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An American National Standard

# Standard Guide for
# Fire Hazard Assessment of Rail Transportation Vehicles[1]

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## INTRODUCTION

The traditional approach to codes and standards is the specification of individual fire-test-response requirements for each material, component, or product that is found in a given environment and is deemed important to maintain satisfactory levels of fire safety. This practice has been in place for so long that it gives a significant level of comfort; manufacturers know what is required to comply with the specifications and specifiers simply apply the requirements. The implicit assumptions are not stated, but they are that the use of the prescribed requirements ensures an adequate level of safety. There is no need to impose any change on those manufacturers who supply safe systems meeting existing prescriptive requirements; however, as new materials, components, and products are developed, manufacturers, designers, and specifiers often desire the flexibility to choose how overall safety requirements are to be met. It is the responsibility of developers of alternative approaches to state explicitly the assumptions being made which result in a design having an equivalent level of safety. One way to generate explicit and valid assumptions is to use a performance-based approach, based on test methods that provide data in engineering units, suitable for use in fire safety engineering calculations, as this guide provides.

This fire hazard assessment guide focuses on rail transportation vehicles. Such a fire hazard assessment requires developing all crucial fire scenarios that must be considered and consideration of the effect of all contents and designs within the rail transportation vehicle, which will potentially affect the resulting fire hazard. The intention of this guide is that rail transportation vehicles be designed either by meeting all the requirements of the traditional prescriptive approach or by conducting a fire hazard assessment, that needs to provide adequate margins of error, in which a level of safety is obtained that is equal to or greater than the level of safety resulting from the traditional approach.



## 1. Scope

1.1 This is a guide to developing fire hazard assessments for rail transportation vehicles. It has been written to assist professionals, including fire safety engineers, who wish to assess the fire safety of rail transportation vehicles, during or after their design (see also 1.6). This guide is not in itself a fire hazard assessment nor does it provide acceptance criteria; thus, it cannot be used for regulation.

1.2 Hazard assessment is a process that results in an estimate of the potential severity of the fires that can develop under defined scenarios, once defined incidents have occurred. Hazard assessment does not address the likelihood of a fire occurring. Hazard assessment is based on the premise that an ignition has occurred, consistent with a specified scenario, and that potential outcomes of the scenario can be reliably estimated.

1.3 Consistent with 1.2, this guide provides methods to evaluate whether particular rail passenger designs provide an equal or greater level of fire safety when compared to designs developed based on the traditional applicable fire-test-response characteristic approaches currently widely used in this industry. Such approaches have typically been based on prescriptive test methodologies. The following are examples of such lists of prescriptive tests: the requirements by the Federal Railroad Administration (FRA) (Table X1.1), the former guidelines of the FRA, the requirements of NFPA 130 (Table X3.1), and the recommended practices of the Federal Transit Administration (FTA). Selective use of parts of the methodology in this guide and of individual

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fire-test-response characteristics from Table X1.1 (or any other set of tests) does not satisfy the fire safety objectives of this guide or of the table. This guide shall be used in its entirety to develop a fire hazard assessment for rail transportation vehicles or to aid in the design of such vehicles.

1.4 This guide includes and applies accepted and clearly defined fire safety engineering techniques and methods consistent with both existing, traditional prescriptive codes and standards and performance based fire codes and standards under development throughout the world.

1.5 This guide provides recommended methods to mitigate potential damage from fires in rail transportation vehicles, by assessing the comparative fire hazard of particular products, assemblies, systems or overall designs intended for use in rail transportation vehicles. Such methods could include changes to the materials, components, products, assemblies, or systems involved in the construction of the rail transportation vehicle or changes in the design features of the vehicle, including the number and location of automatically activated fire safety devices present (see 4.4.4 for further details).

1.6 This guide is intended, among other things, to be of assistance to personnel addressing issues associated with the following areas.

1.6.1 Design and specification of rail transportation vehicles.

1.6.2 Fabrication of rail transportation vehicles.

1.6.3 Supply of assemblies, subassemblies, and component materials, for use in rail transportation vehicles.

1.6.4 Operation of rail transportation vehicles.

1.6.5 Provision of a safe environment for all occupants of a rail transportation vehicle.

1.7 The techniques provided in this guide are based on specific assumptions in terms of rail transportation vehicle designs, construction and fire scenarios. These techniques can be used to provide a quantitative measure of the fire hazards from a specified set of fire conditions, involving specific materials, products, or assemblies. Such an assessment cannot be relied upon to predict the hazard of actual fires, which involve conditions, or vehicle designs, other than those assumed in the analysis. In particular, the fire hazard may be affected by the anticipated use pattern of the vehicle.

1.8 This guide can be used to analyze the estimated fire performance of the vehicle specified under defined specific fire scenarios. Under such scenarios, incidents will begin either inside or outside a vehicle, and ignition sources can involve vehicle equipment as well as other sources. The fire scenarios to be used are described in detail in Section 5.3.

1.8.1 Fires with more severe initiating conditions than those assumed in an analysis may pose more severe fire hazard than that calculated using the techniques provided in this guide. For this reason severe fire conditions must be considered as part of an array of fire scenarios.

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

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



## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

C1166 Test Method for Flame Propagation of Dense and Cellular Elastomeric Gaskets and Accessories

D123 Terminology Relating to Textiles

D2724 Test Methods for Bonded, Fused, and Laminated Apparel Fabrics

D3574 Test Methods for Flexible Cellular Materials—Slab, Bonded, and Molded Urethane Foams

D3675 Test Method for Surface Flammability of Flexible Cellular Materials Using a Radiant Heat Energy Source

D5424 Test Method for Smoke Obscuration of Insulating Materials Contained in Electrical or Optical Fiber Cables When Burning in a Vertical Cable Tray Configuration

D5537 Test Method for Heat Release, Flame Spread, Smoke Obscuration, and Mass Loss Testing of Insulating Materials Contained in Electrical or Optical Fiber Cables When Burning in a Vertical Cable Tray Configuration

D6113 Test Method for Using a Cone Calorimeter to Determine Fire-Test-Response Characteristics of Insulating Materials Contained in Electrical or Optical Fiber Cables

E119 Test Methods for Fire Tests of Building Construction and Materials

E162 Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source

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

E662 Test Method for Specific Optical Density of Smoke Generated by Solid Materials

[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.

E906 Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using a Thermopile Method
E1321 Test Method for Determining Material Ignition and Flame Spread Properties
E1354 Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter
E1355 Guide for Evaluating the Predictive Capability of Deterministic Fire Models
E1472 Guide for Documenting Computer Software for Fire Models (Withdrawn 2011)[3]
E1474 Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter
E1537 Test Method for Fire Testing of Upholstered Furniture
E1546 Guide for Development of Fire-Hazard-Assessment Standards
E1590 Test Method for Fire Testing of Mattresses
E1591 Guide for Obtaining Data for Fire Growth Models
E1623 Test Method for Determination of Fire and Thermal Parameters of Materials, Products, and Systems Using an Intermediate Scale Calorimeter (ICAL)
E1740 Test Method for Determining the Heat Release Rate and Other Fire-Test-Response Characteristics of Wall Covering or Ceiling Covering Composites Using a Cone Calorimeter
F1534 Test Method for Determining Changes in Fire-Test-Response Characteristics of Cushioning Materials After Water Leaching

2.2 *NFPA Standards:*[4]
NFPA 70 National Electrical Code
NFPA 130 Standard for Fixed Guideway Transit Systems
NFPA 262 Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces
NFPA 265 Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings
NFPA 901 Uniform Coding for Fire Protection

2.3 *ISO Standards:*[5]
ISO 13943 Fire Safety: Vocabulary
ISO 4880 Burning Behaviour of Textiles and Textile Products
ISO 9705 Full Scale Room Fire Test for Surface Products

2.4 *Federal Aviation Administration Standards:*[6]
FAR 25.1359 Federal Aviation Administration 60° Bunsen Burner Test for Electric Wire
FAR 25.853 (a) Federal Aviation Administration Vertical Bunsen Burner Test
FAR 25.853 (c) Federal Aviation Administration Oil Burner Test for Seat Cushions

2.5 *Other Federal Standards:*[7]
Americans with Disabilities Act
FED STD 191A Textile Test Method 5830

2.6 *Underwriters Laboratories Standards:*[8]
UL 44: Standard for Safety for Thermoset-Insulated Wires and Cables
UL 83: Standard for Safety for Thermoplastic-Insulated Wires and Cables
UL 1581: Reference Standard for Electrical Wires, Cables, and Flexible Cords, 1080 (VW-1 (Vertical Wire) Flame Test)
UL 1581: Reference Standard for Electrical Wires, Cables, and Flexible Cords, 1160 Vertical Tray Flame Test
UL 1685: Standard Vertical Tray Fire Propagation and Smoke Release Test for Electrical and Optical Fiber Cables
UL 1975: Standard Fire Tests for Foamed Plastics Used for Decorative Purposes

2.7 *Canadian Standards Association Standards:*[9]
CSA Standard C22.2 No. 3, Test Methods for Electrical Wires and Cables, Vertical Flame Test—Cables in Cable Trays/FT4

2.8 *Institute of Electrical and Electronic Engineers Standards:*[10]
IEEE Standard 383, Standard for Type Tests of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations



[3] The last approved version of this historical standard is referenced on www.astm.org.
[4] Available from the National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA, 02269–9101.
[5] Available from International Organization for Standardization (ISO), 1 rue de Varembé, Case postale 56, CH-1211, Geneva 20, Switzerland or American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.
[6] Available from the Federal Aviation Administration, Technical Center, Atlantic City International Airport, Atlantic City, NJ 08405.
[7] Available from General Services Administration, Specifications Activity, Printed Materials Supply Division, Building 197, Naval Weapons Plant, Washington, DC 20407.
[8] Available from Underwriters Laboratories, Inc., 333 Pfingsten Rd., Northbrook, IL 60062.
[9] Available from the Canadian Standards Associations, 178 Rexdale Blvd., Rexdale, Ontario, Canada M9W 1R3.
[10] Available from the Institute of Electrical and Electronic Engineers, Inc., 345 East 47th Street, New York, NY 10017.

2.9 *National Electrical Manufacturing Association Standards:*[11]
NEMA WC 3/ICEA S-19, Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
ICEA S-73–532/NEMA WC-57 Standard for Control, Thermocouple Extension, and Instrumentation Cables
ICEA S-95–658/NEMA WC-70 Nonshielded Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy
2.10 *CA Standards:*[12]
CA Technical Bulletin 129, Flammability Test Procedure for Mattresses for Use in Public Buildings
CA Technical Bulletin 133, Flammability Test Procedure for Seating Furniture for Use in Public Occupancies
2.11 *AATCC Standards:*[13]
Test Method 86 - 2005 Drycleaning: Durability of Applied Designs and Finishes
Test Method 124 - 2006 Appearance of Fabrics after Repeated Home Laundering
2.12 *IEC Standards:*[14]
IEC 60331-11 Tests for electric cables under fire conditions – Circuit integrity – Part 11: Apparatus – Fire alone at a test temperature of at least 750°C

## 3. Terminology

3.1 *Definitions*— For terms related to fire used in this guide, refer to Terminology E176 and ISO 13943. In case of conflict, the terminology in Terminology E176 shall prevail. For terms relating to textiles used in this guide, refer to Terminology D123 or to ISO 4880. In case of conflict, the terminology in Terminology D123 shall prevail.

3.1.1 *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*.)

3.1.1.1 *Discussion*—

An array of fire-test response characteristics is a set of data relevant to the assessment of fire hazard in a particular fire scenario. 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.

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



3.1.2.1 *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 (see Terminology E176).

3.1.3 *fire performance, n*—response of a material, product, or assembly in a particular fire, other than in a fire test involving controlled conditions (different from fire-test-response characteristics, q.v.).

3.1.3.1 *Discussion*—

The ASTM policy on fire standards distinguishes between the response of materials, products, or assemblies to heat and flame "under controlled conditions," which is fire-test-response characteristic, and "under actual fire conditions," which is fire performance. Fire performance depends on the occasion or environment and may not be measurable. In view of the limited availability of fire-performance data, the response to one or more fire tests, approximately recognized as representing end-use conditions, is generally used as a predictor of the fire performance of a material, product, or assembly (see Terminology E176).

3.1.4 *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.

3.1.4.1 *Discussion*—

The conditions describing a fire scenario, or a group of fire scenarios, are those required for the testing, analysis, or assessment

[11] Available from National Electrical Manufacturers Association, 1300 North 17th St., Ste 1847, Rosslyn, VA 22209.
[12] Available from California Bureau of Home Furnishings and Thermal Insulation, State of California, Department of Consumer Affairs, 3485 Orange Grove Avenue, North Highlands, CA 95660–5595.
[13] Available from American Association of Textile Chemists and Colorists (AATCC), One Davis Dr., P.O. Box 12215, Research Triangle Park, NC 27709-2215.
[14] Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, 1st Floor, P.O. Box 131, CH-1211, Geneva 20, Switzerland, http://www.iec.ch.

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 (see Terminology E176).

3.1.5 *flashover, n*—the rapid transition to a state of total surface involvement in a fire of combustible materials within an enclosure.

3.1.5.1 *Discussion*—

Flashover occurs when the surface temperatures of an enclosure and its contents rise, producing combustible gases and vapors, and the enclosure heat flux becomes sufficient to heat these gases and vapors to their ignition temperatures. This commonly occurs when the upper layer temperature reaches 600°C or when the radiant heat flux at the floor reaches 20 $kW/m^2$ (see Terminology E176).

3.1.6 *heat release rate, n*—the heat evolved from the specimen, per unit of time.

3.1.7 *smoke, n*—the airborne solid and liquid particulates and gases evolved when a material undergoes pyrolysis or combustion (see Terminology E176).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *product, n*—material, component, or complete end-use product, in use in rail transportation vehicles.

## 4. Significance and Use

4.1 This guide is intended for use by those undertaking the development of fire hazard assessments for rail transportation vehicles and products contained within rail transportation vehicles.

4.2 This guide provides information on an approach to develop a fire hazard assessment, but fixed procedures are not established. Any limitations in the availability of data, of appropriate test procedures, of adequate fire models, or in the advancement of scientific knowledge, will place significant constraints upon the procedure for the assessment of fire hazard.



4.3 A fire hazard assessment developed following this guide must specify all steps required to determine fire hazard measures for which safety thresholds or pass/fail criteria can be meaningfully set by responsible authorities. It is preferred that such exercises have input from various sources.

4.4 *Outcomes: Use and Application.* A fire hazard assessment developed as a result of using this guide should be able to assess a new product being considered for use in a certain rail transportation vehicle and reach one of the conclusions listed in 4.4.1 – 4.4.4.



4.4.1 *New Product Safer than Product Currently in Use.* The new product is safer, in terms of predicted fire performance, than the one in established use. In this case, the new product is desirable, from the point of view of fire safety.

4.4.2 *New Product Equivalent in Safety to Product Currently in Use.* There is no difference between the predicted fire safety of the new product and of the one in established use. In this case, use of the new product provides neither advantage nor disadvantage, from the point of view of fire safety.

4.4.3 *New Product Less Safe than Product Currently in Use.* The new product is less safe, in terms of predicted fire performance, than the one in established use. In this case, a direct substitution of products would provide a lower level of safety and the new product would be undesirable, and should not be used, from the point of view of fire safety, without other compensatory changes being made.

4.4.3.1 *New Product Different in Safety to Product Currently in Use.* A new product that is less safe, in terms of predicted fire performance, can nevertheless be made acceptable if, and only if, it is part of a complete, comprehensive, fire safety design for the rail transportation vehicle. Such redesign of the vehicle should include other features such as use of an alternative layout or increased use of automatic fire protection systems, that demonstrably produce the same or better safety for the complete design. In such cases, a more in-depth fire hazard assessment would have to be conducted to ensure that the entire design achieves the safety goals, and the new product would be acceptable only as part of the larger, approved design.

4.4.4 The new product could offer some safety advantages and some safety disadvantages over the item in established use. An example of such an outcome could be increased smoke obscuration with decreased heat release. In such cases, a more in-depth fire hazard assessment would have to be conducted to ensure that the advantages outweigh the disadvantages, and the resulting overall level of safety is no less than that provided by the traditional approach (see Table X1.1 and Appendix X1).

4.5 Following the analysis described in 4.4, a fire hazard assessment developed following this guide would reach a conclusion regarding the desirability of the new product studied. It is essential for the results of the assessment to lead to a design that is at least as safe as the one being replaced.

## 5. Procedure

5.1 *Fire Safety Objectives*

5.1.1 The primary fire safety objective is to ensure the safe (unharmed) evacuation of all occupants of a rail transportation vehicle in the event of a fire.

5.1.1.1 This is achieved if the time required, in the event of a fire, to evacuate the vehicle is less than the time for the fire to create untenable conditions, preferably for the fire not to create conditions that cause harm to people, whenever possible, in the passenger compartment. The evacuation time includes the time required for the occupants to reach, or be transported, to a safe location and notification time.

5.1.1.2 The time to untenability shall be the shortest time until untenable conditions are created for any occupant starting at any location within the vehicle or along the evacuation path.

5.1.1.3 If the fire scenario involves a vehicular accident, then the assessment shall assume evacuation is achieved through rescue by emergency personnel. The fire hazard assessment needs to recognize that the accident may take place in an area (or at a time) when such rescue is difficult. Examples of conditions of difficult access are tunnels, bridges, remote locations, and unfavorable weather.

5.1.1.4 Tenability is assessed on the basis of fire effects on the occupants, including both direct effects, such as heat, toxic gases, or oxygen deprivation, and indirect effects, such as reduced visibility due to smoke obscuration. A tenable environment, therefore, will prevent loss of life and reduce the likelihood of harm, including nonfatal injury to individuals.

*(1)* Levels of tenability should be set by the developer of the fire hazard assessment generated from using this guide or by the specific.

NOTE 1—Investigations of the tenability in a fire scenario have shown the maximum temperatures which human beings can withstand (**1-3**),[15] the maximum convected heat humans can tolerate (**4**), the heat flux required to blister or burn skin (**5-8**), the restrictions to escape imposed by smoke obscuration (**9, 10**), the effects of the primary toxic gases (**11-16**), the overall effects of smoke toxicity (**17-20**) and various ways to combine one or more of these effects (**4, 21 and 22**).

*(2)* If no levels of tenability are chosen, the default tenability criteria should be the values specified in the documentation for HAZARD (**21, 22**)

5.1.2 A secondary fire safety objective is to prevent flashover inside the rail transportation vehicle.

5.1.3 The user shall consider inclusion of a third fire safety objective, which is to maintain a safe working environment for safety personnel, including fire fighters.

5.2 *Considerations of Design Factors in Calculations for Estimates of Fire Hazard*

5.2.1 The issue of design of products or entire rail transportation vehicles can have significant impact on fire safety. Design specifications can be used as input into the calculation methods of a fire hazard assessment; however, for design specifications to be useful, they cannot be expressed in vague terms but must be expressed as either numerical values or as other instructions, for example, equations compatible with the fire hazard assessment calculation method used.

5.2.1.1 Once expressed as numerical or other specific values, design specifications are a source for input variables for fire hazard assessment. For example, design specifications will include specification of the materials or components to be used in the vehicle compartment linings, including ceilings, walls, and floors. The calculations required to assess whether flashover will be prevented in the vehicle (an objective specified in 5.1.2) will require heat absorption parameters for the compartment linings. These heat absorption parameters will not be identical to the design specifications for the compartment lining materials but will be derivable from these specifications by reference to data from established test methods. Because this guide does not specify the models as calculation methods to be used, it follows that it cannot list the input variables that will be required or the appropriate procedures to use in deriving those input variables from design specifications.

5.2.1.2 A fire hazard assessment is an evaluation of a complete design that addresses certain fire safety objectives; therefore, the design specifications used must address and include all relevant products and design features used, including those specified by conventional prescriptive practices. A fire hazard assessment of a retrofit, rebuild, or repair cannot be limited to the parts of the design being changed. Rather, a fire hazard assessment of a retrofit carried out according to the practices presented in this guide must address the resulting car, including contents, in its entirety.

5.2.1.3 This guide does not address minor changes to vehicles designed using components or materials that are defined originally by property lists, such as those described in 5.7.8. In such cases, the techniques presented in this guide will have less applicability and may present fewer, if any, economic benefits than continuing the use of the lists described in 5.7.8.

5.2.2 In connection with this guide, the term "design" refers both to the general arrangement of the vehicle (for example, size, location of doors and windows, the nature of emergency exits, the number and configuration of levels and compartments) and to the materials, components, and products used to fabricate the vehicle. The development of such designs often involves decisions that include tradeoffs and ad-hoc benefit analyses and is a traditional approach.

5.2.2.1 An example of such a decision are trade-offs considered between using traditional glazing materials, which are not combustible but have high mass and low impact resistance. The use of these materials may compromise passenger and staff security, due to the hazard of projectiles. An alternative, to address hazards posed by projectiles to noncombustible, but friable, glazing is the use of more impact resistant materials, which are combustible.

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

NOTE 2—The use of plastic glazing materials with high impact resistance is a common practice in the transportation industry and has been since the 1970s.

5.2.3 Design specifications for products, components, and materials will include fire-test-performance characteristics. Appendix X5 provides a list of test methods from which the test methods to be used should be chosen. Appendix X1 and Tables X1.1 and X2.1 (**23, 24**) provide alternative test methods, based on the requirements of the Federal Railroad Administration (FRA), which generate fire-test-response characteristics, albeit ones that cannot be used for fire safety engineering calculations.

5.2.3.1 The test methods in Table X1.1 are those needed to measure the fire-test-response characteristics required by the FRA (**23**). Similar recommendations or guidelines had been issued earlier by the FRA (**24, 25**), the Federal Transit Administration (FTA) (**26**) and Amtrak (**27**). They have also been summarized in research by the National Institute for Standards and Technology (**28**). The requirements issued by the National Fire Protection Association (NFPA 130) in 2001 are shown in Table X3.1.

*(1)* The choice of any test method is nonmandatory, and the developer of a fire hazard assessment will need to provide evidence of its validity for use in testing of rail transportation system components or composites (see also 5.7.7.1). Design and quality control of component materials critically affects the precision of composite fire test results; therefore, manufacturers should ensure consistency in the fire performance of components which are assessed as part of a composite system, perferably by testing the components.

*(2)* Note that testing of individual materials does not indicate the potential effects of antagonistic or synergistic fire behavior of materials found for some combinations.

5.2.3.2 The test methods referenced in Appendix X5 have been designed to yield results in fire safety engineering units, which are appropriate for fire hazard assessment, and measure heat release rate, which has been demonstrated to be an essential component of fire hazard assessment (**29, 30**).

5.2.3.3 It is likely that design specifications of any finished product with different component materials will not be available normally (from the suppliers of the individual materials or components that go into them) in a form suitable for application of fire hazard assessment. Manufacturers of such products normally cannot be expected to have developed data on characteristics that are not part of existing sets of requirements or recommendations for their products. Similarly, suppliers of individual materials cannot be expected to identify or provide materials, components, or products, based exclusively on the kinds of design specifications required for fire hazard assessment; therefore, suppliers of such products may require the translation of the performance specifications into conventional specifications for the individual materials. A prescriptive approach to achieve fire safety objectives should always exist as an alternative. In the case of rail transportation vehicles, such an approach would be through use of the traditional methods as exemplified by the requirements in Table X1.1 and Appendix X1 or in Table X3.1 and Appendix X3. The hazard assessment approach becomes an option available to those manufacturers who prefer to seek alternative means of achieving acceptable levels of fire safety inside rail transportation vehicles.

5.3 *Fire Scenarios*

5.3.1 Fire Scenario 1 is a fire that originates within the rail transportation vehicle.

5.3.1.1 Any one of the Type 1 fire scenarios (where the fire starts inside the rail transportation vehicle) becomes more severe if the fire occurs when the rail transportation vehicle is in a location where escape and rescue is particularly difficult, for example a tunnel (see also 5.4.2).

5.3.1.2 Moreover any of the Type 1 fire scenarios becomes more severe if the vehicle is in motion between stations, at the maximum distance from any station. Note, however, that in fire scenario 1f the fire starts only after the vehicle has become stationary.

5.3.1.3 Fire Scenario 1a, specified as the highest-challenge likely scenario of this type (see also 5.4.2), begins as an incendiary ignition involving the use of accelerants and prior damage exposing the fillings of the two upholstered seats nearest the point of ignition (see also Appendix X3).

5.3.1.4 Fire Scenario 1b, specified as one of the most common scenarios, is a trash fire that begins under a seat assembly and spreads to that seat assembly, in a passenger compartment, within the rail transportation vehicle.

5.3.1.5 If cooking is permitted on any passenger vehicle, an additional fire scenario, to be called Scenario 1c, also must be assessed. Fire Scenario 1c is a cooking fire originating at the cooking equipment and involving initial ignition of cooking fuel, if equipment is gas-fueled, or cooking oil, if equipment is not gas-fueled.

5.3.1.6 If there are one or more vehicles provided for overnight sleeping, Fire Scenario 1d also must be assessed, where Fire Scenario 1d is a small open-flame ignition of bedding in an unoccupied bed in a vehicle, with other beds occupied by sleeping people.

5.3.1.7 If there are one or more vehicles provided for cargo (or cargo storage space is provided within a passenger vehicle), Fire Scenario 1e also must be assessed, where Fire Scenario 1e consists of small open-flame ignition of a combustible, for example trash, in a fully-filled cargo vehicle. The assumed fuel load shall be the maximum allowed, including the highest quality of hazardous materials possible under the planned operating procedures. Openings connecting the cargo vehicle to an assumed adjacent passenger vehicle shall be assumed to be open to the maximum degree permitted by the design.

5.3.1.8 If the rail transportation vehicle overturns and then catches on fire, Scenerio 1f, it is possible that different considerations apply as a function of the way the vehicle ends up. If it remains in its normal orientation, the earlier scenarios apply, but if it falls on its side or if it turns around completely, to end up upside down, they represent different scenarios. In both cases, fire begins while the vehicle is stationary between stations, at the maximum distance between stations.

5.3.2 Fire Scenario 2 is a fire that originates outside the rail transportation vehicle, penetrates the rail transportation vehicle, and endangers the evacuation route from the vehicle through the spread of flames or smoke into the evacuation route.

5.3.2.1 Any one of the Type 2 fire scenarios (where the fire starts outside the rail transportation vehicle) becomes more severe if the fire occurs when the rail transportation vehicle is in a tunnel, at a point maximally distant from a place of safe refuge (see also 5.4.2).

5.3.2.2 Fire Scenario 2a, specified as the highest-challenge likely scenario of this type, begins with ignition of a fuel spill following a collision in which there are survivors. Fire begins in a tunnel, where the vehicle has stopped due to the collision. Evacuation is to a place of safe refuge.

5.3.2.3 If the vehicles are individually electrically powered, Fire Scenario 2b must be assessed, where Fire Scenario 2b is an electrical fire that causes the vehicle to stop in a tunnel. The interruption of electrical power also affects operation of the vehicle doors, in accordance with the vehicle's design. The point of origin is assumed to be whatever point in the electrical system will lead to the fastest spread of smoke and toxic gases to the vehicle interior. Evacuation is to a place of safe refuge.

5.3.2.4 Fire Scenario 2c, where a trash fire occurs outside the rail transportation vehicle is more frequent than Fire Scenario 2a but Fire Scenario 2a is likely to be more severe.

5.3.3 The specification of fire scenarios included in this section assumes that other fire scenarios either are less severe, and therefore, will lead to achievement of fire safety objectives if the design achieves the objectives for the specified fire scenarios, or are sufficiently unlikely that they need not be considered as part of the overall fire hazard assessment, although they may be considered individually.

5.3.3.1 The fire scenarios that are appropriate for a certain rail system may not be adequate for a different rail system. Additional or different fire scenarios may be needed in certain cases.

5.4 *Additional Model Assumptions*

5.4.1 Occupancy of the rail transportation vehicle and any other relevant occupiable spaces, such as the station platform (or any other place of safe refuge) to which occupants may move to evacuate, shall be set for analysis purposes so as to pose the greatest challenge to the fire safety objectives. A logical assumption would be occupancy to capacity and a mix of occupants of different abilities, where some will have various physical or mental disabilities, and capabilities, for example, some will be assumed to be impaired by alcohol, or drugs, or by age-related limitations.



5.4.1.1 Assumptions regarding numbers and abilities of disabled persons shall incorporate relevant provisions of the Americans with Disabilities Act.[7]

5.4.1.2 Assumptions regarding age distributions of the occupants shall reflect data on age patterns among users of the rail system. Assumptions regarding the capabilities of older or younger occupants shall reflect patterns in the general population, or known applications to the specific rail transportation scenario chosen, if they differ, and shall be documented as to sources of data.

5.4.1.3 Assumptions regarding alcohol or drug impairment among occupants shall be documented as to source data and shall be based on patterns in the general population, weighted to reflect the age and economic distribution of users of the rail system. If such data are not available, conservatively assume that 10 % of adult occupants are impaired by alcohol.

5.4.1.4 If the rail vehicles provide sleeping accommodations, assume that fire occurs when the maximum number of occupants will be sleeping. If there are no data available to determine the maximum fraction of people sleeping, assume all passengers are sleeping.

5.4.2 Other necessary assumptions that affect the severity of the calculated hazard shall also be made for analysis purposes so as to pose the greatest challenge to the fire safety objective. In particular, any fire scenario requiring evacuation of an actual vehicle will pose a more severe challenge in a location where escape and rescue are particularly difficult, for example, a tunnel, and so shall be assumed to occur in such a location (see 5.3.1.1 and 5.3.2.1).

5.5 *Required Calculations*

5.5.1 The fire hazard assessment involves using one or more calculation procedures to determine whether the fire safety objectives in Section 5.1 will be met if the design specified in Section 5.2 experiences each of the fires of the scenarios specified in Section 5.3, and given the additional assumptions specified in Section 5.4.

5.5.1.1 This guide does not assign a specific choice of calculation procedure just as it does not assign a specific test method. It simply gives guidance on the types of procedures available and on the required output to generate a valid fire hazard assessment.

5.5.1.2 Use Guide E1546 when developing the procedure.

5.5.1.3 Use NFPA 901 if needed for overall coding of materials or products.

5.5.2 Because the fire safety objectives are all stated in terms of specified fire effects by location and time, the fire hazard assessment calculation procedures must support the calculations in 5.5.2.1 – 5.5.2.5.

5.5.2.1 Translate the fire scenario specifications into a description of the fire in its initial stages, as a function of time in the initially involved space. The fire-test-response characteristics of the materials, components, or products initially involved that should be considered for such a description are rate of heat release, rate of mass loss, total heat release (if burned to completion, or cumulative heat release to end of burning otherwise), flame spread, cumulative full-scale smoke obscuration and toxic potency of the products of combustion released. A thorough analysis of the actual rail transportation vehicle fire scenario should result in a final decision on the properties required for the fire hazard assessment. If the product under consideration is a structural component, assess also its fire endurance.

5.5.2.2 Assess and evaluate the vehicle design specifications to develop and describe foreseeable characteristics of the fuel load environment near the initial fire. Use these and the time-based description of the initial fire as a function of time to calculate the spread of fire to secondary items and the ignition of those secondary items.

5.5.2.3 For each space, or potential fire compartment, calculate the timing of major fire events, including the onset of flashover, as well as, fire spread from one space to an adjacent space, whether through barriers or not, particularly from outside a rail vehicle to inside the vehicle. The calculation of fire spread from one space to another will require measurement of barrier fire resistance characteristics.

5.5.2.4 For each potentially exposed occupant, calculate the time to reach safe refuge and compare it to the calculated time until exposure to an unacceptable potential for harm (hazard). The former requires calculation of occupant alerting response, travel speed, and other behavior. For occupants requiring rescue, calculations will need to estimate the size, capabilities, and arrival time of fire department or other rescue personnel. The latter can be calculated as time to exposure to an untenable cumulative dose of fire effects or conservatively calculated as time to first exposure to unacceptably hazardous fire conditions. Calculations will be required for the area of fire origin, any occupied spaces, and any spaces that are part of escape or rescue routes.

5.5.2.5 When making the calculations described in 5.5.2.3 and 5.5.2.4, incorporate the activation and effects of any fire protection systems, including automatic or manual fire suppression, detection, and smoke control systems. Consider that, once a collision has occurred, electrically-controlled detection and protection systems may be damaged.

5.5.3 For the fire safety objective of preventing flashover, flashover shall be calculated as occurring when the radiative heat flux at the center of the floor reaches 20 $kW/m^2$. Other fire characteristics that are sometimes used as indicators of flashover, such as an upper layer temperature of 600°C, can be used in the calculations but are not to be used to assess achievement of the objective.

5.6 *Procedural Steps in Conducting a Fire Hazard Assessment*

5.6.1 The detailed procedural steps for conducting a fire hazard assessment on a product in a rail transportation vehicle are given in Section 5.7, for the fire safety objectives in Section 5.1. Conducting these procedures requires applying the design considerations in Section 5.2; for the scenarios considered in Section 5.3; and, under the additional assumptions presented in Section 5.4. Appendix X5 provides a list of test methods from which the test methods to be used should be chosen (see also X3.3). Some appropriate calculation methods are listed in Appendix X6 and Appendix X7. Appendix X1 and Appendix X3 (and Tables X1.1 and X3.1 in particular) provide the test methods and the required criteria for complying with the requirements of the FRA (**24**) and NFPA 130, respectively. The use of the test methods and criteria in Table X1.1 or in Table X3.1, in their entirety, is an alternative method for conducting a fire hazard assessment. The Fire Protection Research Foundation of NFPA has issued, in 2004, a "White Paper on Fire and Transportation Vehicles-State of the Art of Regulatory Requirements and Guidelines" (**31**); Chapter 6 of that white paper addresses rail transportation vehicles (rail, intercity trains and surface trains) and Chapter 7 addresses underground fixed guideway vehicles (subways). That white paper provides a guide to other types of regulations and requirements beyond those of the FRA.



5.6.2 Following the steps in Section 5.7, the final step in a fire hazard assessment procedure should be the development of a detailed procedure to ensure consistent quality control over time.[16] In the absence of prescriptive small-scale tests that dictate the minimum fire-test response characteristics required for each material, component, or product, alternative means should be described so that the fire safety of the rail transportation vehicle can be ensured without having to conduct full rail transportation vehicle burn tests.

5.7 *Steps in Conducting a Fire Hazard Assessment*

5.7.1 Fire hazard assessment begins by choosing fire safety objective(s) to be achieved. This step is described in Section 5.1.

5.7.2 Fire hazard assessment requires specification of the design to be assessed, in a form that permits the fire safety performance of the design to be tested and modeled. This step is described in Section 5.2.

5.7.3 Fire hazard assessment requires specification of the fire scenarios for which a design must meet the fire safety objectives. This step is described in Section 5.3.

5.7.4 Fire hazard assessment requires specification of any additional assumptions, such as conditions of the environment, in the assessment. This step is described in Section 5.3.

5.7.5 Fire hazard assessment finds a specified design to be acceptable if, under the specified assumptions, a vehicle built to the design will meet each of the objectives for each of the specified fire scenarios.

5.7.6 It is the intention of this standard to maintain or exceed the levels of fire safety in rail transportation vehicles associated with the traditional applicable fire-test-response characteristic requirements for rail transportation systems, including the recommendations from the Federal Transit Administration and the guidelines from the Federal Railroad Administration, while providing an alternative method of assessing designs to achieve equivalent safety. Appendix X8 (**32, 33**) illustrates the level of safety achieved in 1990–1991.

[16] One way to ensure consistent quality control is by listing materials, components, products, or assemblies.

5.7.6.1 Fire hazard assessment requires the use of testing and calculation methods to determine whether the objectives will be met by a specified design for a specified fire scenario, under the specified assumptions. The calculations to be performed are described in Section 5.3, and the selection and qualifying of calculation methods for the assessment are described in Section 5.3.

5.7.7 For the fire hazard assessment procedure to be valid, it is necessary that the calculation methods and the fire-test-response characteristics used produce valid estimates of success or failure in achievement of the fire safety objectives, given the specified fire scenario(s).

5.7.7.1 It is advisable for the validity of the fire hazard assessment procedure to be confirmed by peer review.

5.7.8 One way in which acceptable levels of safety would be achieved is through a design that complies with the applicable fire-test-response characteristic requirements for rail transportation systems, including the FRA requirements, shown in Appendix X1 (**24**), or those in NFPA 130, shown in Appendix X3. If a rail transportation vehicle is designed fully with materials and products meeting those requirements or recommendations, that vehicle would not traditionally need to be subjected to the fire hazard assessment procedure described here.

5.7.8.1 A complete listing of the fire-test-response characteristics of a design, together with the corresponding FRA requirements for those characteristics (see Table X1.1 and Appendix X1) or the NFPA 130 requirements for the corresponding characteristics (see Table X3.1 and Appendix X3), would constitute an acceptable design.

5.7.9 The requirements cited in 5.7.8 should be used to set specific values in the fire safety objectives and in other qualified elements of the fire hazard assessment in any instance where those values are not specified by this guide. This should be done so as not to compromise the fire safety levels reflected in the statistics of fire incidents shown in Appendix X8. Any values or other assumptions specified by the user must be set explicitly and conservatively, that is, providing greater safety, with an explicitly stated rationale for the specific values or assumptions.

## 6. Selection and Qualification of Fire Hazard Calculation Methods

6.1 Because no applicable calculation methods have been adopted as ASTM standards, the choice of calculation methods is nonmandatory and must include written evidence of the validity of the method for this purpose. Use Guide E1355 in order to evaluate the predictive capability of the fire model used. Guide E1591 provides guidelines on how to obtain the appropriate input data, in particular material properties, that are needed for fire modeling. Guide E1472 illustrates the type of documentation required for fire models to be satisfactory.



6.2 The user must provide guidance on safety factors needed to offset the uncertainties and biases associated with the method or with the data used by the method. Any valid calculation method is valid only for certain applications and within the limits of its own uncertainties and biases and the uncertainties of its source data; therefore, the evidence of validity required in 5.4.1 will provide the basis for specifying safety factors.



6.3 See Appendix X6 and Appendix X7 for candidate calculation methods.



6.4 Under the provisions in 5.7.8, a design fully complying with the existing requirements based on fire-test-response characteristics is deemed to satisfy the fire hazard assessment. This is equivalent to stating that a fire-characteristic profile for the design is deemed to satisfy the fire hazard assessment if it satisfies the fire-test-response characteristic limits in Table X1.1 and Appendix X1 or those in Table X3.1 and Appendix X3. However, this does not constitute acceptance of the fire-characteristic profile in general as a simplification of the fire hazard assessment procedure. Any use of the fire-characteristic profile other than this specific application must be shown to be valid.

## ANNEX

**(Mandatory Information)**

### A1. CLEANING PROCEDURES FOR ASSESSING PERMANENCE OF FIRE-TEST-RESPONSE CHARACTERISTICS OF TEXTILE FABRICS

A1.1 This annex provides guidance for subjecting textile fabrics to cleaning procedures, which shall be conducted prior to testing, to determine the permanence of their fire-test-response characteristics. This cleaning shall be conducted in accordance with the appropriate requirements (if any) and in a manner consistent with maintenance practices used for such fabrics in the field.

A1.2 When the manufacturer, or other interested party (such as the party responsible for maintaining the fabric in service), has a recommended procedure specified for cleaning the fabric item, that method shall be used to assess the permanence of the fire-test-response characteristics of interest for the fabric in question.

A1.2.1 In order to make the assessment of permanence, test specimens of the fabric shall be subjected to the recommended cleaning procedure (such as washing, shampooing or dry cleaning) no fewer than ten times in succession, with complete drying of the fabric between each washing cycle.

A1.2.2 Following the required number of cleaning cycles, subject the cleaned specimen to the required fire test method or methods.

A1.3 When no recommended procedures have been specified for the fabric in questions, cleaning procedures shall be chosen from those listed in A1.4 through A1.7, in order to use the most suitable cleaning procedure for the fabric in question to assess the permanence of its fire-test-response characteristics. Unless the specific recommended procedure is machine washing or dry cleaning, conduct the cleaning as indicated in A1.4 (hand washing) or in A1.6 (alternate procedure). If the recommended cleaning procedure is machine washing, follow the procedure indicated in A1.5. If the recommended cleaning procedure is dry-cleaning, follow the procedure in A1.7.

A1.4 *Hand Washing Procedure:*

A1.4.1 Cut the number of test specimens to the dimensions required by the fire test to be conducted.

A1.4.2 Vacuum the cut specimens or shake them vigorously to remove any loose fibers, dust or possible accumulated debris.

A1.4.3 Place individual specimen face down in a shallow pan, which has been filled to a depth of 50 mm (2 in.) with a wash solution of 1.5 g per liter of AATCC (American Association of Textile Chemists and Colorists) Standard Detergent as specified in AATCC Test Method 124 (or equivalent), with the water preheated to 41 ± 1EC (105 ± 2EF). Knead the back of the specimen with hand for 1 min. Maintain the water level and the temperature separately for each specimen.

A1.4.4 Rinse specimen thoroughly, face down, with warm water, at 40 ± 5EC (105 ± 9EF), for 1 min, under a faucet with strong water pressure.

A1.4.5 Remove excess liquor by using a wringer, hydro-extractor or by gentle hand squeezing. Then dry in a circulating air oven at 95 ± 5EC (200 ± 9EF) until dry.

A1.4.6 Repeat the above procedure 10 times, each time using fresh detergent and fresh water, for each set of specimens being laundered.

A1.4.7 Following the required number of cleaning cycles, subject the cleaned specimen to the required fire test method or methods.

A1.5 *Machine Washing Procedure:*

A1.5.1 A fabric sample, or oversized specimens selected for the fire testing procedure, shall be washed 10 times, prior to the preparation of test specimens, by the washing and drying procedure prescribed in AATCC Test Method 124.

A1.5.2 Prepare the test specimens from the laundered fabrics.

A1.5.3 Following the required number of cleaning cycles, subject the cleaned specimen to the required fire test method or methods.

A1.6 *Special Procedure:*

A1.6.1 Alternatively the selected fabric sample, or oversized specimens, shall be permitted to be washed, dry-cleaned, or