

NFPA®

556

Guide on Methods for Evaluating Fire Hazard to Occupants of Passenger Road Vehicles

2020



IMPORTANT NOTICES AND DISCLAIMERS CONCERNING NFPA® STANDARDS

NFPA® codes, standards, recommended practices, and guides (“NFPA Standards”), of which the document contained herein is one, are developed through a consensus standards development process approved by the American National Standards Institute. This process brings together volunteers representing varied viewpoints and interests to achieve consensus on fire and other safety issues. While the NFPA administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in NFPA Standards.

The NFPA disclaims liability for any personal injury, property, or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of, or reliance on NFPA Standards. The NFPA also makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

In issuing and making NFPA Standards available, the NFPA is not undertaking to render professional or other services for or on behalf of any person or entity. Nor is the NFPA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

The NFPA has no power, nor does it undertake, to police or enforce compliance with the contents of NFPA Standards. Nor does the NFPA list, certify, test, or inspect products, designs, or installations for compliance with this document. Any certification or other statement of compliance with the requirements of this document shall not be attributable to the NFPA and is solely the responsibility of the certifier or maker of the statement.

REVISION SYMBOLS IDENTIFYING CHANGES FROM THE PREVIOUS EDITION

Text revisions are shaded. A **Δ** before a section number indicates that words within that section were deleted and a **Δ** to the left of a table or figure number indicates a revision to an existing table or figure. When a chapter was heavily revised, the entire chapter is marked throughout with the **Δ** symbol. Where one or more sections were deleted, a **•** is placed between the remaining sections. Chapters, annexes, sections, figures, and tables that are new are indicated with an **N**.

Note that these indicators are a guide. Rearrangement of sections may not be captured in the markup, but users can view complete revision details in the First and Second Draft Reports located in the archived revision information section of each code at www.nfpa.org/docinfo. Any subsequent changes from the NFPA Technical Meeting, Tentative Interim Amendments, and Errata are also located there.

REMINDER: UPDATING OF NFPA STANDARDS

Users of NFPA codes, standards, recommended practices, and guides (“NFPA Standards”) should be aware that these documents may be superseded at any time by the issuance of a new edition, may be amended with the issuance of Tentative Interim Amendments (TIAs), or be corrected by Errata. It is intended that through regular revisions and amendments, participants in the NFPA standards development process consider the then-current and available information on incidents, materials, technologies, innovations, and methods as these develop over time and that NFPA Standards reflect this consideration. Therefore, any previous edition of this document no longer represents the current NFPA Standard on the subject matter addressed. NFPA encourages the use of the most current edition of any NFPA Standard [as it may be amended by TIA(s) or Errata] to take advantage of current experience and understanding. An official NFPA Standard at any point in time consists of the current edition of the document, including any issued TIAs and Errata then in effect.

To determine whether an NFPA Standard has been amended through the issuance of TIAs or corrected by Errata, visit the “Codes & Standards” section at www.nfpa.org.

ADDITIONAL IMPORTANT NOTICES AND DISCLAIMERS CONCERNING NFPA® STANDARDS

Updating of NFPA Standards

Users of NFPA codes, standards, recommended practices, and guides (“NFPA Standards”) should be aware that these documents may be superseded at any time by the issuance of a new edition, may be amended with the issuance of Tentative Interim Amendments (TIAs), or be corrected by Errata. It is intended that through regular revisions and amendments, participants in the NFPA standards development process consider the then-current and available information on incidents, materials, technologies, innovations, and methods as these develop over time and that NFPA Standards reflect this consideration. Therefore, any previous edition of this document no longer represents the current NFPA Standard on the subject matter addressed. NFPA encourages the use of the most current edition of any NFPA Standard [as it may be amended by TIA(s) or Errata] to take advantage of current experience and understanding. An official NFPA Standard at any point in time consists of the current edition of the document, including any issued TIAs and Errata then in effect.

To determine whether an NFPA Standard has been amended through the issuance of TIAs or corrected by Errata, visit the “Codes & Standards” section at www.nfpa.org.

Interpretations of NFPA Standards

A statement, written or oral, that is not processed in accordance with Section 6 of the Regulations Governing the Development of NFPA Standards shall not be considered the official position of NFPA or any of its Committees and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

Patents

The NFPA does not take any position with respect to the validity of any patent rights referenced in, related to, or asserted in connection with an NFPA Standard. The users of NFPA Standards bear the sole responsibility for determining the validity of any such patent rights, as well as the risk of infringement of such rights, and the NFPA disclaims liability for the infringement of any patent resulting from the use of or reliance on NFPA Standards.

NFPA adheres to the policy of the American National Standards Institute (ANSI) regarding the inclusion of patents in American National Standards (“the ANSI Patent Policy”), and hereby gives the following notice pursuant to that policy:

NOTICE: The user’s attention is called to the possibility that compliance with an NFPA Standard may require use of an invention covered by patent rights. NFPA takes no position as to the validity of any such patent rights or as to whether such patent rights constitute or include essential patent claims under the ANSI Patent Policy. If, in connection with the ANSI Patent Policy, a patent holder has filed a statement of willingness to grant licenses under these rights on reasonable and nondiscriminatory terms and conditions to applicants desiring to obtain such a license, copies of such filed statements can be obtained, on request, from NFPA. For further information, contact the NFPA at the address listed below.

Law and Regulations

Users of NFPA Standards should consult applicable federal, state, and local laws and regulations. NFPA does not, by the publication of its codes, standards, recommended practices, and guides, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

NFPA Standards are copyrighted. They are made available for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of safe practices and methods. By making these documents available for use and adoption by public authorities and private users, the NFPA does not waive any rights in copyright to these documents.

Use of NFPA Standards for regulatory purposes should be accomplished through adoption by reference. The term “adoption by reference” means the citing of title, edition, and publishing information only. Any deletions, additions, and changes desired by the adopting authority should be noted separately in the adopting instrument. In order to assist NFPA in following the uses made of its documents, adopting authorities are requested to notify the NFPA (Attention: Secretary, Standards Council) in writing of such use. For technical assistance and questions concerning adoption of NFPA Standards, contact NFPA at the address below.

For Further Information

All questions or other communications relating to NFPA Standards and all requests for information on NFPA procedures governing its codes and standards development process, including information on the procedures for requesting Formal Interpretations, for proposing Tentative Interim Amendments, and for proposing revisions to NFPA standards during regular revision cycles, should be sent to NFPA headquarters, addressed to the attention of the Secretary, Standards Council, NFPA, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101; email: stds_admin@nfpa.org.

For more information about NFPA, visit the NFPA website at www.nfpa.org. All NFPA codes and standards can be viewed at no cost at www.nfpa.org/docinfo.

Copyright © 2019 National Fire Protection Association®. All Rights Reserved.

NFPA® 556

Guide on

Methods for Evaluating Fire Hazard to Occupants of Passenger Road Vehicles

2020 Edition

This edition of NFPA 556, *Guide on Methods for Evaluating Fire Hazard to Occupants of Passenger Road Vehicles*, was prepared by the Technical Committee on Hazard and Risk of Contents and Furnishings. It was issued by the Standards Council on April 28, 2019, with an effective date of May 18, 2019, and supersedes all previous editions.

This edition of NFPA 556 was approved as an American National Standard on May 18, 2019.

Origin and Development of NFPA 556

The 2011 edition was the first for this guide. Its development was prompted in part by fire statistics associated with vehicles as well as car and van fire research documented by the National Highway Traffic Safety Administration. Those statistics and research prompted the committee's opinion that the current method of evaluating vehicle materials was unsatisfactory. NFPA 556 identified major fire safety concerns associated with passenger road vehicles and provided guidance on newer evaluation methods with the aim of decreasing the fire hazard and fire risk associated with such vehicles. In addition, NFPA 556 provided guidance and tools for those persons investigating methods to decrease the fire hazard or fire risk in passenger road vehicles and for a hazard-based assessment for the development of hazardous conditions from fire involving passenger road vehicles.

The 2016 edition contained new language for noncombustible material criteria and new language recognizing the school bus seat upholstery fire block test. Table 10.1 was revised to include test methods and tools for seat materials for school buses and additional evaluation options for windshields based on flame spread or fire resistance testing. Additional updates to terminology, definitions, and testing notations were made throughout the document to reflect industry standards and technology.

The 2020 edition contains new language for defining a limited-combustible material and recognizes ASTM E2965, *Standard Test Method for Determination of Low Levels of Heat Release Rate for Materials and Products Using an Oxygen Consumption Calorimeter*, as one way to assess whether a material is a limited-combustible material. Reference documents were updated to reflect the most current editions available.

Technical Committee on Hazard and Risk of Contents and Furnishings

Steven D. Wolin, *Chair*

Reliable Automatic Sprinkler Company, Inc., SC [M]

Farid Alfawakhiri, American Iron and Steel Institute, IL [M]

Craig L. Beyler, JENSEN HUGHES, MD [SE]

David A. Boverman, NSW Rural Fire Service, Australia [E]

Elizabeth C. Buc, Fire & Materials Research Laboratory, LLC, MI [RT]

David G. Bueche, Hoover Treated Wood Products, CO [M]

Michael T. Burr, Safety Engineering Laboratories, Inc., MI [RT]

Cam Cope, Auto Fire and Safety Consultants, TX [SE]

Gordon H. Damant, Inter-City Testing & Consulting Corp. of California, CA [SE]

Jason Daniels, Code Consultants, Inc., MO [SE]

Richard J. Davis, FM Global, MA [I]
Rep. FM Global

Jonathan Hernandez, Boston Fire Department, MA [U]

Marcelo M. Hirschler, GBH International, CA [SE]

Xianxu (Sherri) Hu, Verisk Analytics/Insurance Services Office, Inc., NJ [I]

William E. Koffel, Koffel Associates, Inc., MD [SE]

Sergei V. Levchik, Israel Chemicals Ltd. (ICL-IP), NY [M]

James R. Richardson, Lisle Woodridge Fire District, IL [E]

Jeffrey Santrock, General Motors Company, MI [M]
Rep. Alliance of Automobile Manufacturers

Dwayne E. Sloan, UL LLC, NC [RT]

Peter J. Willse, AXA XL/Global Asset Protection Services, LLC, CT [I]

Alternates

Erik H. Anderson, Koffel Associates, Inc., MD [SE]
(Alt. to William E. Koffel)

Timothy Earl, GBH International, MI [SE]
(Alt. to Marcelo M. Hirschler)

William Randall Edwards, Alliance of Automobile Manufacturers, MI [M]
(Alt. to Jeffrey Santrock)

John A. Frank, Global Asset Protection Services, LLC, GA [I]
(Alt. to Peter J. Willse)

William Jeffrey Ivans, Verisk/Insurance Services Office, NJ [I]
(Alt. to Xianxu (Sherri) Hu)

Nestor R. Iwankiw, JENSEN HUGHES, IL [SE]
(Alt. to Craig L. Beyler)

Joel E. Sipe, Exponent, Inc., CA [SE]
(Voting Alt.)

Jerry W. Wallace, Safety Engineering Laboratories, Inc., MI [RT]
(Alt. to Michael T. Burr)

Shaohua Xia, Fire & Rescue New South Wales, [E]
(Alt. to David A. Boverman)

Valerie Ziavras, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the final text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of the document.

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on fire hazard calculation procedures for use by other Committees in writing provisions to control the fire hazards of contents and furnishings. This Committee shall also provide guidance and recommendations to Committees in assessing the fire hazard of contents and furnishings. It shall establish classification and rating systems, request the development and standardization of appropriate fire tests, and identify and encourage necessary research as it relates to the fire hazards of contents and furnishings. It shall act in a liaison capacity between NFPA and the committees of other organizations with respect to the hazard of contents and furnishings.

Contents

Chapter 1 Administration	556– 4	7.2 Design Criteria.	556– 15
1.1 Scope.	556– 4	Chapter 8 Selecting Candidate Design	556– 15
1.2 Purpose.	556– 4	8.1 General.	556– 15
1.3 Application.	556– 5	Chapter 9 Typical Fire Scenarios to Be Investigated .	556– 15
1.4 Units and Formulas.	556– 5	9.1 General.	556– 15
Chapter 2 Referenced Publications	556– 5	9.2 Passenger Road Vehicle Motion.	556– 16
2.1 General.	556– 5	9.3 Factors Contributing to Ignition.	556– 16
2.2 NFPA Publications.	556– 5	9.4 Areas of Fire Origination.	556– 17
2.3 Other Publications.	556– 5	9.5 Fire Scenarios.	556– 17
2.4 References for Extracts in Advisory Sections.	556– 7	Chapter 10 Evaluation Methods and Tools	556– 17
Chapter 3 Definitions	556– 8	10.1 General.	556– 17
3.1 General.	556– 8	10.2 Use of Test Methods.	556– 17
3.2 NFPA Definitions.	556– 8	10.3 Relevant Test Methods and Evaluation Tools. ...	556– 17
3.3 General Definitions.	556– 8	Chapter 11 Individual Fire Scenarios	556– 19
Chapter 4 Types of Vehicles	556– 9	11.1 Fires Starting in the Passenger Compartment. ..	556– 19
4.1 General.	556– 9	11.2 Fires Starting in the Engine Compartment.	556– 20
Chapter 5 General Description of Passenger Road Vehicle Fires and Background Information	556– 10	11.3 Fires Starting Inside the Trunk or Load-Carrying Area.	556– 25
5.1 Fire Statistics.	556– 10	11.4 Pool Fires Resulting from Fuel Tank Failure and Burning Under the Vehicle.	556– 26
5.2 Materials Used in Passenger Road Vehicles.	556– 11	11.5 Fires Resulting from Other External Heat Sources.	556– 26
5.3 Current Prescriptive Testing.	556– 13	Chapter 12 Further Guidance	556– 27
5.4 Noncombustible Material.	556– 13	12.1 Traditional Approach.	556– 27
5.5 Limited-Combustible Material.	556– 13	12.2 Mitigation Strategies.	556– 27
5.6 Fire Performance Properties.	556– 13	12.3 Testing to Assess Improved Fire Performance of Materials or Products.	556– 27
5.7 Tenability Criteria.	556– 13	Annex A Explanatory Material	556– 28
Chapter 6 Approach to Evaluating Passenger Road Vehicle Fire Hazard	556– 14	Annex B Fire Retardants	556– 36
6.1 General.	556– 14	Annex C Informational References	556– 36
6.2 Basic Performance-Based Approach.	556– 14	Index	556– 45
6.3 Design Considerations.	556– 14		
6.4 Regulatory Considerations.	556– 14		
Chapter 7 Objectives and Design Criteria	556– 15		
7.1 Objectives.	556– 15		

NFPA 556

Guide on

Methods for Evaluating Fire Hazard to
Occupants of Passenger Road Vehicles

2020 Edition

IMPORTANT NOTE: This NFPA document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading “Important Notices and Disclaimers Concerning NFPA Standards.” They can also be viewed at www.nfpa.org/disclaimers or obtained on request from NFPA.

UPDATES, ALERTS, AND FUTURE EDITIONS: New editions of NFPA codes, standards, recommended practices, and guides (i.e., NFPA Standards) are released on scheduled revision cycles. This edition may be superseded by a later one, or it may be amended outside of its scheduled revision cycle through the issuance of Tentative Interim Amendments (TIAs). An official NFPA Standard at any point in time consists of the current edition of the document, together with all TIAs and Errata in effect. To verify that this document is the current edition or to determine if it has been amended by TIAs or Errata, please consult the National Fire Codes® Subscription Service or the “List of NFPA Codes & Standards” at www.nfpa.org/docinfo. In addition to TIAs and Errata, the document information pages also include the option to sign up for alerts for individual documents and to be involved in the development of the next edition.

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

A reference in brackets [] following a section or paragraph indicates material that has been extracted from another NFPA document. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced and extracted publications can be found in Chapter 2 and Annex C.

Chapter 1 Administration

1.1 Scope.

1.1.1 This document addresses issues associated with the development of hazardous conditions from fire involving passenger road vehicles and the time available for safe egress or rescue.

1.1.2 This document provides guidance toward a systematic approach of the determination of the relationship between the properties of passenger road vehicles, including the materials, components and systems, and the development of hazardous conditions in the vehicle. This approach can include small-scale testing, full-scale testing of systems or entire vehicles, and computer modeling techniques in specified, well-defined scenarios.

1.1.3 The principles and concepts presented in this document provide a methodology that can be used to determine the effects of changes in design or in the properties of materials, components, and assemblies in passenger road vehicles on the development of hazardous fire conditions in passenger road vehicles in response to specified well-defined scenarios.

1.1.4 This document provides a methodology that can be used in the selection of materials and design of components and systems, with the intent of providing a desired level of fire safety to occupants in passenger road vehicles in response to specific fire scenarios.

1.1.5 The use of this document cannot eliminate all fire risk in passenger road vehicles.

1.1.6 The uncertainty of the fire hazard analysis resulting from the application of this document is a function of the accuracy, precision, and relevance of the data, correlations, test methods, calculations, and simulations used.

1.2 Purpose.

1.2.1 The purpose of this document is to provide guidance and tools for persons investigating methods to decrease the fire hazard or fire risk in passenger road vehicles by providing additional time for occupants of the passenger road vehicle to be able to exit or be rescued in case of the occurrence of a fire involving the passenger road vehicle.

1.2.2 This document is intended to provide guidance for a hazard-based assessment for the development of hazardous conditions from fire involving passenger road vehicles. This document does not provide guidance for a complete risk-based assessment. A risk analysis, taking into account the probability and consequences of an event or events, can help focus passenger road vehicle safety efforts on solutions with the greatest impact on passenger road vehicle-related deaths. Strategies for reducing fire deaths in passenger road vehicles should not adversely affect efforts to reduce the overall number of deaths in passenger road vehicles. This statistic can be gauged by comparing the estimated lives saved per year by various strategies.

1.2.3 Flammability is one of a number of material properties to be considered in the design of components for passenger road vehicles. The physical properties of materials used in passenger road vehicles affect the vehicles' overall safety (including crashworthiness and fire safety), fuel economy, emissions (both tailpipe and evaporative emissions), manufacturability, utility, and durability. Optimizing a material for flammability could result in substantial degradation of other properties of that material, which could, in turn, render that material unsuitable for use in its intended application in a passenger road vehicle. Material properties that have been found to affect the overall safety, fuel economy, emissions, manufacturability, utility, and durability of passenger road vehicles and are currently considered when selecting a material for use in a passenger road vehicle are discussed in this document. Therefore, proposed changes to flammability properties of a material or component should also consider how those changes could affect the properties discussed in this document.

1.3 Application.

1.3.1 This document applies to passenger road vehicles used to transport people who are either drivers or passengers in the passenger road vehicle.

1.3.2 This document applies to all portions of a passenger road vehicle that have the potential to affect the fire safety of drivers or passengers.

1.3.3 It is not intended that the provisions of this document be applied to compartments in vehicles such as ships, trains, airplanes, or off-road vehicles, irrespective of whether they are or are not intended for use by human passengers or drivers.

1.3.4 This document describes standard tests conducted under controlled laboratory conditions. Such tests should not be deemed to establish performance levels for all situations.

1.3.5 The choice of an effective and reliable means to achieve the fire performance objectives should be based on an evaluation that includes all conditions of the hazard and protection as well as the quantification of egress time.

1.3.6 The use of sound scientific and engineering principles and recognition of limitations in data, test procedures, fire models, and state-of-the-art scientific knowledge should be considered in the application of this document.

1.3.7 As every passenger road vehicle fire and explosion incident is in some way different and unique from all other incidents, this document is not designed to encompass all the necessary components of a complete analysis of any one scenario. Thus, not every portion of this document may be applicable to every passenger road vehicle fire scenario. It is up to the user of this document to apply the appropriate methodology to a particular passenger road vehicle fire scenario.

1.4 Units and Formulas. Table 1.4 provides the nomenclature used in this document.

Table 1.4 Nomenclature

<i>FPI</i>	Fire performance index (sec m ² /kW)
<i>H_{c, eff}</i>	Effective heat of combustion (MJ/kg)
<i>HRR_{a, avg}</i>	Average heat release rate per unit area over entire test period (kW/m ²)
<i>HRR_{180 sec}</i>	Average heat release rate per unit area over a 3-minute period following ignition (kW/m ²)
<i>M_{sec}L_{sec}</i>	Mass loss
<i>MLR_{avg}</i>	Average mass loss rate (g/sec)
<i>PHRR_a</i>	Peak heat release rate per unit area (MJ/m ²)
<i>PSRR_a</i>	Peak smoke release rate (l/sec)
<i>SEA</i>	Average specific extinction area (m ² /kg)
<i>SmkFct</i>	Smoke factor
<i>t_{ig}</i>	Time to ignition (sec)
<i>t_{400 kW}</i>	Predicted time to 400 kW (sec or min)
<i>THR_a</i>	Total heat released per unit area (kW/m ²)
<i>TSR_a</i>	Total smoke release (nondimensional)
<i>TTE</i>	Time to extinction (sec)

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this guide and should be considered part of the recommendations of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source*, 2019 edition.

NFPA 257, *Standard on Fire Test for Window and Glass Block Assemblies*, 2017 edition.

NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, 2018 edition.

NFPA 260, *Standard Methods of Tests and Classification System for Cigarette Ignition Resistance of Components of Upholstered Furniture*, 2019 edition.

NFPA 261, *Standard Method of Test for Determining Resistance of Mock-Up Upholstered Furniture Material Assemblies to Ignition by Smoldering Cigarettes*, 2018 edition.

NFPA 270, *Standard Test Method for Measurement of Smoke Obscuration Using a Conical Radiant Source in a Single Closed Chamber*, 2018 edition.

NFPA 289, *Standard Method of Fire Test for Individual Fuel Packages*, 2019 edition.

NFPA 555, *Guide on Methods for Evaluating Potential for Room Flashover*, 2017 edition.

2.3 Other Publications.

2.3.1 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959.

ASTM D2859, *Test Method for Ignition Characteristics of Finished Textile Floor Covering Materials*, 2016.

ASTM D3675, *Test Method for Surface Flammability of Flexible Cellular Materials Using a Radiant Heat Energy Source*, 2017.

ASTM D6113, *Test Method for Using a Cone Calorimeter to Determine Fire-Test-Response Characteristics of Insulating Materials Contained in Electrical or Optical Fire Cables*, 2016.

ASTM E84, *Test Method for Surface Burning Characteristics of Building Materials*, 2018b.

ASTM E119, *Test Methods for Fire Tests of Building Construction and Materials*, 2018b.

ASTM E136, *Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 2016a.

ASTM E162, *Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source*, 2016.

ASTM E603, *Guide for Room Fire Experiments*, 2017.

ASTM E648, *Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source*, 2017a.

ASTM E662, *Test Method for Specific Optical Density of Smoke Generated by Solid Materials*, 2017a.

ASTM E814, *Test Method for Fire Tests of Penetration Firestop Systems*, 2013a (2017).

ASTM E1321, *Test Method for Determining Material Ignition and Flame Spread Properties*, 2018.

ASTM E1354, *Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, 2017.

ASTM E1474, *Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter*, 2014.

ASTM E1529, *Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies*, 2016e1.

ASTM E1546, *Guide for Development of Fire-Hazard-Assessment Standards*, 2015.

ASTM E1623, *Test Method for Determination of Fire and Thermal Parameters of Materials, Products, and Systems Using an Intermediate Scale Calorimeter (ICAL)*, 2016.

ASTM E1995, *Test Method for Measurement of Smoke Obscuration Using a Conical Radiant Source in a Single Closed Chamber, With the Test Specimen Oriented Horizontally*, 2016.

ASTM E2061, *Guide for Fire Hazard Assessment of Rail Transportation Vehicles*, 2018.

ASTM E2067, *Practice for Full-Scale Oxygen Consumption Calorimetry Fire Tests*, 2015.

ASTM E2102, *Test Method for Measurement of Mass Loss and Ignitability for Screening Purposes Using a Conical Radiant Heater*, 2017.

ASTM E2280, *Guide for Fire Hazard Assessment of the Effect of Upholstered Seating Furniture Within Patient Rooms of Health Care Facilities*, 2017.

ASTM E2574/E2574M, *Test Method for Fire Testing of School Bus Seat Assemblies*, 2017.

ASTM E2652, *Test Method for Behavior of Materials in a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750°C*, 2016.

ASTM E2965, *Test Method for Determination of Low Levels of Heat Release Rate for Materials and Products Using an Oxygen Consumption Calorimeter*, 2017.

2.3.2 ISO Publications. International Organization for Standardization, ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland.

ISO 3795, *Road Vehicles, and Tractors and Machinery for Agriculture and Forestry — Determination of Burning Behaviour of Interior Materials*, 1989.

ISO TS 17431, *Fire Tests — Reduced Scale Model Box Test*, 2006.

2.3.3 SAE Publications. SAE International, Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

ANSI/SAE Z-26.1, *American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways - Safety Standard*, 1996.

SAE J2464, *Electric and Hybrid Electric Rechargeable Energy Storage System (RESS) Safety and Abuse Testing*, 2009.

2.3.4 SFPE Publications. Society of Fire Protection Engineers, 9711 Washingtonian Blvd, Suite 380, Gaithersburg, MD 20878.

SFPE Engineering Guide to Performance-Based Fire Protection, 2nd edition.

2.3.5 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 9, *Fire Tests of Window Assemblies*, 2009, revised 2015.

UL 263, *Fire Tests of Building Construction and Materials*, 2011, revised 2018.

UL 723, *Test for Surface Burning Characteristics of Building Materials*, 2018.

UL 1479, *Fire Tests of Through-Penetration Firestops*, 2015.

UL 1685, *Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables*, 2015.

UL 1709, *Rapid Rise Fire Tests of Protection Materials for Structural Steel*, 2017.

UL 2556, *Wire and Cable Test Methods*, 2015.

2.3.6 U.S. DOT Publications. Federal Motor Vehicle Safety Standards, U.S. Department of Transportation/National Highway Traffic Safety Administration, 400 Seventh Street, SW, Washington, DC 20590.

49 CFR 571.302/FMVSS 302, "Flammability of Interior Materials," October 1, 2011.

2.3.7 Other Publications.

BS EN 13823, *Reaction to fire tests for building products. Building products excluding floorings exposed to the thermal attack by a single burning item*, British Standards Institution, London, United Kingdom.

ECE R34.01, Annex 5, Fire Risks — European Economic Community Regulation — *Fire safety of plastic fuel tanks for automobiles* (ECE R34, Annex 5, RREG 70/221/EWG, 2000/8/EG).

JIS D 1201, *Road Vehicles, and Tractors and Machinery for Agriculture and Forestry — Determination of Burning Behaviour of Interior Materials*, Japanese Standards Association, Tokyo, Japan, 1998.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield MA, 2003.

National School Transportation Specifications & Procedures, Adopted by the Fifteenth National Congress on School Transportation, 2010 revised edition.

2.3.8 List of Publications.

(1) "Traffic Safety Facts 2006." National Center for Statistics and Analysis, National Highway Traffic Safety Administration.

(2) Blincoe, L. J., et al. "The Economic Impact of Motor Vehicle Crashes 2000." DOT HS 809 446, U.S. Department of Transportation, National Highway Traffic Safety Administration, May 2002.

(3) Digges, K. H. and Stephenson, R. R. "A Research Program to Study Impact Related Fire Safety." Motor Vehicle Fire Research Institute (MVFRI) Paper Number 050448.

- (4) Ahrens, M., "U.S. Vehicle Fire Trends and Patterns," National Fire Protection Association, Quincy, MA, July 2008.
- (5) "Motor Vehicle Facts and Figures 2006," Alliance of the Automobile Manufacturers, Ward's, Southfield, MI, 2006.
- (6) Committee on Fire Safety Aspects of Polymeric Materials. 1979. "Fire Safety Aspects of Polymeric Materials, Volume 8, Land Transportation Vehicles." Washington, DC: National Materials Advisory Board, National Academy of Sciences, Publication NMAB 318-8: 158. [Original reference is Ward's *Automotive Yearbook*, 1975.]
- (7) Abu-Isa, I. A., D. R. Cummings, D. E. LaDue, and A. Tewarson. June 1–4, 1998. "Thermal Properties and Flammability Behavior of Automotive Polymers," Paper No. 98-54-P-17, 16th International Technical Conference on Enhanced Safety of Vehicles, Windsor, Canada. [References "Automotive Plastics Newsletter," April 1996, Market Search, Inc.]
- (8) Tewarson, A. October 1997. "A Study of the Flammability of Plastics in Vehicle Components and Parts." Factory Mutual Research Corp. Technical Report FMRC J.I. 0B1R7.RC, on General Motors Corp. Research Project.
- (9) Bundy, M., and Ohlemiller, T.J., "Bench-Scale Flammability Measures for Electronic Equipment, NISTIR-7031," NIST, Gaithersburg, MD, 2003.
- (10) Bundy, M., and Ohlemiller, T.J., "Full-Scale Flammability Measures for Electronic Equipment, NIST Technical Note 1461," NIST, Gaithersburg, MD, 2004.
- (11) "Recommendations for testing the flammability and smoke emission characteristics of transit bus and van materials such as seating, panels, flooring, insulation, and miscellaneous." October 20, 1993. *Federal Register*, Vol. 58. No. 201.
- (12) "Motor Vehicle Safety Standard No. 302, Flammability of Materials — Passenger Cars, Multipurpose Passenger Vehicles, Trucks and Buses." Washington, DC: National Highway Traffic Safety Administration. [Code of Federal Regulations § 571.302, originally *Federal Register* 34, No. 229, pp. 20434–20436 (December 31, 1969).]
- (13) Storrs, C. D. and O. H. Lindemann. July 1972. "Federal Flammability Standards for Interiors of Motor Vehicles." *Fire Journal*, pp. 34–44.
- (14) Hirschler, M. M. 1999. "Use of Heat Release Rate to Predict Whether Individual Furnishings Would Cause Self Propagating Fires." *Fire Safety Journal*, Vol. 32, 273–296.
- (15) Janssens, M. L., S. E. Dillon, and M. M. Hirschler. 2001. "Using the Cone Calorimeter as a Screening Tool for the NFPA 265 and NFPA 286 Room Test Procedures." *Fire and Materials 2001 Conference*, San Francisco, CA, January 22–24, 2001. London: Interscience Communications, 529–540.
- (16) Karlsson, B. 1994. "Models for Calculating Flame Spread on Wall Lining Materials and the Resulting Heat Release Rate in a Room." *Fire Safety Journal*, Vol. 23, No. 4, 365–386.
- (17) Hirschler, M. M. 1998. "How to Assess the Effect of an Individual Product on the Fire Hazard in a Real Occupancy, Based on Heat Release Rate." *Flame Retardants '98*, February 3–4, 1998, London. London: Interscience Communications, 225–240.
- (18) Janssens, M. L. and Huczek, J. P., "Comparison of Fire Properties of Automotive Materials," in Business Communications Company Fourteenth Ann. Conference on Recent Advances in Flame Retardancy of Polymeric Materials, June 2–4, 2003, Stamford, CT, Ed. M. Lewin, Norwalk, CT, 2003.
- (19) Peacock, R. D., W. W. Jones, R. W. Bukowski, and C. L. Forney. 1991. "Technical Reference Guide for the HAZARD I Fire Hazard Assessment Method, Version 1.1." In NIST Handbook 146, Vol. II. Gaithersburg, MD: National Institute of Standards and Technology.
- (20) Peacock, R. D., W. W. Jones, G. P. Forney, R. W. Portier, P. A. Reneke, R. W. Bukowski, and J. H. Klotz. 1994. "An Update Guide for HAZARD I, Version 1.2." NISTIR 5410. Gaithersburg, MD: National Institute of Standards and Technology.
- (21) Battipaglia, K., J. Huczek, M. L. Janssens, and G. Miller. 2004. "Development of a Method to Assess the Fire Hazard of Automotive Materials." *Proceedings Interflam 2004*. Interscience Communications Ltd.
- (22) Santrock J., August 2002. "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 7: Propagation of an Engine Compartment Fire in a 1997 Rear Wheel Drive Passenger Car." Docket # NHTSA-1998-178, General Motors Corporation.
- (23) Shields, L., R. Scheibe, and T. Angelos. November 17, 1998. "Motor-Vehicle Collision — Fire Analysis Methods and Results." Washington State Transportation Center, 1–18.
- (24) Karter, M. J. September/October 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001. "U.S. Fire Loss." *NFPA Journal*.
- (25) "Traffic Safety Facts," Fatal Analysis Reporting System (FARS). 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001. Washington, DC, U.S. Department of Transportation, National Highway Traffic Safety Administration.
- (26) Cole, L. S. 1992. *Investigation of Motor Vehicle Fires*, Novato, CA: Lee Books, 27–63.
- (27) Ahrens, M. February 2004. "U.S. Vehicle Fire Trends and Patterns." Quincy, MA: National Fire Protection Association.
- (28) Trisko, E. March 1975. "Results of the 1973 National Survey of Motor Vehicle Fires." *Fire Journal*, 19–27.
- (29) "Ontario Fire Losses by Property Class — 1990 to 1999." Office of the Ontario Province Fire Marshal.

2.4 References for Extracts in Advisory Sections.

- NFPA 268, *Standard Test Method for Determining Ignitability of Exterior Wall Assemblies Using a Radiant Heat Energy Source*, 2017 edition.
- NFPA 270, *Standard Test Method for Measurement of Smoke Obscuration Using a Conical Radiant Source in a Single Closed Chamber*, 2018 edition.
- NFPA 289, *Standard Method of Fire Test for Individual Fuel Packages*, 2019 edition.
- NFPA 318, *Standard for the Protection of Semiconductor Fabrication Facilities*, 2018 edition.
- NFPA 555, *Guide on Methods for Evaluating Potential for Room Flashover*, 2017 edition.

NFPA 921, *Guide for Fire and Explosion Investigations*, 2017 edition.

NFPA 5000®, *Building Construction and Safety Code*®, 2018 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter apply to the terms used in this guide. Where terms are not defined in this chapter or within another chapter, they should be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, is the source for the ordinarily accepted meaning.

3.2 NFPA Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 Guide. A document that is advisory or informative in nature and that contains only nonmandatory provisions. A guide may contain mandatory statements such as when a guide can be used, but the document as a whole is not suitable for adoption into law.

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

3.2.6 Should. Indicates a recommendation or that which is advised but not required.

3.2.7 Standard. An NFPA Standard, the main text of which contains only mandatory provisions using the word “shall” to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase “standards development process” or “standards development activities,” the term “standards” includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

3.3 General Definitions.

3.3.1 Accidental Fire. Fire for which the cause does not involve a human act with the intent to ignite or spread a fire.

▲ **3.3.2 Area of Fire Origin.** See 3.3.3.

3.3.3 Area of Origin. The area where a fire began.

3.3.4 Bed (in the cargo-carrying area). A rear cargo area predominantly found in trucks.

3.3.5 Bulkhead. The separation between the passenger compartment and the engine compartment; however, bulkhead(s) may also separate other vehicle compartments.

3.3.6 Cause. The circumstances, conditions, or agencies that brought about or resulted in the fire or explosion incident, damage to property resulting from the fire or explosion incident, or bodily injury or loss of life resulting from the fire or explosion incident. [921, 2017]

3.3.7* Combustible. Capable of undergoing combustion. [921, 2017]

3.3.8 Combustion Products. The heat, gases, volatilized liquids and solids, particulate matter, and ash generated by combustion. [921, 2017]

3.3.9* Contents and Furnishings of a Vehicle. Any objects in a vehicle that normally are secured or otherwise put in place for functional or decorative reasons, excluding parts of the structure of the vehicle.

3.3.10 Egress. The process of vehicle occupants traveling to location(s) outside of the vehicle.

3.3.11 Engine Compartment. The compartment where the engine and its associated parts are permanently installed.

3.3.12 Fire. An oxidation process, which is a chemical reaction resulting in the evolution of light, heat, and combustion products.

3.3.13* Fire Performance Index (as related to cone calorimeter data). Ratio of the time to ignition to the peak heat release rate (in sec m²/kW).

3.3.14 Fire Resistance. The ability of a material, product, or assembly to withstand fire or give protection from it for a period of time.

3.3.15* Fire Scenario (Vehicular). A set of conditions that defines the development of fire, the spread of combustion products throughout a vehicle or portion of a vehicle, the reactions of people to fire, and the effects of combustion products.

3.3.16 Fire Spread. The movement of fire from one place to another. [921, 2017]

3.3.17 Flame Spread. Progression of the leading edge of a flame through a gaseous mixture or across the surface of a liquid or solid.

3.3.18 Flammable. (1) Capable of burning with a flame under specified conditions, or (2) when used to designate high hazard, subject to easy ignition and rapid flaming combustion.

3.3.19 Flashover. A stage in the development of a contained fire in which all exposed surfaces reach ignition temperatures more or less simultaneously and fire spreads rapidly throughout the space.

3.3.20* Fuel Package. A grouping of one or more furnishings or contents items, or both, whose proximity is sufficiently close that the ignition of one item can be expected to cause the spread of fire to the remaining items in the fuel package. [555, 2017]

3.3.21 Heat Flux. The rate of heat transfer per unit area to a surface, typically expressed in kW/m² or Btu/ft²-sec. [268, 2017]

3.3.22 Heat of Combustion.

3.3.22.1 Effective Heat of Combustion. The measured heat release divided by the mass loss for a specified time period. [289, 2019]

3.3.22.2 Net Heat of Combustion. The oxygen bomb calorimeter value for the heat of combustion, corrected for the gaseous state of product water. [289, 2019]

3.3.23 Heat Release Rate. The heat evolved from the specimen, per unit of time.

3.3.24 Heating, Ventilating, and Air-Conditioning System (HVAC). A system used to provide a means of supplying, returning, and exhausting air from a conditioned space.

3.3.25 Ignitability. The propensity for ignition, as measured by the time to sustained flaming, in seconds, at a specified initial test heat flux. [268, 2017]

3.3.26 Ignitable Gas. Any gas or the gas phase of any material that is capable of fueling a fire and burning, including a flammable gas.

3.3.27 Ignitable Liquid. Any liquid or the liquid phase of any material that is capable of fueling a fire, including a flammable liquid, combustible liquid, or any other material that can be liquefied and burned.

3.3.28 Ignition. The initiation of combustion evidenced by glow, flame, detonation, or explosion, either sustained or transient.

3.3.29 Initial Test Heat Flux. Amount of heat received by a specimen surface per unit area and unit time at the initiation of a test. [268, 2017]

3.3.30* Item. A single combustible object within the compartment that is permanent or transient, movable, or fixed. [555, 2017]

N 3.3.31 Limited-Combustible Material. See Section 5.5.

3.3.32 Motor Vehicle. A vehicle driven or drawn by mechanical power and manufactured primarily to transport passengers or freight, for use on public streets, roads, and highways, but not a vehicle operated only on a rail line.

3.3.33 Noncombustible Material. See Section 5.4.

3.3.34 Oxygen Consumption Principle. The expression of the relationship between the mass of oxygen consumed during combustion and the heat released. [289, 2019]

3.3.35 Passenger Compartment. The space inside a vehicle designed for passenger occupancy.

3.3.36 Passenger Road Vehicle. Motor vehicles for use on public streets, roads, and highways for the transport of passengers, such as automobiles (including pickups, minivans, and sports utility vehicles), buses (including school buses), fire department vehicles, trackless trolleys, and motor homes or recreational vehicles.

3.3.37 Performance-Based Analysis. An engineering approach to fire protection design based on (1) established fire safety goals and objectives, (2) deterministic and probabilistic

analysis of fire scenarios, and (3) quantitative assessment of design alternatives against the fire safety goals and objectives using accepted engineering tools, methodologies, and performance criteria.

3.3.38 Prescriptive Requirements. Specific requirements for materials, products, and elements based on their compliance with a test or specification.

3.3.39 Radiant Heat. Heat energy carried by electromagnetic waves that are longer than light waves and shorter than radio waves; radiant heat (electromagnetic radiation) increases the sensible temperature of any substance capable of absorbing the radiation, especially solid and opaque objects. [921, 2017]

3.3.40 Radiation. Heat transfer by way of electromagnetic energy. [921, 2017]

3.3.41 Smoke. The airborne solid and liquid particulates and gases evolved when a material undergoes pyrolysis or combustion, together with the quantity of air that is entrained or otherwise mixed into the mass. [318, 2018]

3.3.42 Smoke Obscuration. The reduction of light transmission by smoke, as measured by light attenuation. [270, 2018]

3.3.43 Smoldering. Combustion without flame, usually with incandescence and smoke. [921, 2017]

3.3.44 Tenability. Environmental conditions in which smoke and heat are limited or otherwise restricted to maintain the impact on occupants to a level that is not life-threatening.

3.3.45 Thermoplastic. Plastic materials that soften and melt under exposure to heat and can reach a flowable state. [921, 2017]

3.3.46 Untenable Conditions. Environmental conditions in which smoke or heat result in threat to life.

3.3.47* Visible Smoke. The obscuration of transmitted light caused by combustion products.

Chapter 4 Types of Vehicles

4.1 General.

4.1.1 Vehicles are often assigned to one of the following seven classes:

- (1) Passenger road vehicles
- (2) Freight road vehicles
- (3) Rail transport vehicles
- (4) Water transport vehicles
- (5) Aircraft
- (6) Heavy equipment vehicles
- (7) Special vehicles

4.1.2 Passenger road vehicles are all those vehicles carrying passengers that travel on public roads or highways. This category contains automobiles (including pickups, minivans, and sports utility vehicles), buses (including school buses), fire department vehicles, trackless trolleys, and motor homes or recreational vehicles.

4.1.3 Freight road vehicles are trucks of various kinds.

Chapter 5 General Description of Passenger Road Vehicle Fires and Background Information

5.1 Fire Statistics.

5.1.1 The United States National Highway Traffic Safety Administration (NHTSA) indicates that approximately 43,000 people were killed and approximately 2.6 million people were injured in motor vehicle crashes in 2006. [1] In addition, property damage losses from motor vehicle crashes totaled approximately \$5.9 billion in 2000, the latest year for which statistics are available. [2] Fatal Accident Reporting System (FARS) data indicates that motor vehicle crashes where fire was the most harmful event result in approximately 430 fatally injured occupants [3] per year, corresponding to approximately 1 percent of the motor vehicle crash fatalities each year.

5.1.2 The NFPA survey indicates that approximately 278,000 vehicle fires occurred in 2006. [4] This is 17 percent of the total number of fires. The number of civilian deaths and injuries from vehicle fires in 2006 amounted to 490 (15 percent) and 1200 (7 percent), respectively. The direct property damage from vehicle fires in 2006 was \$1.3 billion, or 12 percent of the total direct property damage from all fires. Table 5.1.2 illustrates annual average U.S. vehicle fire losses by type of vehicle for 2002 through 2005. The statistics indicate that road vehicle fires accounted for nearly 90 percent of civilian deaths in vehicle fires. Figure 5.1.2(a) through Figure 5.1.2(d) show the evolution of vehicle fire losses over the years.

Table 5.1.2 U.S. Vehicle Fire Losses by Type of Vehicle, 2002–2005 Annual Averages

Vehicle Type	Fires	Civilian Deaths	Civilian Injuries	Damage (millions)
Passenger cars	208,600 (68%)	305 (58%)	864 (53%)	\$549 (41%)
Other passenger road vehicles	54,770 (18%)	103 (20%)	392 (24%)	\$238 (18%)
Freight road vehicles	24,380 (8%)	62 (12%)	183 (11%)	\$240 (18%)
Other vehicles	19,060 (6%)	52 (10%)	205 (12%)	\$315 (23%)

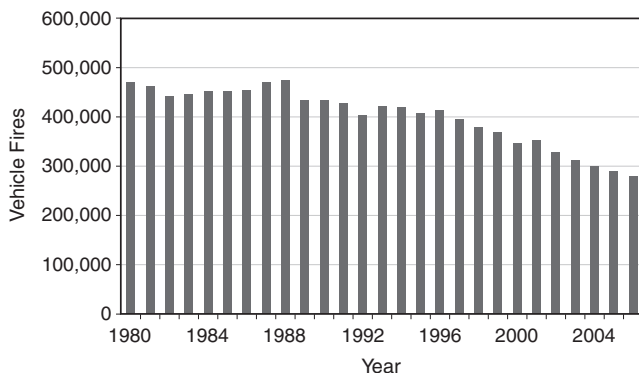


FIGURE 5.1.2(a) U.S. Vehicle Fire Trend: Number of Fires.

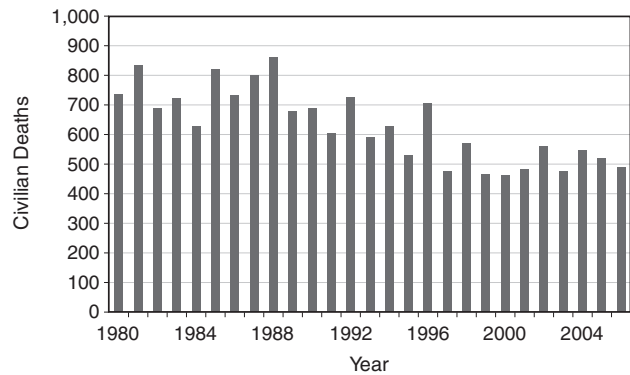


FIGURE 5.1.2(b) U.S. Vehicle Fire Trend: Number of Civilian Deaths.

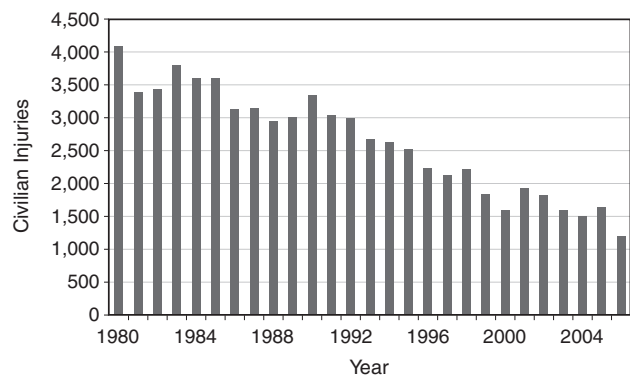


FIGURE 5.1.2(c) U.S. Vehicle Fire Trend: Number of Civilian Injuries.

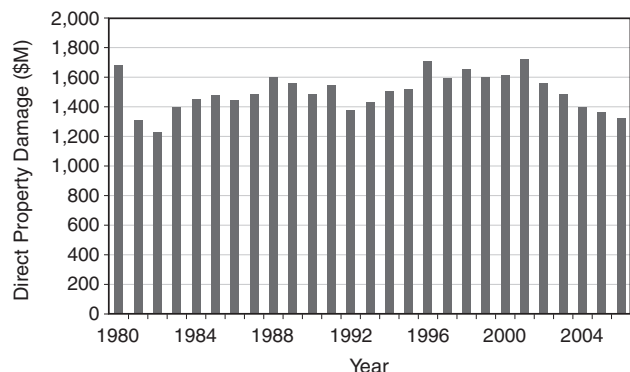


FIGURE 5.1.2(d) U.S. Vehicle Fire Trend: Direct Property Damage.

5.1.3 Passenger road vehicle fires can be grouped into the following three categories:

- (1) Accidental fires following a collision
- (2) Accidental fires without collision
- (3) Arson fires

Table 5.1.3 gives the annual average number of fires, number of civilian deaths and injuries, and direct property damage for these three categories for 2002 through 2005. The table shows that the first two categories accounted for more than 90 percent of the civilian fire deaths. Since the objective of this document is to reduce the number of passenger road vehicle fire deaths, the focus is on these two categories.

5.1.4 Table 5.1.4(a) and Table 5.1.4(b) show collision and noncollision fire statistics by area of origin. Note that the "other" category consists primarily of fires with unknown area of origin. The data presented in these tables suggest that the focus of this document should be on the following four scenarios:

- (1) Accidental fire following a collision originating in the engine compartment
- (2) Accidental fire following a collision involving a fuel spill
- (3) Accidental fire following a collision originating in the passenger compartment
- (4) Accidental fire following a collision in other or unknown areas

5.1.5 Table 5.1.5 shows the number of fire deaths and injuries by reported cause. The data in this table suggest that thermal exposure (temperature and heat flux) as well as inhalation of toxic gases must be considered when establishing tenability criteria in a passenger road vehicle fire assessment.

5.1.6 Figure 5.1.6(a) and Figure 5.1.6(b) show the number of vehicles in use in the United States, for 1991 through 2006, and the total miles of travel per year, for 1985 through 2006, respectively. [1] Table 5.1.6 shows a breakdown of material usage in the construction of passenger road vehicles based on vehicles retired from use. [5]

5.2 Materials Used in Passenger Road Vehicles.

5.2.1 Table 5.2.1 identifies the plastics most commonly used in passenger road vehicles, with their typical applications and locations. The weight of polymeric materials used in both the engine compartment and the passenger compartment of U.S. automobiles increased from 10 kg/car (22 lb/car) in 1960 to greater than 91 kg/car (200 lb/car) in 1996. [6–8] The substitution of plastic components for metal has increased the fuel load.

Table 5.1.3 U.S. Highway Vehicle Fire Loss by Fire Category, 2002–2005 Annual Averages [4]

Fire Category	Number of Fires	Civilian Deaths	Civilian Injuries	Damage (millions)
Collision	8,100 (3%)	268 (57%)	219 (15%)	\$87 (8%)
No collision	255,700 (89%)	160 (34%)	1,157 (80%)	\$804 (78%)
Arson	23,900 (8%)	43 (9%)	63 (4%)	\$136 (13%)
Total	287,700	471	1,439	\$1,027

Table 5.1.4(a) Collision Fire Statistics by Area of Origin, 2002–2005 Annual Averages [4]

Area of Fire Origin	Number of Fires	Civilian Deaths	Civilian Injuries	Damage (millions)
Engine compartment	5700 (70%)	112 (42%)	102 (47%)	\$45 (52%)
Fuel tank or fuel line	700 (9%)	70 (26%)	52 (24%)	\$14 (16%)
Passenger compartment	300 (4%)	19 (7%)	15 (7%)	\$3 (3%)
Other	1400 (17%)	67 (25%)	50 (23%)	\$25 (29%)

Table 5.1.4(b) Noncollision Fire Statistics by Area of Origin, 2002–2005 Annual Averages [4]

Area of Fire Origin	Number of Fires	Civilian Deaths	Civilian Injuries	Damage (millions)
Engine compartment	177,400 (69%)	50 (31%)	559 (48%)	\$490 (61%)
Fuel tank or fuel line	3,800 (1%)	14 (9%)	93 (8%)	\$17 (2%)
Passenger compartment	26,400 (10%)	40 (25%)	207 (18%)	\$112 (14%)
Other	48,100 (19%)	56 (35%)	298 (26%)	\$185 (23%)

Table 5.1.5 Vehicle Deaths and Injuries by Reported Cause, 2002–2005 Annual Averages [4]

Reported Cause	Civilian Deaths	Civilian Injuries
Burns and smoke inhalation	275 (58%)	209 (15%)
Burns only	99 (21%)	658 (46%)
Smoke inhalation only	20 (4%)	233 (16%)
Other	77 (16%)	339 (24%)
Total	471	1439

Table 5.1.6 Material Usage for Vehicles Retired from Use in the United States [5] (Percentage)

Year	Ferrous Metals	Non-ferrous Metals	Plastics	Rubber	Other Materials
1995	68.1	10.1	6.5	4.0	11.3
2000	66.3	10.6	7.3	4.3	11.5
2003	64.1	11.6	8.1	4.3	11.9
2004	63.8	11.8	8.3	4.3	11.8

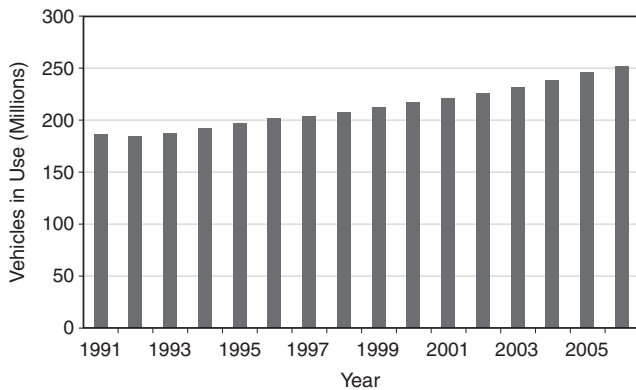


FIGURE 5.1.6(a) Number of Vehicles in Use in the United States, 1991-2006.

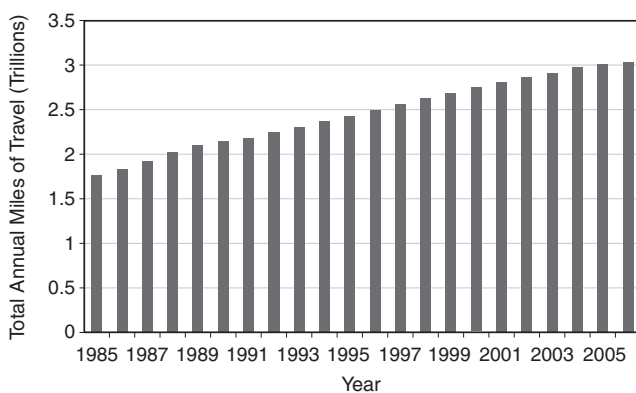


FIGURE 5.1.6(b) Total Travel Miles for Vehicles in Use in the United States [1], 1985-2006.

5.2.2 One factor affecting the severity of passenger road vehicle fire incidents is the fire performance of the materials used in constructing the vehicles. Other factors include collision or noncollision and the presence of ignitable liquids and gases. The principal properties of materials that affect fire severity are susceptibility of ignition, heat release rate once ignited, and the rate of flame spread over the surface. Additional characteristics include smoke production, effects of material orientation on burning rate, and melting and production of flaming droplets. Strategies for providing an adequate level of fire safety in passenger road vehicles include the use of prescriptive material requirements or performance-based analysis and design. A prescriptive approach would require that individual materials or component assemblies meet specified pass/fail criteria based on one or more fire tests. A performance-based approach would require that the complete vehicle meet certain performance objectives.

5.2.2.1 If materials undergo melting and also generate flaming droplets, such materials are typically deemed to present fire safety concerns because the burning material can possibly generate flames that spread to a nearby substrate/target, and thus cause the fire to move beyond the object of origin. This phenomenon has been discussed in research at NIST [9,10], which showed that flaming melt flow can reach the floor or spread on a surface and cause radiant ignition of remote objects. Therefore, the fire hazard associated with materials that undergo melting but generate no flaming droplets may be different, depending on several variables from that of materials that both melt and generate flaming droplets.

5.2.3 The performance-based approach includes evaluation of candidate designs to assess the adequacy of the time available for escape or assisted rescue of passengers from collision and noncollision fire scenarios. This type of analysis and design process can be based on fire growth modeling and testing of final designs. To apply this method of hazard control, fire properties of candidate materials should be determined, including heat release rate and ignitability.

Table 5.2.1 Plastics Commonly Used in Passenger Road Vehicles

Polymer	Average Weight per Vehicle (1996) (kg)	Typical Applications in Vehicles
Polyurethane (PU)	20.0	Body panel, fender, roof panel, bumpers, headliner, seat, upholstery
Polypropylene (PP)	18.1	HVAC, fan, shroud, battery tray, console radiator, cowl vent, air duct, instrument panel, package shelf
Polyvinylchloride (PVC)	9.5	Bumper trim, electrical wiring, boots, bellows, seat cover, steering wheel, floor
Polyethylene (PE)	9.1	Gas tank, bumper, electrical wire, reservoir, fuel filler pipe
Nylon (polyamide) (PA)	8.2	Fuel system, fuel line, gas cap, canister, grill head lamp support, brake, radiator, end tank engine cover, intake manifold, lamp housing
Acrylonitrile/styrene butadiene (ABS)	7.3	Bumper beam, console, cowl vent, engine cover fascia, headliner, duct
Thermoset polyester (SMC/BMC)	7.3	Door lift gate, fenders, hood, quarter panels, rear deck, spoiler, body panel
Polycarbonate (PC) and ABS	4.1	Bumper trim, electrical, grill, lamp support, lens, lamp, instrument panel console, door fender, instrument panel
Thermoplastic polyester polyethylene and polybutylene terephthalate (PET and PBT)	3.6	Body panel, hood, connector, door, fuse junction, HVAC components, fuel rail
Polystyrene (PS) / polyphenylene oxide (PPO)	3.2	Connectors, console, engine air cleaner, instrument panel
Styrene maleic anhydride polymer (SMA)	1.8	Console, head liner, instrument panel
Phenolic	1.8	Brake system, engine pulley, ash tray, transmission component
Acrylic polymers	1.4	Emblems, lamp and instrument panel lenses
Poly acetal	0.9	Radiator fan, door handle, carburetor, fuel pump, fuel filler neck
Epoxy resins	0.1	Electrical, fuel tank (filament wound), adhesives

5.3 Current Prescriptive Testing.

5.3.1 The United States has regulatory authorities dealing with fires in transportation vehicles. The NHTSA is responsible for reducing deaths, injuries, and economic losses resulting from passenger road vehicle crashes. The Federal Transit Administration (FTA) is responsible for urban mass transportation and would thus be the agency responsible for regulating the fire safety of urban mass transit buses transporting passengers; however, it has issued guidelines, but no regulations, with respect to flammability of materials and fire safety. The primary tests included in the FTA recommendations are ASTM D3675, ASTM E162, ASTM E648, and ASTM E662. [11] Although none of these tests can be used for engineering fire properties, they can be useful in ranking relative measures of fire performance.

5.3.2* Federal Motor Vehicle Safety Standard 302 (FMVSS 302), [12] which became effective in September 1972, is the only regulatory test method for assessing the flammability of materials used in the interior of passenger road vehicles. This test method exposes a sample of material in a horizontal orientation to a Bunsen burner flame at one end. The horizontal rate of flame spread away from the burner flame is measured. To be acceptable, the flame spread rate cannot exceed 102 mm/min (4 in./min). [12, 13] This test is also used in other parts of the world, with different designations (ISO 3795 or JIS D 1201).

5.3.3 FMVSS 302 does not address heat release, smoke production, or melting of materials, including flaming drips.

5.3.4 FMVSS 302 provides some measure of fire growth from a match-sized ignition source. However, because it involves only horizontal flame spread, FMVSS 302 provides no direct measure of flame spread on a vertical surface. It does not provide information on how a material might respond to the levels of external radiation input that inevitably occur as a fire grows larger and begins to involve multiple surfaces that exchange radiation. Other devices such as the cone calorimeter (ASTM E1354) can provide these types of data. [14–18] These data are measures of ignition delay time and heat release rate as a function of the level of external radiative input.

5.4* Noncombustible Material. A material that complies with any of the following should be considered a noncombustible material:

- (1)* A material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat.
- (2) A material that is reported as passing ASTM E136.
- (3) A material that is reported as complying with the pass/fail criteria of ASTM E136 when tested in accordance with the test method and procedure in ASTM E2652.

N 5.5 Limited-Combustible Material.

N 5.5.1 This section is part of an NFPA guide and, therefore, is not mandatory. The term *shall* in this section is used to indicate that if provisions relating to limited-combustible materials are applied, the material needs to meet the definition of a limited-combustible material.

N 5.5.2* A material shall be considered a limited-combustible material where both of the following conditions of 5.5.2(1),

and 5.5.2(2), and the conditions of either 5.5.2.1 or 5.5.2.2 are met:

- (1) The material does not comply with the requirements for noncombustible material in accordance with 5.4.
- (2) The material, in the form in which it is used, exhibits a potential heat value not exceeding 3500 Btu/lb (8141 kJ/kg) when tested in accordance with NFPA 259.

[5000:7.1.4.2]

N 5.5.2.1 The material shall have a structural base of noncombustible material with a surfacing not exceeding a thickness of $\frac{1}{8}$ in. (3.2 mm) where the surfacing exhibits a flame spread index not greater than 50 when tested in accordance with ASTM E84 or UL 723. [5000:7.1.4.2.1]

N 5.5.2.2 The material shall be composed of materials that in the form and thickness used, neither exhibit a flame spread index greater than 25 nor evidence of continued progressive combustion when tested in accordance with ASTM E84 or UL 723 and are of such composition that all surfaces that would be exposed by cutting through the material on any plane would neither exhibit a flame spread index greater than 25 nor exhibit evidence of continued progressive combustion when tested in accordance with ASTM E84 or UL 723. [5000:7.1.4.2.2]

N 5.5.2.3 Materials shall be considered limited-combustible materials where tested in accordance with ASTM E2965 at an incident heat flux of 75 kW/m² for a 20-minute exposure and both the following conditions are met:

- (1) The peak heat release rate shall not exceed 150 kW/m² for longer than 10 seconds.
- (2) The total heat released shall not exceed 8 MJ/m².

[5000:7.1.4.2.3]

N 5.5.2.4 Where the term *limited-combustible* is used in this document, it shall also include the term *noncombustible*. [5000:7.1.4.2.4]

5.6 Fire Performance Properties. The fire properties that are used to assess the fire safety of vehicles include heat release, smoke production, ignitability, flaming drips, and effects of orientation of vehicle components. A number of standardized test methods that can be used to assess these properties are available (*see Chapter 10*). It has been demonstrated by studies of the fire properties of materials used in other fire situations in compartments and vehicles (aircraft, trains, soft furnishings) that changes in flammability characteristics affect fire safety. Examples include the materials used in rail transport and aircraft such as seating and wall panels. With regard to compartments, there is ample evidence that improved fire properties in consumer products such as upholstered furniture, mattresses, wall linings, and electric cables have resulted in lower fire losses. Real world vehicle fires are variable and difficult to predict in full detail; this arises from the very complex geometries present, especially in post-crash situations, and from the thermoplastic character of many of the materials involved. However, measures that limit the rate at which the materials can release heat can, in most cases, be expected to slow fire growth. This, in turn, allows more time for escape or rescue.

5.7 Tenability Criteria. Table 5.7 contains a generic set of tenability criteria. [19, 20] In another publication, tenability was defined as the first indication of flame spread into the passenger compartment. [21] Tenability criteria should apply

irrespective of the fire scenario because tenability criteria are a function of the people exposed and the time of exposure — not the fire environment/compartment. The specific tenability criterion that is reached first in a passenger road vehicle fire could be different from that reached in a building. It has also been found in a full-scale test study that (a) the first tenability criterion breached was associated with heat, and (b) in that same study, the concentrations of carbon dioxide, carbon monoxide, and hydrogen cyanide were less than the respective threshold concentrations for computing fractional effective doses. [22]

Table 5.7 Tenability Criteria from HAZARD I and ASTM E2280

Hazard	Incapacitation Criterion	Lethality Criterion
Smoke toxicity Ct* (g/min/m ³)	450	900
Smoke toxicity FED†	0.5	1
CO concentration (ppm min)	45,000	90,000
Convected heat/temperature (EC)	65	100
Radiated heat/ heat flux (kW min/m ²)	1.0	2.5

*Smoke toxicity Ct: concentration-time product of toxic gases. If exposure is 30 minutes, smoke toxicity criteria will be 15 g/m³ for incapacitation and 30 g/m³ for lethality.

†Smoke toxicity FED: fractional effective dose of toxic insult required to cause lethality (if FED = 1).

Chapter 6 Approach to Evaluating Passenger Road Vehicle Fire Hazard

6.1 General. Altering a material in composition or form for improved fire performance can result in degradation of other key properties of that material. Properties that have been found to affect overall passenger road vehicle safety, fuel economy, emissions, manufacturability, utility, and durability and that should be considered when selecting materials for use in passenger road vehicles include those indicated in Table 6.1.

6.2 Basic Performance-Based Approach.

6.2.1 The performance-based approach employs a systematic analysis as depicted schematically in Figure 6.2.1. This approach is applicable to both new and existing designs. See the *SFPE Engineering Guide to Performance-Based Fire Protection*. The process begins with the establishment of fire performance design criteria that establish the limiting hazard levels for the desired fire safety (see Chapter 7). Next, the candidate design for the passenger road vehicle components or systems to be evaluated is established. The relevant fire scenario for the specific analysis is selected, including the scenario elements in Figure 6.2.1. Some generic scenarios are described in Chapter 11.

6.2.2 Performance-based evaluation requires that information regarding the expected fire conditions be developed. This can be accomplished through small-scale tests or intermediate-scale tests of materials, composites, fuel packages or subsystems, or full-scale vehicle tests. Calculation methods and simulations can also be employed, based on fire performance properties such as heat release rate, ignitability, or combustion products yield. A discussion of test methods and guidance documents

Table 6.1 Some Key Properties for Passenger Road Vehicle Materials

Ability to meet appearance requirements
Chemical resistance
Chrome platability
Composition
Compressive strength
Density
Dimensional stability
Fire performance
Flexural modulus
Glass transition temperature
Impact strength
Melt flow rate
Melting temperature
Moisture absorption
Molding shrinkage
Paintability
Recyclability
Reinforcement type and amount
Strain at break
Stress at break
Surface defects
Tensile modulus
Thermal stability
UV resistance
Volume resistivity

that could be used at this stage in the performance-based design process is found in Chapter 10.

6.2.3 Fire conditions predicted by calculation, simulation, or testing are compared to the design criteria to see whether they have been satisfied. If the design criteria are not satisfied, there are several options for proceeding. The objectives and design criteria, or selected fire scenario, can be reassessed, additional fire performance data collected, or the candidate design modified and the performance-based process repeated.

6.3 Design Considerations. When evaluating material, component, or system fire properties, the designer should also consider the effects on the properties indicated in Table 6.1. Selection of materials based on their fire properties should not impair the electrical, mechanical, or physical function, or other safety properties of the passenger road vehicle. Sufficient technology and advances in plastics engineering could allow for a combination of properties to achieve both adequate fire performance and mechanical properties.

6.4* Regulatory Considerations. Use of this document should not adversely impact compliance with federal, state, local, or other applicable regulations. For example, in the United States, motor vehicle safety for light duty vehicles and school buses is regulated by NHTSA. Some specific performance requirements are established in Federal Motor Vehicle Safety Standards.