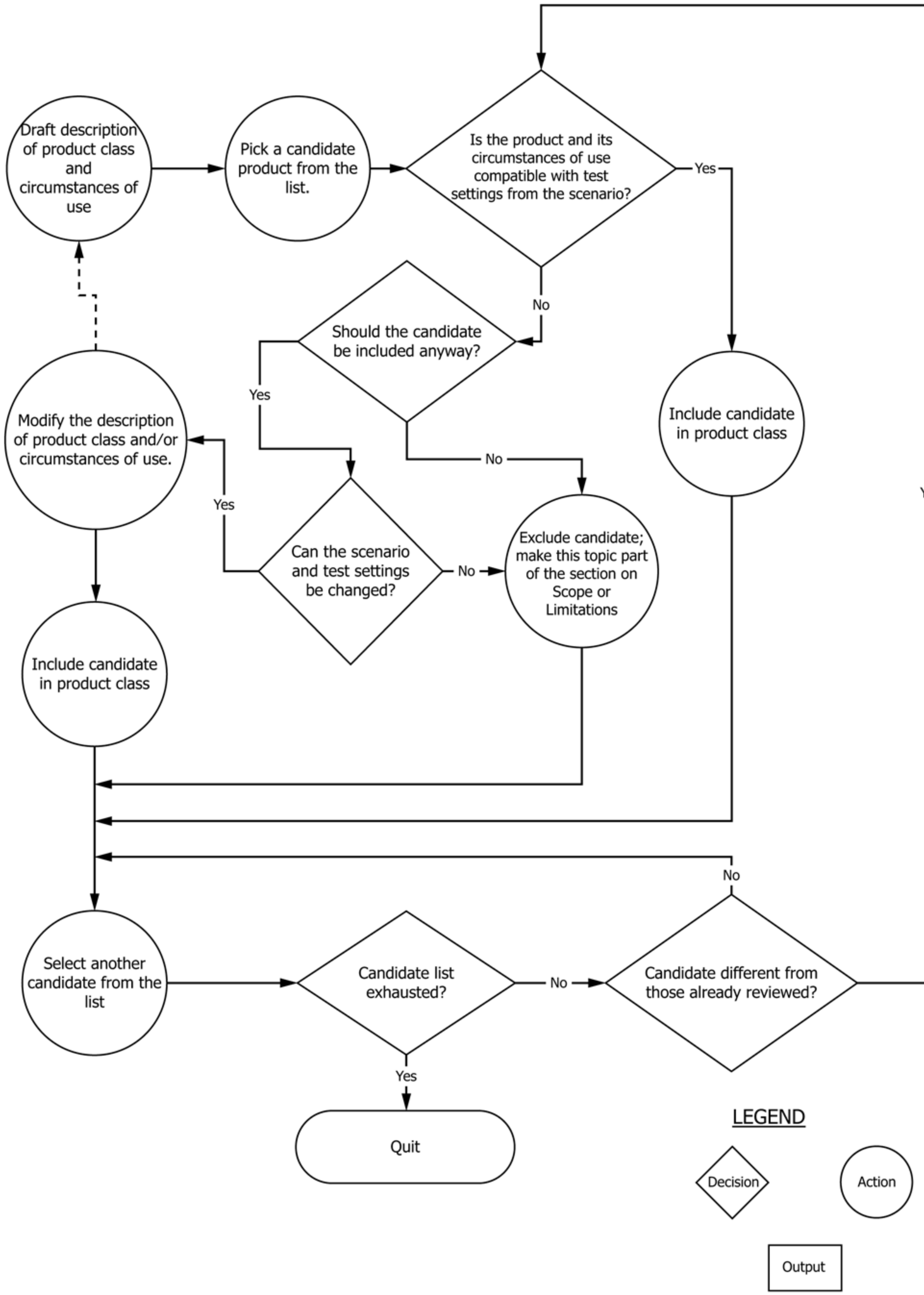

FIG. X2.5 Flow Chart 2 – Description of Range of Products and Circumstances of Use

REFERENCES

(1) Delichatsios, M.A., "Fire Growth Rates in Wood Cribs," *Combustion and Flame*, Vol 27, 1976, pp. 267–278.

(2) *The SFPE Handbook of Fire Protection Engineering*, 2nd ed., Quincy, MA, Society of Fire Protection Engineers and National Fire Protection Association, June 1995.

(3) *Fire Protection Handbook*, 18th ed., Quincy, MA, National Fire Protection Association, February 1997.

(4) No reference has been identified for this assumption on effective heat of combustion. If this standard is used as more than an example, a reference will be needed.

(5) Gross, D., and Fang, J.B.," Definition of a Low-Intensity Fire," *Performance Concepts in Buildings, Proceedings from the Joint RILEM-ASTM-CIB Symposium* , May 1972, *NBS Special Publication 361*, Vol 1, Washington, DC, National Bureau of Standards, March 1972 .

(6) Tu, K-M., and Davis, S., *Flame Spread of Carpet Systems Involved in Room Fires*, NBSIR 76-1013, Washington, DC, National Bureau of Standards, June 1976.

(7) Quintiere, J.G., *A Characterization and Analysis of NBS Corridor Fire Experiments in Order to Evaluate the Behavior and Performance of Floor Covering Materials* , NBSIR 75-691, Washington, DC, National Bureau of Standards, June 1975.

(8) Fang, J.B., and Breese, J.N., *Fire Development in Residential Basement Rooms*, NBSIR 80-2120, Washington, DC, National Bureau of Standards, October 1980.

(9) CFAST, TENAB, and DETACT are modeling components of HAZARD, a model developed and maintained by the Building and Fire Research Laboratory, National Institute of Standards and Technology.