NFPA 130

Standard for Fixed Guideway Transit and Passenger Rail Systems

2003 Edition

NFPA, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

IMPORTANT NOTICES AND DISCLAIMERS CONCERNING NFPA DOCUMENTS

NOTICE AND DISCLAIMER OF LIABILITY CONCERNING THE USE OF NFPA DOCUMENTS

NFPA codes, standards, recommended practices, and guides, 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 its codes and 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 this document. The NFPA also makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

In issuing and making this document 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 this document. 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.

ADDITIONAL NOTICES AND DISCLAIMERS

Updating of NFPA Documents

Users of NFPA codes, standards, recommended practices, and guides should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of Tentative Interim Amendments. An official NFPA document at any point in time consists of the current edition of the document together with any Tentative Interim Amendments and any Errata then in effect. In order to determine whether a given document is the current edition and whether it has been amended through the issuance of Tentative Interim Amendments or corrected through the issuance of Errata, consult appropriate NFPA publications such as the National Fire Codes® Subscription Service, visit the NFPA website at www.nfpa.org, or contact the NFPA at the address listed below.

Interpretations of NFPA Documents

A statement, written or oral, that is not processed in accordance with Section 6 of the Regulations Governing Committee Projects 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 asserted in connection with any items which are mentioned in or are the subject of NFPA codes, standards, recommended practices, and guides, and the NFPA disclaims liability for the infringement of any patent resulting from the use of or reliance on these documents. Users of these documents are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

NFPA adheres to applicable policies of the American National Standards Institute with respect to patents. For further information contact the NFPA at the address listed below.

Law and Regulations

Users of these documents 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

Use of NFPA documents 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 documents, contact NFPA at the address below.

For Further Information

All questions or other communications relating to NFPA codes, standards, recommended practices, and guides 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 documents 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.

For more information about NFPA, visit the NFPA website at www.nfpa.org.

NFPA 130

Standard for

Fixed Guideway Transit and Passenger Rail Systems

2003 Edition

This edition of NFPA 130, *Standard for Fixed Guideway Transit and Passenger Rail Systems*, was prepared by the Technical Committee on Fixed Guideway Transit Systems and acted on by NFPA at its May Association Technical Meeting held May 18–21, 2003, in Dallas, TX. It was issued by the Standards Council on July 18, 2003, with an effective date of August 7, 2003, and supersedes all previous editions.

This edition of NFPA 130 was approved as an American National Standard on July 18, 2003.

Origin and Development of NFPA 130

The Fixed Guideway Transit Systems Technical Committee was formed in 1975 and immediately began work on the development of NFPA 130. One of the primary concerns of the committee in the preparation of this document centered on the potential for entrapment and injury of large numbers of people who routinely utilize these mass transportation facilities.

During the preparation of the first edition of this document, several significant fires occurred in fixed guideway systems, but fortunately the loss of life was limited. The committee noted that the minimal loss of life was due primarily to chance events more than any preconceived plan or the operation of protective systems.

The committee developed material on fire protection requirements to be included in NFPA 130, *Standard for Fixed Guideway Transit Systems*. This material was adopted by NFPA in 1983. The 1983 edition was partially revised in 1986 to conform with the NFPA *Manual of Style;* incorporated revisions included a new Chapter 8; a new Appendix F, "Creepage Distance"; minor revisions to the first four chapters and to Appendices A, B, C, and E; and a complete revision of Appendix D.

The scope of the 1988 edition was expanded to include automated guideway transit (AGT) systems. The sample calculations in Appendix C were revised, and Appendix D was completely revised.

The 1990 edition included minor changes to integrate provisions and special requirements for AGT systems into the standard. Table 1 from Appendix D was moved into Chapter 4, "Vehicles," and new vehicle risk assessment material was added to Appendix D.

Definitions for *enclosed station* and *open station* were added in the 1993 edition, along with minor changes to Chapters 2 and 3, and the 1995 edition made minor changes to Chapters 1, 2, and 3.

The 1997 edition included a new chapter on emergency ventilation systems for transit stations and trainways. A new Appendix B addressing ventilation replaced the previous Appendix B, "Air Quality Criteria in Emergencies." Also, the first three sections of Chapter 6 (renumbered as Chapter 7 in the 1997 edition), "Emergency Procedures," were revised, and several new definitions were added.

The 2000 edition of NFPA 130 addressed fixed guideway transit and passenger rail systems, and changes were made throughout the document to incorporate passenger rail requirements. Additionally, much of Chapter 2 was rewritten to incorporate changes that were made to the egress calculations in NFPA *101*®, *Life Safety Code*®. The examples in Appendix C were modified using the new calculation methods. The protection requirements for Chapter 3 were modified, addressing emergency lighting and standpipes. Chapter 4 also was modified to clarify and expand the emergency ventilation requirements.

The 2003 edition has been reformatted in accordance with the NFPA 2003 *Manual of Style*. Beyond these editorial changes, there are technical revisions to the egress requirements and calculations for stations. The chapter on vehicles has been extensively rewritten to include a performance-based design approach to vehicle design as well as changes to the traditional prescriptive-based requirements.

Technical Committee on Fixed Guideway Transit Systems

William D. Kennedy, *Chair*
Parsons Brinckerhoff Quade & Douglas, Inc., NY [SE]

William R. Segar, *Secretary*
Adtranz, PA [M]

Dennis J. Becker, Parsons Transportation Group, MA [IM]
John F. Bender, Maryland Office of State Fire Marshal, MD [E]
Rep. International Fire Marshals Association
Richard A. Brusato, National Railroad Passenger Corporation (Amtrak), NY [U]
David M. Casselman, Lea & Elliott, Inc., TX [SE]
Mark Chan, Bay Area Rapid Transit, CA [U]
Frank J. Cihak, American Public Transportation Association, DC [U]
Rep. Transit Development Corporation, Inc.
Frederic B. Clarke, Benjamin Clarke Associates, Inc., VA [M]
Rep. Society of the Plastics Industry Inc.
John F. Devlin, Schirmer Engineering Corporation, MD [I]
E. Rejean Dubois, STCUM (Montreal Urban Community Transit Corporation), Canada [U]
Angelo Duggins, Seattle Fire Department, WA [E]
David R. Fiedler, Kellog Brown & Root, TX [SE]
Richard G. Gewain, Hughes Associates, Inc., MD [SE]
Harold L. Levitt, Port Authority of New York & New Jersey, NJ [U]
Michael E. Littleton, Los Angeles City Fire Department, CA [E]
Harold A. Locke, Locke MacKinnon Domingo Gibson & Associates Ltd., Canada [SE]
Donald MacLennan, Metropolitan Transportation Authority, NY [U]
Stephanie H. Markos, U.S. Department of Transportation, MA [SE]
Thomas G. Middlebrook, Toronto Transit Commission, Canada [U]
William R. Mooney, Chicago Transit Authority, IL [U]
Richard D. Peacock, U.S. National Institute of Standards & Technology, MD [RT]
Thomas R. Rampe, Washington Metropolitan Area Transit Authority, DC [U]
William D. Rice, MTA Long Island Rail Road, NY [E]
Richard B. Schiehl, R. B. Schiehl & Associates, CA [SE]
Siyou Kim Tham, Land Transport Authority, Singapore [U]
John J. Troy, FPC Sierra Inc., OH [SE]
Joseph B. Zicherman, IFT Inc./Fire Cause Analysis, CA [RT]

Alternates

Jason D. Averill, U.S. National Institute of Standards & Technology, MD [RT]
(Alt. to R. D. Peacock)
Arthur G. Bendelius, Parsons Brinckerhoff Quade & Douglas, Inc., GA [SE]
(Alt. to W. D. Kennedy)
John Bumanis, Parsons Transportation Group, VA [IM]
(Alt. to D. J. Becker)
John F. Deubler, Schirmer Engineering Corporation, VA [I]
(Alt. to J. F. Devlin)
Emmanuel A. Domingo, Locke MacKinnon Domingo Gibson & Associates Limited, Canada [SE]
(Alt. to H. A. Locke)
Robert W. Falvey, Lea & Elliott, Inc., WA [SE]
(Alt. to D. M. Casselman)
Michael E. Fetsko, Bombardier Transportation, PA [M]
(Alt. to W. R. Segar)
Joseph Gould, Los Angeles City Fire Department, CA [E]
(Alt. to M. E. Littleton)
Martha K. Gulick, Port Authority of New York & New Jersey, NJ [U]
(Alt. to H. L. Levitt)
James A. Harrison, U.S. Department of Transportation, MA [SE]
(Alt. to S. H. Markos)
Kum Fatt Ho, Land Transport Authority, Singapore [U]
(Alt. to S. K. Tham)
Joseph F. Krempasky, Washington Metropolitan Area Transit Authority, DC [U]
(Alt. to T. R. Rampe)
Brian Y. Lattimer, Hughes Associates, Inc., MD [SE]
(Alt. to R. G. Gewain)
James K. Mann, Jr., National Railroad Passenger Corporation (Amtrak), PA [U]
(Alt. to R. A. Brusato)
John H. Nelsen, Seattle Fire Department, WA [E]
(Alt. to A. Duggins)
Bruce C. Nelson, Chicago Transit Authority, IL [U]
(Alt. to W. R. Mooney)
David R. Phelps, American Public Transportation Association, DC [U]
(Alt. to F. J. Cihak)
Susan Reed Tanaka, Toronto Transit Commission, Canada [U]
(Alt. to T. G. Middlebrook)
Christian Thibault, STCUM (Montreal Urban Community Transit Corporation), Canada [U]
(Alt. to E. R. Dubois)

Nonvoting

Norman H. Danziger, Boynton Beach, FL
(Member Emeritus)
Vince Dowling, CSIRO Fire Science & Technology Laboratory, Australia [RT]

Edward K. Farrelly, E. Farelly & Associates, NJ
(Member Emeritus)

James D. Lake, 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 protection requirements for underground, surface, and elevated fixed guideway transit systems including trainways, vehicles, transit stations, and vehicle maintenance and storage areas; and for life safety from fire in transit stations, trainways, vehicles, and outdoor vehicle maintenance and storage areas. Transit stations shall pertain to stations accommodating only passengers and employees of the fixed guideway transit systems and incidental occupancies in the stations.

Contents

NFPA 130

Standard for

Fixed Guideway Transit and Passenger Rail Systems

2003 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 Documents." They can also be obtained on request from NFPA or viewed at www.nfpa.org/disclaimers.

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

Changes other than editorial are indicated by a vertical rule beside the paragraph, table, or figure in which the change occurred. These rules are included as an aid to the user in identifying changes from the previous edition. Where one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, Annex G lists the complete title and edition of the source documents for both mandatory and nonmandatory extracts. Editorial changes to extracted material consist of revising references to an appropriate division in this document or the inclusion of the document number with the division number when the reference is to the original document. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

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

Chapter 1 Administration

1.1 Scope.

1.1.1 This standard shall cover fire protection requirements for passenger rail, underground, surface, and elevated fixed guideway transit systems, including trainways, vehicles, fixed guideway transit stations, and vehicle maintenance and storage areas, and for life safety from fire in fixed guideway transit stations, trainways, vehicles, and outdoor vehicle maintenance and storage areas.

1.1.2 Fixed guideway transit stations shall pertain to stations accommodating only passengers and employees of the fixed guideway transit and passenger rail systems and incidental occupancies in the stations. This standard establishes minimum requirements for each of the identified subsystems.

1.1.3 This standard shall not cover requirements for the following:

(1) Conventional freight systems
(2) Buses and trolley coaches
(3) Circus trains
(4) Tourist, scenic, historic, or excursion operations
(5) Any other system of transportation not included in the definition of fixed guideway transit system *(see 3.3.52.1)*

1.1.4 To the extent where a system, including those listed in 1.1.3(1) through 1.1.3(5), introduces hazards of a nature similar to those addressed herein, this standard shall be permitted to be used as a guide.

1.2 Purpose. The purpose of this standard shall be to establish minimum requirements that will provide a reasonable degree of safety from fire and its related hazards in fixed guideway transit and passenger rail system environments.

1.3 Application.

1.3.1 This standard shall apply to new fixed guideway transit and passenger rail systems and to extensions of existing systems.

1.3.2 The portion of the standard dealing with emergency procedures shall apply to new and existing systems.

1.3.3 The standard also shall be used for purchases of new rolling stock and retrofitting of existing equipment or facilities except in those instances where compliance with the standard will make the improvement or expansion incompatible with the existing system.

1.4 Equivalency. Nothing in this standard is intended to prevent or discourage the use of new methods, materials, or devices, provided that sufficient technical data are submitted to the authority having jurisdiction to demonstrate that the new method, material, or device is equivalent to or superior to the requirements of this standard with respect to fire resistance and safety.

1.5 Units and Formulas.

1.5.1 SI Units. Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI).

1.5.2 Primary and Equivalent Values. If a value for a measurement as given in this standard is followed by an equivalent value in other units, the first stated value shall be regarded as the requirement. A given equivalent value might be approximated.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, USA.

NFPA 1, *Uniform Fire Code™*, 2003 edition.
NFPA 10, *Standard for Portable Fire Extinguishers,* 2002 edition.
NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2002 edition.
NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 2003 edition.
NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances,* 2002 edition.
NFPA 30, *Flammable and Combustible Liquids Code,* 2003 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials,* 2003 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 2003 edition.

NFPA 58, *Liquefied Petroleum Gas Code,* 2001 edition.

NFPA 70, *National Electrical Code®,* 2002 edition.

NFPA 72®, National Fire Alarm Code®, 2002 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows,* 1999 edition.

NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems,* 2002 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids,* 1999 edition.

NFPA *101®, Life Safety Code®,* 2003 edition.

NFPA 110, *Standard for Emergency and Standby Power Systems,* 2002 edition.

NFPA 220, *Standard on Types of Building Construction,* 1999 edition.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations,* 2000 edition.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials,* 1999 edition.

NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source,* 2000 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials,* 2000 edition.

NFPA 256, *Standard Methods of Fire Tests of Roof Coverings,* 2003 edition.

NFPA 262, *Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces,* 2002 edition.

NFPA 271, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter,* 2001 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation,* 2002 edition.

NFPA 1963, *Standard for Fire Hose Connections,* 2003 edition.

2.3 Other Publications.

2.3.1 AMCA Publications. Air Movement and Control Association, Inc., 30 West University Drive, Arlington Heights, IL, 60004-1893, USA.

AMCA 300-96, *Reverberant Room Method for Sound Testing of Fans*, 1996.

ANSI/AMCA 210-99, *Laboratory Methods of Testing Fans for Aerodynamic Performance Rating*, 1999.

2.3.2 ANSI Publications. American National Standards Institute, Inc., 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

ANSI B56.1, *Safety Standard for Low Lift and High Lift Trucks*, 1993.

ANSI C2, *National Electrical Safety Code*, 1993.

2.3.3 ASHRAE Publication. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329-2305, USA.

ASHRAE Fundamentals Handbook, 2001.

ASHRAE 149-2000, *Standard of Laboratory Methods of Testing Fans Used to Exhaust Smoke in Smoke Management Systems.*

2.3.4 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA.

ASTM C 1166, *Standard Test Method for Flame Propagation of Dense and Cellular Elastometric Gaskets and Accessories,* 1991.

ASTM D 2724, *Standard Test Method for Bonded, Fused, and Laminated Apparel Fabrics*, 1987.

ASTM D 3574, *Test I_2 (Dynamic Fatigue Test by the Roller Shear at Constant Force) or Test I_3 (Dynamic Fatigue Test by Constant Force Pounding).*

ASTM D 3675, *Standard Test Method for Surface Flammability of Flexible Cellular Materials Using a Radiant Heat Energy Source*, 1994.

ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 1994.

ASTM E 119, Rev. B-92, *Standard Test Method for Fire Tests of Building Construction and Materials*, 1988.

ASTM E 136, Rev. A-92, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 1994.

ASTM E 162, *Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source*, 1994.

ASTM E 648, *Standard Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source*, 1994.

ASTM E 662, *Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials*, 1994.

ASTM E 810, *Standard Test Method for Coefficient of Retroreflection of Retroreflective Sheeting Utilizing the Coplanar Geometry*, 2003.

ASTM E 814, *Standard Test Method for Fire Tests of Through-Penetration Fire Stops*, 2002.

ASTM E 1354, *Standard Test Method for Heating and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, 2002d.

ASTM E 1537, *Standard Test Method for Fire Testing of Upholstered Furniture*, 2002a.

ASTM E 1590, *Standard Test Method for Fire Testing of Mattresses*, 2002.

ASTM E 1591, *Standard Guide for Obtaining Data for Deterministic Fire Models*, 2000.

ASTM E 2061, *Guide for Fire Hazard Assessment of Rail Transportation Vehicles*, 2002a.

2.3.5 CSA Publication. Canadian Standards Association, 178 Rexdale Boulevard, Toronto, Ontario M9W IR3, Canada.

CSA C22.2 No. 0.3, *Test Methods for Electrical Wires and Cables*, 2001.

2.3.6 California Technical Bulletins. State of California, Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation, 3485 Orange Grove Avenue, North Highlands, CA 95660-5595, USA.

Technical Bulletin 129, *Flammability Test Procedure for Mattresses for Use in Public Buildings*, October 1992.

Technical Bulletin 133, *Flammability Test Procedure for Seating Furniture for Use in Public Occupancies*, January 1991.

2.3.7 ICEA Publication. Insulated Cable Engineers Association, P.O. Box 440, South Yarmouth, MA 02664, USA.

ICEA S-19-1981/NEMA WC3, *Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.*

2.3.8 IEC Publication. International Electrotechnical Commission, 3 rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

IEC 60331–11, *Tests for electric cables under fire conditions — Circuit integrity — Part 11: Apparatus — Fire alone at a flame temperature of at least 750°C*, 1999.

2.3.9 IEEE Publications. Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

IEEE 11, *Standard for Rotating Electric Machinery for Rail and Road Vehicles*, 2000.

IEEE 16, *American Standard for Electric Control Apparatus for Land Transportation Vehicles.*

IEEE 383, *Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations*, 1974.

IEEE 1202, *Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies*, 1991.

2.3.10 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062, USA.

ANSI/UL 1666, *Standard Test for Flame Propagation Heights of Electrical and Optical-Fiber Cable Installed Vertically in Shafts*, 1997.

UL 44, *Standard for Safety Rubber-Insulated Wires and Cables*, 1991.

UL 83, *Standard for Safety Thermoplastic-Insulated Wires and Cables*, 1991.

UL 1581, *Reference Standard for Electrical Wires, Cables and Flexible Cords*, 2001.

UL 1685, *Standard Vertical Cable Tray Propagation and Smoke Release Test for Electrical and Optical Fiber Cables.*

UL 1666, *Standard Test for Flame Propagation Height of Electrical and Optical-Fiber Cable Installed Vertically in Shafts.*

2.3.11 U.S. Government Publication. U.S. Government Printing Office, Washington, DC 20402, USA.

Federal Test Method Standard 191A, Textile Test Method 5830, July 1978.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not included, common usage of the terms shall apply.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction. 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 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

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.

3.3 General Definitions.

3.3.1 Ancillary Area/Ancillary Space. The nonpublic areas or spaces of the stations usually used to house or contain operating, maintenance, or support equipment and functions.

3.3.2 Authority. The agency legally established and authorized to operate a fixed guideway transit and/or passenger rail system.

3.3.3 Backlayering. The reversal of movement of smoke and hot gases counter to the direction of the ventilation airflow.

3.3.4 Blue Light Station. A location along the trainway, indicated by a blue light, where emergency service or authorized personnel can communicate with the central supervising stations and disconnect traction power.

3.3.5 Building. Any structure or group of structures in which fixed guideway transit and/or passenger rail vehicles are stored or maintained, including those in which inspection and service functions are performed, and other ancillary structures, such as substations and air conditioning or ventilation facilities.

3.3.6 Central Supervising Station. The operations center where the authority controls and coordinates the systemwide movement of passengers and trains from which communication is maintained with supervisory and operating personnel of the authority and with participating agencies when required.

3.3.6.1 ***Alternate Central Supervising Station.*** A prearranged location that is equipped, or can be equipped quickly, to function as the central supervising station in the event the central supervising station is inoperative or untenable for any reason.

3.3.7 Combustible Load of a Vehicle. The total value of heat energy that can be released through complete combustion of the components of a vehicle or fuel expressed in joules [British thermal units (Btu)].

3.3.8 Command Post (CP). The location at the scene of an emergency where the incident commander is located and where command, coordination, control, and communications are centralized. [**402:**3.3]

3.3.9 Communications. Radio, telephone, and messenger services throughout the system and particularly at the central supervising station and command post.

3.3.10 Computational Fluid Dynamics. A solution of fundamental equations of fluid flow using computer techniques allowing the engineer to identify velocities, pressures, temperatures, and so forth.

3.3.11* Critical Radiant Flux. The level of incident radiant heat energy on the floor covering system at the most distant flameout point, as measured in NFPA 253 or ASTM E 648 (units: W/cm^2).

3.3.12 Critical Velocity. The minimum steady-state velocity of the ventilation airflow moving toward the fire within a tunnel or passageway that is required to prevent backlayering at the fire site.

3.3.13 Effective Fire Load. The portion of the total fire load under a given, specific fire scenario of a certain fuel package that would be expected to be released in a design fire incident (units: joules or Btu). This can include transit and/or passenger rail vehicle(s), luggage, fuel, and/or wayside facilities or structures, that, because of the fuel package configuration, separation, and combustion characteristics, would be expected to be released in a design fire incident.

3.3.14 Emergency Procedures Plan. A plan that is developed by the authority with the cooperation of all participating agencies and that details specific actions required by all those who will respond during an emergency.

3.3.15 Engineering Analysis (Fire Hazard/Fire Risk Assessment). An analysis that evaluates all the various factors that affect the fire safety of the system or component. A written report of the analysis is submitted to the authority indicating recommended fire protection method(s) that will provide a level of fire safety commensurate with this standard.

3.3.16 Fire Command Center. The principal attended or unattended location where the status of the detection, alarm communications, and control systems is displayed and from which the system(s) can be manually controlled. [***72:***3.3]

3.3.17 Fire Emergency. The existence of, or threat of, fire or the development of smoke or fumes, or any combination thereof, that calls for immediate action to correct or alleviate the condition or situation. [**502:**3.3]

3.3.18 Fire Growth Rate. Rate of change of the heat release rate. Some factors that affect the fire growth rate are exposure, geometry, flame spread, and fire barriers.

3.3.19 Fire Smoke Release Rate. Rate of smoke release for a given fire scenario expressed as a function of time (units: m^2/s or ft^2/s).

3.3.20 Fixed Guideway Transit Vehicle. An electrically propelled passenger-carrying vehicle characterized by high acceleration and braking rates for frequent starts and stops and fast passenger loading and unloading.

3.3.21 Flaming Dripping. Periodic dripping of flaming material from the site of material burning or material installation.

3.3.22 Flaming Running. Continuous flaming material leaving the site of material burning or material installation.

3.3.23 Guideway. That portion of the transit or passenger rail line included within right-of-way fences, outside lines of curbs or shoulders, underground tunnels and stations, cut or fill slopes, ditches, channels, and waterways, and including all appertaining structures.

3.3.24 Headway. The interval of time between the arrivals of consecutive trains at a platform in a station.

3.3.25 Heat Release Rate (HRR). The rate at which heat energy is generated by burning. The heat release rate of a fuel is related to its chemistry, physical form, and availability of oxidant and is ordinarily expressed as kilowatts (kW) or Btu/s. [**921:**1.3]

3.3.25.1 ***Average Heat Release Rate (HRR_{180}).*** The average heat release rate per unit area, over the time period starting at time to ignition and ending 180 seconds later, as measured in NFPA 271 or ASTM E 1354 (units: kW/m^2).

3.3.25.2 ***Fire Heat Release Rate for Ventilation Calculations.*** Rate of energy release for a given fire scenario expressed as a function of time (units: W or Btu/s).

3.3.26 Incident Commander. The person who is responsible for all decisions relating to the management of the incident and is in charge of the incident site. [**472:**3.3]

3.3.27 Incidental Occupancies in Stations. The use of the station by others who are neither transit system employees nor passengers.

3.3.28 Local Control. The point of control of the emergency ventilation system or ventilation plant that is remote from the central supervising station.

3.3.29 Noncombustible. Not capable of supporting combustion. [**80:**3.3]

3.3.30 Nonmechanical Emergency Ventilation System. A system of smoke reservoirs, smoke vents, and/or dampers that are designed to support the tenability criteria without the use of fans.

3.3.31 Nontransit Occupancy. An occupancy not under the control of the system operating authority.

3.3.32 Participating Agency. A public, quasipublic, or private agency that has agreed to cooperate with and assist the authority during an emergency.

3.3.33 Passenger Load.

3.3.33.1 ***Detraining Load.*** The number of passengers alighting from a train at a platform.

3.3.33.2 ***Entraining Load.*** The number of passengers boarding a train at a platform.

3.3.33.3 ***Link Load.*** The number of passengers traveling between two stations on board a train or trains.

3.3.34 Passenger Rail Vehicle. A vehicle and/or power unit running on rails used to carry passengers and crew.

3.3.35 Point of Safety. An enclosed fire exit that leads to a public way or safe location outside the structure, or an at-grade point beyond any enclosing structure, or another area that affords adequate protection for passengers.

3.3.36 Power Station. An electric generating plant for supplying electrical energy to the system.

3.3.37 Power Substation. Location of electric equipment that does not generate electricity but receives and converts or transforms generated energy to usable electric energy.

3.3.38 Radiant Panel Index (I_s). The product of the flame spread factor (F_s) and the heat evolution factor (Q_s), as determined in ASTM E 162.

3.3.39 Replace in Kind. As applied to vehicles and facilities, to furnish with new parts or equipment of the same type but not necessarily of identical design.

3.3.40 Retrofit. As applied to vehicles and facilities, to furnish with new parts or equipment to constitute a deliberate modification of the original design (as contrasted with an overhaul or a replacement in kind).

3.3.41 Smoke Obscuration. The reduction of light transmission by smoke, as measured by light attenuation. [**271:**3.3]

3.3.42 Specific Extinction Area. A measure of smoke obscuration potential per unit mass burnt, determined as the product of the specific extinction coefficient and the volumetric mass flow rate, divided by the mass loss rate.

3.3.43 Specific Optical Density (D_s). The optical density, as measured in ASTM E 662, over unit path length within a chamber of unit volume, produced from a specimen of unit surface area, that is irradiated by a heat flux of 2.5 W/cm^2 for a specified period of time.

3.3.44 Station. A place designated for the purpose of loading and unloading passengers, including patron service areas and ancillary spaces associated with the same structure.

3.3.44.1 ***Enclosed Station.*** A station or portion thereof that does not meet the definition of an open station.

3.3.44.2 ***Open Station.*** A station that is constructed in such a manner that it is open to the atmosphere, and smoke and heat are allowed to disperse directly into the atmosphere.

3.3.45 Station Platform. The area of a station used primarily for loading and unloading transit vehicle passengers.

3.3.46 Structure.

3.3.46.1 ***Elevated Structure.*** Any structure not otherwise defined as a surface or underground structure.

3.3.46.2 ***Surface Structure.*** Any at-grade or unroofed structure other than an elevated or underground structure.

• **3.3.47 System.** See 3.3.52.1, Fixed Guideway Transit System, or 3.3.52.2, Passenger Rail System.

3.3.48 Tenable Environment. An environment that permits the self-rescue of occupants for a specific period of time.

3.3.49 Total Fire Load. The total heat energy of all combustibles available from the constituent materials of a certain fuel package (units: joules or Btu). This can include a transit and/or passenger rail vehicle(s), luggage, fuel, and/or wayside facilities or structures.

3.3.50 Tourist, Scenic, Historic, or Excursion Operations. Railroad operations that carry passengers, often using antiquated equipment, with the conveyance of the passengers to a particular destination not being the principal purpose.

3.3.51 Trainway. That portion of the guideway in which the fixed guideway transit or passenger rail vehicles operate.

3.3.52 Transportation Systems.

3.3.52.1 ***Fixed Guideway Transit System.*** An electrified transportation system, utilizing a fixed guideway, operating on right-of-way for the mass movement of passengers within a metropolitan area, and consisting of its fixed guideways, transit vehicles, and other rolling stock; power system; buildings; maintenance facilities; stations; transit vehicle yard; and other stationary and movable apparatus, equipment, appurtenances, and structures.

3.3.52.1.1 ***Automated Fixed Guideway Transit System.*** A fixed guideway transit system that operates fully automated, driverless vehicles along an exclusive right-of-way.

3.3.52.2 ***Passenger Rail System.*** A transportation system, utilizing a rail guideway, operating on right-of-way for the movement of passengers within and between metropolitan areas, and consisting of its rail guideways, passenger rail vehicles, and other rolling stock; power systems; buildings; maintenance facilities; stations; passenger rail vehicle yard; and other stationary and movable apparatus, equipment, appurtenances, and structures.

3.3.53 Underground System. The system or that part of the system located beneath the surface of the earth or of the water.

Chapter 4 General

4.1 Characteristics of Fire Safety.

4.1.1 Fire safety on fixed guideway transit and passenger rail systems shall be achieved through a composite of facility design, operating equipment, hardware, procedures, and software subsystems that are integrated to provide requirements for the protection of life and property from the effects of fire.

4.1.2 The level of fire safety desired for the whole system shall be achieved by integrating the required levels for each subsystem.

4.2 Goal.

4.2.1 The goal of this standard is to provide an environment for occupants of fixed guideway and passenger rail system elements that is safe from fire and similar emergencies to a practical extent based on the following measures:

(1) Protect occupants not intimate with the initial fire development
(2) Maximize the survivability of occupants intimate with the initial fire development

4.2.2 This standard is prepared with the intent of providing minimum requirements for those instances where noncombustible materials (as defined in 3.3.29) are not used due to other considerations in the design and construction of the fixed guideway and passenger rail system elements.

4.3 Objectives.

4.3.1 Occupant Protection. Fixed guideway transit and passenger rail systems shall be designed, constructed, and maintained to protect occupants who are not intimate with the initial fire development for the time needed to evacuate or relocate them, or defend such occupants in place during a fire or fire-related emergency.

4.3.2 Structural Integrity. Structural integrity of stations, trainways, and vehicles shall be maintained for the time needed to evacuate, relocate, or defend in place occupants who are not intimate with the initial fire development.

4.3.3 Systems Effectiveness. Systems utilized to achieve goals stated in Section 4.2 shall be effective in mitigating the hazard or condition for which they are being used, shall be reliable, shall be maintained to the level at which they were designed to operate, and shall remain operational.

4.4 Assumption of a Single Fire Source. The protection methods described in this standard shall assume a single fire source.

Chapter 5 Stations

5.1 General.

5.1.1* Application. This chapter shall apply to all fixed guideway transit and passenger rail stations whether they are entirely, or in any part, below, at, or above grade.

5.1.2 Occupancy.

5.1.2.1 The primary purpose of a station shall be for the use of the fixed guideway transit and passenger rail passengers who normally stay in a station structure for a period of time no longer than that necessary to wait for and enter a departing transit or passenger rail vehicle or to exit the station after arriving on an incoming transit or passenger rail vehicle.

5.1.2.2 Where contiguous commercial occupancies are in common with the station, or where the station is integrated into a building the occupancy of which is neither for transit nor for passenger rail, special considerations beyond this standard shall be necessary.

5.1.2.3 A station shall also be for the use of employees whose work assignments require their presence in the station structures.

5.2 Construction.

5.2.1 Construction Materials. Building construction for all new stations shall be not less than Type I– or Type II– or combinations of Type I– and Type II–approved noncombustible construction as defined in NFPA 220, as determined by an engineering analysis of potential fire exposure hazards to the structure.

5.2.2 Safeguards During Construction. During the course of construction or major modification of any structure, provisions of NFPA 241 shall apply.

5.2.3 Compartmentation and Fire Separation.

5.2.3.1 Stair and Escalator Enclosure. Stairs and escalators regularly used by passengers shall not be required to be enclosed.

5.2.3.1.1 Such stairs and escalators shall be included in exit capacity calculations as detailed in 5.5.3 and 5.5.4.

5.2.3.2 Ancillary Spaces. In all stations, fire resistance ratings of separations between occupancies shall be established as required by the local building code in accordance with NFPA 251.

5.2.3.2.1 All power substations shall have a fire separation of at least 3 hours from all other occupancies.

5.2.3.2.2 Electrical control rooms, auxiliary electrical rooms, and associated battery rooms shall have a fire separation of at least 2 hours from all other occupancies.

5.2.3.2.3 Trash rooms shall have a fire separation of at least 1 hour from all other occupancies.

5.2.3.2.4 Train control rooms and associated battery rooms shall have a fire separation of at least 2 hours from all other occupancies.

5.2.3.2.5 All public areas shall have a fire separation of at least 2 hours from nonpublic areas.

5.2.3.3 Doors and Openings. Doors and other openings through the separations identified in 5.2.3.2, including 5.2.3.2.2 through 5.2.3.2.5, shall be protected by fire door assemblies having a protection rating of 1½ hours.

5.2.3.3.1 Power substations, identified in 5.2.3.2.1, shall be protected by fire door assemblies having a protection rating of 3 hours.

5.2.3.4 Agents' and Information Booths. Agents' or information booths shall be constructed of approved noncombustible materials.

5.2.3.5 Fire Separation.

5.2.3.5.1* All station public areas shall have a fire separation of at least 3 hours from all nontransit occupancies.

5.2.3.5.2 The fire separation for stations shall be permitted to be modified based on an engineering analysis of potential fire exposure hazards.

5.2.3.6 Openings.

5.2.3.6.1 All openings (e.g., private entrances) from station public areas to all nontransit occupancies shall be protected by approved fire-protective assemblies with an appropriate rating for the location in which they are installed.

5.2.3.6.2 Where a fire door is required to be open, one of the following shall apply:

(1) The door shall be of the automatic closing type.
(2) The door shall be activated by listed smoke detectors.
(3) Where a separate smoke barrier is provided, the operation shall be permitted to be by fusible links.

5.2.3.6.3 Fire doors shall be installed in accordance with NFPA 80.

5.2.4 Automatic Sprinkler System Requirements. See 5.7.3.

5.3 Ventilation. Emergency ventilation shall be provided in enclosed stations in accordance with Chapter 7.

5.4 Wiring Requirements.

5.4.1 All wiring materials and installations within stations other than for traction power shall conform to requirements of NFPA 70 and, in addition, shall satisfy the requirements of 5.4.2 through 5.4.9.

5.4.2 Materials manufactured for use as conduits, raceways, ducts, boxes, cabinets, equipment enclosures, and their surface finish materials shall be capable of being subjected to temperatures up to 500°C (932°F) for 1 hour and shall not support combustion under the same temperature condition.

5.4.2.1 Other materials when encased in concrete shall be acceptable.

5.4.3 All conductors shall be insulated. Ground wires shall be permitted to be bare.

5.4.3.1 All thicknesses of insulation and all thicknesses of jackets shall conform to NFPA 70.

5.4.4 All insulations shall conform to Article 310 of NFPA 70 and shall be moisture- and heat-resistant types carrying temperature ratings corresponding to the conditions of application and in no case lower than 90°C (194°F).

5.4.5 Wire and cable constructions intended for use in operating train signal circuits, power circuits to emergency lights, and so forth shall be listed as being resistant to the spread of fire and shall have reduced smoke emissions.

5.4.5.1 Cable shall be permitted to be listed in accordance with any of the following methods:

(1) The cable does not spread fire to the top of the tray in the vertical-tray flame test in UL 1581, Section 1160, and the cable exhibits a specific optical density of smoke at 4 minutes into the test that does not exceed 200 (in the flaming mode) or 75 (in the nonflaming mode), when tested in accordance with ASTM E 662.
(2) The cable exhibits damage (char length) that does not exceed 1.5 m (4.9 ft) when the vertical flame test, with cables in cable trays, is performed as described in CSA C22.2 No. 0.3, and the cable exhibits a specific optical density of smoke at 4 minutes into the test that does not exceed 200 (in the flaming mode) or 75 (in the nonflaming mode), when tested in accordance with ASTM E 662.
(3) The cable is listed as a limited smoke cable (/LS) by meeting the cable damage height, total smoke released, and peak smoke release rate criteria required when tested in the vertical tray flame test in UL 1685. The following performance criteria shall be met when testing according to UL 1685.
   (a) When testing in the UL vertical tray flame exposure:
      i. The cable damage height shall be less than 2.44 m (8 ft) when measured from the bottom of the cable tray.
      ii. The total smoke released shall not exceed 95 m^2 (1023 ft^2).
      iii. The peak smoke release rate shall not exceed 0.25 m^2/s (2.69 ft^2/s).
   (b) Alternatively, when testing in the IEEE 1202 flame exposure:
      i. The cable damage height shall be less than 1.5 m (4.9 ft) when measured from the lower edge of the burner face.
      ii. The total smoke released shall not exceed 150 m^2 (1615 ft^2).
      iii. The peak smoke release rate shall not exceed 0.40 m^2/s (4.3 ft^2/s).
(4) The cable is listed as having fire-resistant characteristics capable of preventing the carrying of fire from floor to floor, by being capable of passing the requirements of ANSI/UL 1666, and the cable exhibits a specific optical density of smoke at 4 minutes into the test that does not exceed 200 (in the flaming mode) or 75 (in the nonflaming mode), when tested in accordance with ASTM E 662.
(5) The cable is listed as having adequate fire-resistant and low-smoke-producing characteristics, by having a flame travel distance that does not exceed 1.52 m (5 ft), generating a maximum peak optical density of smoke of 0.5 and a maximum average optical density of smoke of 0.15 when tested in accordance with NFPA 262.

5.4.6 All conductors, except radio antennas, shall be enclosed in their entirety in armor sheaths, conduits, or enclosed raceways, boxes, and cabinets except in ancillary areas or other nonpublic areas.

5.4.6.1 Conductors in conduits or raceways shall be permitted to be embedded in concrete or run in concrete electrical duct banks, but they shall not be installed exposed or surface-mounted in air plenums that might carry air at the elevated temperatures accompanying fire-emergency conditions.

5.4.7 Overcurrent elements that are designed to protect conductors serving emergency equipment motors (pumps, etc.), emergency lighting, and communications equipment that are located in spaces other than the main electrical distribution system equipment rooms shall not depend on thermal properties for operation.

5.4.8 Conductors for emergency lighting and communications shall be protected from physical damage by transit or passenger rail vehicles or other normal system operations and from fires in the system by either of the following:

(1) Suitable embedment or encasement
(2) Routing of such conductors external to the interior underground portions of the transit system facilities

5.4.9 Power Supply for Emergency Ventilation Fans. See Chapter 7.

5.5 Means of Egress. See also Annex C.

5.5.1 General. The provisions for means of egress for a station shall comply with Chapter 7 and Chapter 12 of NFPA *101*, except as herein modified.

5.5.1.1* For a station, the design of the means of egress shall be based on an emergency condition requiring evacuation of the train(s) and station occupants to a point of safety.

5.5.2 Occupant Load. See also Annex C.

5.5.2.1 The occupant load for a transit station shall be determined based on the emergency condition requiring evacuation of that station to a point of safety.

5.5.2.2 The occupant load shall be based on the calculated train load of trains simultaneously entering the station on all tracks in normal traffic direction during the peak 15-minute period plus the simultaneous entraining load awaiting a train.

5.5.2.3 As a basis for computing the detraining load during an emergency, not more than one train will unload at any one track to a platform during an emergency.

5.5.2.4 The required egress capacity in stations shall be based on evacuation of the occupant load calculated in accordance with 5.5.2.7 and 5.5.2.8.

5.5.2.4.1 The basis for calculating the platform occupant load shall be the peak hour patronage figures as projected for design of a new transit system or as updated for an operating system.

5.5.2.5* Special consideration shall be given to station(s) servicing areas such as civic centers, sports complexes, and convention centers, where events that occur establish occupant loads not included in normal passenger loads.

5.5.2.6 At multiplatform stations, each platform shall be considered separately, and the arrival of trains from all normal traffic directions plus entraining loads shall be considered.

5.5.2.6.1 At concourses, mezzanines, or multilevel stations, simultaneous loads shall be considered for all egress routes passing through that area.

5.5.2.7 Where an area within a station is intended for use by other than passengers or employees, the occupant load for that area shall be determined in accordance with the provisions of NFPA *101* as appropriate for the class of occupancy.

5.5.2.7.1 The additional occupant load shall be included in determining the required egress from that area.

5.5.2.7.2 The additional occupant load is not required to be added to the station occupant load when the area has independent means of egress of sufficient number and capacity.

5.5.2.8 Calculation of Platform Occupant Load. The platform occupant load for each platform in a station shall be the greater of the peak period loads calculated as follows.

5.5.2.8.1 The peak period occupant load for each platform shall be based on the simultaneous evacuation of the entraining load and the train load for that platform in the peak period.

5.5.2.8.2 The entraining load for each platform shall be the sum of the entraining loads for each track serving that platform. The entraining load for each track shall be based on the entraining load per train headway multiplied by both of the following:

(1)*The system surge factor
(2) In the peak direction for each route, an additional factor of 2 to account for one missed headway

5.5.2.8.3 The train load for each platform shall be the sum of the train loads for each track serving that platform. The train load for each track shall be the train load per train headway multiplied by both of the following:

(1)*The system surge factor
(2) In the peak direction for each route, an additional factor of 2 to account for one missed headway

5.5.2.8.4* The maximum train load at each track shall be the maximum passenger train capacity.

5.5.3 Number and Capacity of Exits.

5.5.3.1 Platform Evacuation Time. There shall be sufficient egress capacity to evacuate the platform occupant load as defined in 5.5.2.8 from the station platform in 4 minutes or less.

5.5.3.1.1 The maximum travel distance on the platform to a point at which a means of egress route leaves the platform shall not exceed 91.4 m (300 ft).

5.5.3.1.2 Modification of the evacuation time shall be permitted based on an engineering analysis by evaluating material heat release rates, station geometry, and emergency ventilation systems.

5.5.3.2 Evacuation Time to a Point of Safety. The station also shall be designed to permit evacuation from the most remote point on the platform to a point of safety in 6 minutes or less.

5.5.3.2.1 For at-grade and elevated structures where the station platform is open to the elements and where the concourse is below or protected from the platform by distance or materials as determined by an appropriate engineering analysis, that concourse shall be permitted to be defined as a point of safety.

5.5.3.2.2 For an underground or enclosed station equipped with an emergency ventilation system designed in accordance with Chapter 7, where the emergency ventilation system provides protection for the concourse from exposure to the effects of a train fire at the platform as confirmed by engineering analysis, that concourse is permitted to be defined as a point of safety.

5.5.3.2.3 Modification of the evacuation time shall be permitted based on an engineering analysis by evaluating material heat release rates, station geometry, and emergency ventilation systems.

5.5.3.3 Exit Lanes, Doors, and Gates. The capacity in persons per inch per minute (pim), passenger travel speeds in feet per minute (fpm), and for gates in people per minute (ppm) shall be in accordance with 5.5.3.3.1 through 5.5.3.3.3.

5.5.3.3.1 Platforms, Corridors, and Ramps of 4 Percent Slope or Less.

5.5.3.3.1.1 Exit corridors and ramps shall be a minimum of 1.73 m (5 ft 8 in.) wide.

5.5.3.3.1.2 In computing the capacity available, 304.8 mm (1 ft) shall be deducted at each side wall and 457.2 mm (1 ft 6 in.) at platform edges.

(A) Capacity shall be 2.27 pim.

(B) Travel speed shall 61 m/min (200 fpm).

5.5.3.3.2* Stairs, Stopped Escalators, and Ramps of Over 4 Percent Slope.

5.5.3.3.2.1 Exit stairs shall be a minimum of 1.12 m (44 in.) wide.

5.5.3.3.2.2 Stopped escalators shall be permitted to be considered as emergency exits.

5.5.3.3.2.3 Exit ramps shall be a minimum of 1.83 m (6 ft) wide.

5.5.3.3.2.4 Capacities and travel speeds for stairs, stopped escalators, and ramps of over 4 percent slope shall be as follows:

(1) Up direction
  (a) Capacity — 0.0626 p/mm-min (1.59 pim)
  (b) Travel speed — 15.24 m/min (50 fpm) (indicates vertical component of travel speed)
(2) Down direction
  (a) Capacity — 0.0716 p/mm-min (1.82 pim)
  (b) Travel speed — 18.3 m/min (60 fpm) (indicates vertical component of travel speed)

5.5.3.3.2.5 Escalators shall not account for more than half of the units of exit at any one level.

5.5.3.3.2.6 In the calculation of egress requirements, one escalator at each station shall be considered as being out of service.

5.5.3.3.2.7 The escalator chosen shall be the one having the most adverse effect upon egress capacity.

5.5.3.3.3 Doors and Gates.

5.5.3.3.3.1 Exit doors and gates shall be a minimum of 914.4 mm (36 in.) wide.

5.5.3.3.3.2 Capacity shall be 0.0893 p/mm-min (2.27 pim).

5.5.3.3.4 Fare Collection Gates.

5.5.3.3.4.1 Fare collection gates shall meet the following criteria:

(1) They shall provide a minimum of 508 mm (20 in.) clear width when deactivated.
(2) Consoles shall not exceed 1016 mm (40 in.) in height.
(3) They shall have a capacity of 50 people per minute (ppm) for egress calculations.

5.5.3.3.4.2 Turnstile-type fare collection gates shall meet the following criteria:

(1) They shall provide a minimum of 457.2 mm (18 in.) clear width.
(2) They shall have a maximum height of 914.4 mm (36 in.) at the turnstile bar.
(3) They shall free-wheel in the direction of egress when deactivated.
(4) They shall have a capacity of 25 people per minute (ppm) for egress calculations.

5.5.3.4 Emergency exit gates shall be in accordance with NFPA *101*.

5.5.3.4.1 Gate-type exits shall be provided for at least 50 percent of the required emergency exit capacity unless fare collection equipment provides unobstructed exiting under all conditions.

5.5.3.5 A second means of egress at least 1120 mm (44 in.) wide shall be provided from each station platform.

5.5.3.5.1 Means of egress from separate platforms shall be permitted to converge.

5.5.3.5.2 Where means of egress routes from separate platforms converge, the subsequent capacity of the egress route shall be sufficient to maintain the required evacuation time from the incident platform.

5.5.3.6 A common path of travel from the platform ends shall not exceed 22.8 m (75 ft) or one car length, whichever is greater.

5.5.4 Escalators. *(See also Section C.2.)*

5.5.4.1 Escalators shall be permitted as a means of egress in stations provided the following criteria are met:

(1)*The escalators are constructed of noncombustible materials.
(2) Escalators running in the direction of egress shall be permitted to remain operating.
(3) Escalators running reverse to the direction of egress shall be capable of being stopped remotely or manually. *(See Section C.2.)*

5.5.4.2 Escalators with or without intermediate landings shall be acceptable as a means of egress, regardless of vertical rise.

5.5.4.3 Escalators exposed to the outdoor environment shall be provided with slip-resistant landing and floor plates, and if they are exposed to freezing temperatures, the landing and floor plates and steps shall be heated to prevent the accumulation of ice and snow.

5.5.5 Fare Collection Gates or Turnstiles. The following design features shall be provided to facilitate the exit of passengers in the event of an emergency.

5.5.5.1 The fare gates or turnstiles shall assume an emergency exit mode in the event of loss of power to the fare gates or turnstiles or upon actuation of a manual or remote control.

5.5.5.2 Fare collection gates or turnstiles shall be designed so that their failure to operate properly will not prohibit movement of passengers in the direction of the emergency egress.

5.5.6 Platform Edge Doors. Horizontal sliding platform screen or platform edge doors shall be permitted to separate the platform from the trainway in stations provided that the following criteria are met:

(1) The doors permit emergency egress from the train to the platform regardless of the stopping position of the train.
(2) The doors provide egress when a force not exceeding 222 N (50 lb) is applied from the train side of the doors.
(3) The doors are designed to withstand positive and negative pressures caused by passing trains.

5.6 Emergency Lighting.

5.6.1 Stations shall be provided with a system of emergency lighting in accordance with NFPA *101*, except as otherwise noted in this standard.

5.6.2 Emergency lighting for stairs and escalators shall be designed to emphasize illumination on the top and bottom steps and landings.

5.6.2.1 All newel- and comb-lighting on escalator steps shall be on emergency power circuits.

5.7 Fire Protection.

5.7.1 Protective Signaling Systems.

5.7.1.1 Stations equipped with fire alarm devices shall be protected by a proprietary system as defined in *NFPA 72*.

5.7.1.2* Each station having fire alarm initiating devices shall be provided with a fire alarm annunciator panel at a location that is accessible to emergency response personnel in accordance with *NFPA 72*.

5.7.1.2.1 The location shall be approved by the authority having jurisdiction.

5.7.1.2.2 Annunciator panels shall announce by audible alarm the activation of any fire alarm–initiating device in the station and visually display the location of the actuated device.

5.7.1.3 All fire alarm, smoke detection, valve switches, and water flow indicator signals — when activated — shall be transmitted simultaneously to the local station and to the central supervising station.

5.7.1.4* Separate zones shall be established on local station annunciator panels to monitor water flow on sprinkler systems and supervise main control valves.

5.7.1.5 Automatic fire detection shall be provided in all ancillary spaces by the installation of listed combination fixed-temperature and rate-of-rise heat detectors or listed smoke detectors except where protected by automatic sprinklers.

5.7.2 Emergency Communication.

5.7.2.1 A public address (PA) system and emergency voice alarm reporting devices, such as emergency telephone boxes or manual fire alarm boxes, conforming to *NFPA 72* shall be required in stations.

5.7.2.2 The central supervising station and each passenger station shall be equipped with an approved emergency voice/alarm communication system so that appropriate announcements can be made regarding fire alarms, including provisions for giving necessary information and directions to the public upon receipt of any manual or automatic fire alarm signal.

5.7.2.2.1 These notification devices shall be placed in approved locations at each facility.

5.7.2.3 Emergency alarm reporting devices shall be located on passenger platforms and throughout the passenger station such that the travel distance from any point in the public area shall not exceed 91.4 m (300 ft) unless otherwise approved by the authority having jurisdiction.

5.7.2.3.1 Such emergency devices shall be distinctive in color, and their location shall be plainly indicated by appropriate signs.

5.7.3 Automatic Sprinkler Systems.

5.7.3.1 An automatic sprinkler protection system shall be provided in areas of stations used for concessions, in storage areas, in trash rooms, and in the steel truss area of all escalators and other similar areas with combustible loadings, except trainways.

5.7.3.1.1 Sprinkler protection is not required in areas of open stations remotely located from public spaces.

5.7.3.2 Installation of sprinkler systems shall comply with NFPA 13 or applicable local codes as required.

5.7.3.3 A sprinkler system water flow alarm and supervisory signal service shall be installed.

5.7.3.4 Other approved fire suppression systems shall be permitted to be substituted for automatic sprinkler systems in the areas listed in 5.7.3.1 with the approval of the authority having jurisdiction.

5.7.4 Standpipe and Hose Systems.

5.7.4.1 Each underground transit station shall be equipped with a standpipe system of either Class I or Class III type, as defined in NFPA 14.

5.7.4.1.1 Class of service shall be determined by the authority having jurisdiction. *(See A.5.7.4.3.)*

5.7.4.2 The authority having jurisdiction shall be consulted as to location, spacing, and number of standpipe hose outlets and valves and shall determine the need for provision and type of hose.

5.7.4.3* Fire department connections for fire department use in supplying the standpipe system shall be located as follows:

(1) Within 30.5 m (100 ft) of vehicular access
(2) Within operating distance of fire hydrants as determined by the local authority having jurisdiction

5.7.4.3.1 In addition to the usual identification required on fire department connections for standpipes, there shall also be wording to identify the fire department connection as part of the transit station system.

5.7.4.4 Where underground stations include more than one platform level (such as crossover subway lines), there shall be a cross-connection pipe of a minimum size of 101.6 mm (4 in.) in diameter between each standpipe system, so that supplying water through any fire department connection will furnish water throughout the entire system.

5.7.5 Portable Fire Extinguishers. Portable fire extinguishers in such number, size, type, and location as determined by the authority having jurisdiction shall be provided.

5.7.6* Fire Command Center. Underground stations shall be provided with a fire command center in accordance with *NFPA 72*.

5.7.6.1 The ventilation systems at adjacent tunnels and stations shall be permitted to be omitted from the controls of the fire command center.

5.8 Storage Tanks and Service Stations.

5.8.1 Aboveground storage tanks above subsurface stations shall meet the requirements of 6.2.8.4.

5.8.2 Underground storage tanks above subsurface station structures shall meet the requirements of 6.2.8.5.

5.8.3 Service stations above subsurface station structures shall meet the requirements of 6.2.8.6.

5.8.4 Existing storage tanks in or under buildings shall meet the requirements of 6.2.8.7.

Chapter 6 Trainways

6.1 General.

6.1.1* Application. This chapter contains requirements for all fixed guideway transit and passenger rail trainways whether they are entirely or in any part below, at, or above grade.

6.1.2 Occupancy.

6.1.2.1 Passengers shall enter the trainways only in the event that it becomes necessary to evacuate a disabled train.

6.1.2.2 Evacuation shall take place only under the guidance and control of authorized, trained transit system employees or other authorized personnel as warranted under an emergency situation.

6.1.3 Warning Signs.

6.1.3.1 Warning signs shall be posted on entrances to the trainway (e.g., station platforms and portals), on fences or barriers adjacent to the trainway, and at such other places where nontransit authority employees might trespass.

6.1.3.2 The warning signs shall clearly state the hazard (e.g., DANGER HIGH VOLTAGE — 750 VOLTS) with letter sizes and colors in conformance with NFPA 70 and Occupational Safety and Health Administration (OSHA) requirements.

6.1.4 Blue Light Station.

6.1.4.1* Blue light stations shall be provided at the following locations:

(1) At the ends of station platforms
(2) At cross passageways *(see 6.2.4.3)*
(3) At emergency access points
(4) At traction power substations
(5) In underground trainways as required by the authority having jurisdiction

6.1.4.2 Adjacent to each blue light station, information shall be provided that identifies the location of that station and the distance to an exit in each direction.

6.2 Underground (Subways).

6.2.1 Construction Materials.

6.2.1.1 General. Where line sections are to be constructed by the cut-and-cover method, perimeter walls and related construction shall be not less than Type I- or Type II- or combinations of Type I- or Type II-approved noncombustible construction as defined in NFPA 220, as determined by an engineering analysis of potential fire exposure hazards to the structure.

6.2.1.2 Lining. Where line sections are to be constructed by a tunneling method through earth, unprotected steel liners, reinforced concrete, shotcrete, or equivalent shall be used.

6.2.1.2.1 Rock tunnels shall be permitted to utilize steel bents with concrete liner if lining is required.

6.2.1.3 Walking Surfaces. Walking surfaces designated for evacuation of passengers shall be constructed of noncombustible materials.

6.2.1.3.1 Walking surfaces shall have a slip-resistant design.

6.2.1.4 Underwater Tubes. Underwater tubes shall be not less than Type II (000) approved noncombustible construction as defined in NFPA 220, as applicable.

6.2.1.5 Rail Ties. Noncombustible rail ties shall be used in underground locations except at switch or crossover locations, where fire-retardant, pressure-treated ties shall be permitted to be used.

6.2.1.6 Structures. Remote vertical exit shafts and ventilation structures shall be not less than Type I (332) approved noncombustible construction as defined in NFPA 220.

6.2.1.7 Ancillary Areas. Ancillary areas shall be separated from trackway areas within underwater line sections by a minimum of 3-hour fire-resistive construction.

6.2.1.7.1 Ancillary areas shall be separated from trackway areas within underground line sections by a minimum of 2-hour fire-resistive construction.

6.2.2 Ventilation. Emergency ventilation shall be provided in enclosed trainways in accordance with Chapter 7.

6.2.3 Wiring Requirements. *(See Section 5.4.)*

6.2.3.1 All wiring materials and installations within trainways, other than for traction power, shall conform to the requirements of NFPA 70 and, in addition, shall satisfy the requirements of 6.2.3.2 through 6.2.3.9.

6.2.3.1.1 Where the top of the subsurface trainway or station is more than 15 m (50 ft) below the surface of the earth, an engineering analysis to determine the need for the requirement of 6.2.3.1 shall be permitted to be conducted.

6.2.3.2 Materials manufactured for use as conduits, raceways, ducts, boxes, cabinets, equipment enclosures, and their surface finish materials shall be capable of being subjected to temperatures up to 932°F (500°C) for 1 hour and shall not support combustion under the same temperature condition.

6.2.3.2.1 Other materials, where encased in concrete or suitably protected, shall be acceptable.

6.2.3.3 All conductors shall be insulated.

6.2.3.3.1 Ground wires shall be permitted to be bare.

6.2.3.3.2 All thicknesses of insulation and all thicknesses of jackets shall conform to NFPA 70.

6.2.3.4 All insulations shall conform to Article 310 of NFPA 70 and shall be moisture- and heat-resistant types carrying temperature ratings corresponding to the conditions of application and in no case lower than 90°C (194°F).

6.2.3.5 All wire and cable constructions intended for use in trainways, other than traction power cables, shall be listed as being resistant to the spread of fire and shall have reduced smoke emissions in accordance with 6.2.3.5.1.

6.2.3.5.1 Cable shall be permitted to be listed by any of the following methods:

(1) The cable does not spread fire to the top of the tray in the vertical-tray flame test in UL 1581, Section 1160, and the cable exhibits a specific optical density of smoke at 4 minutes into the test that does not exceed 200 (in the flaming mode) or 75 (in the nonflaming mode) when tested in accordance with ASTM E 662.
(2) The cable exhibits damage (char length) that does not exceed 1.5 m (4.9 ft) when the vertical flame test, with cables in cable trays, is performed as described in CSA C22.2 No. 0.3, and the cable exhibits a specific optical density of smoke at 4 minutes into the test that does not exceed 200 (in the flaming mode) or 75 (in the nonflaming mode) when tested in accordance with ASTM E 662.
(3) The cable is listed as a limited smoke cable (/LS) by meeting the cable damage height, total smoke released, and peak smoke release rate criteria required when tested in the vertical tray flame test in UL 1685. The following performance criteria shall be met when testing by UL 1685.
    (a) When testing in the UL vertical tray flame exposure:
        i. The cable damage height shall be less than 2.44 m (8 ft) when measured from the bottom of the cable tray.
        ii. The total smoke released shall not exceed 95 m^2 (1023 ft^2).
        iii. The peak smoke release rate shall not exceed 0.25 m^2/s (4.3 ft^2/s).
    (b) Alternatively, when testing in the IEEE 1202 flame exposure:
        i. The cable damage height shall be less than 1.5 m (4.9 ft) when measured from the lower edge of the burner face.
        ii. The total smoke released shall not exceed 150 m^2 (1615 ft^2).
        iii. The peak smoke release rate shall not exceed 0.40 m^2/s (4.5 ft^2/s).
(4) The cable is listed as having fire-resistant characteristics capable of preventing the carrying of fire from floor to floor, by being capable of passing the requirements of ANSI/UL 1666, and the cable exhibits a specific optical density of smoke at 4 minutes into the test that does not exceed 200 (in the flaming mode) or 75 (in the nonflaming mode) when tested in accordance with ASTM E 662.
(5) The cable is listed as having adequate fire-resistant and low smoke-producing characteristics, by having a flame travel a distance that does not exceed 1.52 m (5 ft), generating a maximum peak optical density of smoke of 0.5 and a maximum average optical density of smoke of 0.15 when tested in accordance with NFPA 262.

6.2.3.6* All conductors, except radio antennas, shall be enclosed in their entirety in armor sheaths, conduits, or enclosed raceways, boxes, and cabinets.

6.2.3.6.1 Conductors in conduits or raceways shall be permitted to be embedded in concrete or run in protected electrical duct banks, but shall not be installed exposed or surface mounted in air plenums that could carry air at the elevated temperatures accompanying fire emergency conditions.

6.2.3.7 Overcurrent elements that are designed to protect conductors serving emergency equipment motors (pumps, etc.), emergency lighting, and communications equipment and that are located in spaces other than the main electrical distribution system equipment rooms shall not depend on thermal properties for operation.

6.2.3.8 Conductors for emergency lighting and communications shall be protected from physical damage by vehicles or other normal system operations and from fires in the system by suitable embedment or encasement, or by routing such conductors external to the interior underground portions of the system facilities.

6.2.3.9 Power Supply for Emergency Ventilation. See Chapter 7.

6.2.4 Emergency Exit Details.

6.2.4.1 General. Emergency exits shall be provided from tunnels to a point of safety.

6.2.4.2* Number and Location of Means of Egress Routes. Within underground or enclosed trainways, the maximum distance between exits shall not exceed 762 m (2500 ft).

6.2.4.3 Cross Passageways.

6.2.4.3.1 Cross passageways shall be permitted to be used in lieu of emergency exit stairways to the surface where trainways in tunnels are divided by a minimum of 2 hour–rated fire walls or where trainways are in twin bores.

6.2.4.3.2 Where cross passageways are utilized in lieu of emergency exit stairways, the following shall apply:

(1) Cross passageways shall not be farther than 244 m (800 ft) apart.
(2) Openings in open passageways shall be protected with fire door assemblies having a fire protection rating of 1½ hours with a self-closing fire door.
(3) A noncontaminated environment shall be provided in that portion of the trainway that is not involved in an emergency and that is being used for evacuation.
(4) A ventilation system for the contaminated tunnel shall be designed to control smoke in the vicinity of the passengers.
(5) An approved method shall be provided for evacuating passengers in the uncontaminated trainway.
(6) An approved method for protecting passengers from oncoming traffic shall be provided.
(7) An approved method for evacuating the passengers to a nearby station or other emergency exit shall be provided.

6.2.4.4 Doors.

6.2.4.4.1 Doors in the means of egress, except cross passageway doors, shall open in the direction of exit travel and comply with both of the following criteria:

(1) Open fully when a force not exceeding 222 N (50 lb) is applied to the latch side of the door
(2) Be adequate to withstand positive and negative pressures caused by passing trains

6.2.4.4.2 Horizontal sliding doors shall be permitted in cross passageways.

6.2.4.5 Exit Hatches.

6.2.4.5.1 Exit hatches shall be permitted in the means of egress provided the following conditions are met:

(1) Hatches shall be equipped with a manual opening device that can be readily opened from the egress side.
(2) Hatches shall be operable with not more than one releasing operation.
(3) The force required to open the hatch when applied at the opening device shall not exceed 133 N (30 lb).
(4) The hatch shall be equipped with a hold-open device that automatically latches the door in the open position to prevent accidental closure.

6.2.4.5.2 Exit hatches shall be capable of being opened from the discharge side to permit access by authorized personnel.

6.2.4.5.3* Exit hatches shall be conspicuously marked on the discharge side to prevent possible blockage.

6.2.4.6 Identification. Emergency exit facilities shall be suitably identified and maintained to allow for their intended use.

6.2.4.7 Emergency Lighting.

6.2.4.7.1 The requirements of 6.2.4.7.2 through 6.2.4.7.5.1 shall apply to all underground or enclosed trainways that are greater than 30.5 m (100 ft) in length or 2 car lengths, whichever is greater.

6.2.4.7.2 Emergency lighting systems shall be installed and maintained in accordance with NFPA 70.

6.2.4.7.3 Exit lights, essential signs, and emergency lights shall be included in the emergency lighting system and shall be powered by a standby power supply or a supply independent of the traction power system.

6.2.4.7.4 Emergency fixtures, exit lights, and signs shall be wired separately from emergency distribution panels.

6.2.4.7.5* The illumination levels of underground or enclosed trainway walkways and walking surfaces (i.e., track way and bench wall walkway) shall not be less than 2.69 lx (0.25 ft-candles) at the walking surface.

6.2.4.7.5.1 The emergency lighting system in the trainway shall produce illumination on the walkway that does not exceed a uniformity ratio of 10:1 for the maximum maintained horizontal illuminance to the minimum maintained horizontal illuminance.

6.2.4.8* Directional Signs.

6.2.4.8.1 Underground or enclosed trainways greater in length than the minimum length of one train shall be provided with directional signs as appropriate for the emergency procedures developed for the fixed guideway transit or passenger rail system in accordance with Chapter 10.

6.2.4.8.2 Signs shall be installed at maximum 22.8 m (75 ft) intervals on either side of the underground or enclosed trainways indicating station or portal directions.

6.2.4.8.3 Signs shall be readily visible by passengers for emergency evacuation.

6.2.4.8.4 Points of exit from elevated and underground or enclosed trainways shall be marked with signs internally or externally illuminated signs.

6.2.5 Traction Power.

6.2.5.1 Application.

6.2.5.1.1* Subsection 6.2.5 shall apply to life safety and fire protection criteria for the traction power subsystem installed in the underground trainway.

6.2.5.1.2 Subsection 6.2.5 shall apply to traction power, which shall include the wayside pothead, the cable between the pothead and the contact (third) rail or overhead contact system (OCS), the contact rail or OCS supports, and special warning and identification devices, as well as electrical appurtenances associated with overhead contact systems.

6.2.5.2 Traction Power Contact Rail Protection.

6.2.5.2.1 To provide safety isolation from the contact rail, the requirements of 6.2.5.2.2 through 6.2.5.2.6 shall apply.

6.2.5.2.2 Power rail conductor(s) (dc or ac, which supply power to the vehicle for propulsion and other loads) shall be secured to insulating supports, bonded at joints, and protected to prevent contact with personnel.

6.2.5.2.3 The design shall include measures to prevent inadvertent contact with the live power rails where such power rails are adjacent to emergency or service walkways and where walkways cross over trainways.

6.2.5.2.4 Coverboards, where used, shall be capable of supporting a vertical load of 1112 N (250 lb) at any point with no visible permanent deflection.

6.2.5.2.5 Coverboard or protective material shall have a flame spread rating of not more than 25 when tested in accordance with NFPA 255 (ASTM E 84).

6.2.5.2.6 Insulating material for the cable connecting power to the rail shall meet the requirements of IEEE 383, Section 2.5.

6.2.5.3 Traction Power Overhead Contact System Protection.

6.2.5.3.1 To provide isolation from the overhead contact system, the requirements of 6.2.5.3.2 and 6.2.5.3.3 shall apply.

6.2.5.3.2 Power conductor(s) (dc or ac, which supply power to the vehicle for propulsion and other loads) shall be secured to insulating supports, bonded at joints, and protected to prevent contact with personnel.

6.2.5.3.3 Insulating material for the cable connecting power to the overhead contact system shall meet the requirements of IEEE 383, Section 2.5.

6.2.6 Egress for Passengers.

6.2.6.1 The system shall incorporate means for passengers to evacuate a train at any point along the trainway and reach a point of safety.

6.2.6.2 System egress points shall be illuminated.

6.2.6.3 Where the trainway track bed serves as the emergency egress pathway, it shall be nominally level and free of obstructions.

6.2.6.4 Walking surfaces shall have a uniform, slip-resistant design.

6.2.6.5 In areas where cross passageways are provided, walkways shall be provided on the cross passageway side of the trainway for unobstructed access to the cross passageway.

6.2.6.6 Raised walkways, ramps, and stairs shall be provided with a handrail that shall not obstruct egress from the train.

6.2.6.7 Crosswalks shall be provided at track level to ensure walkway continuity.

6.2.6.8 Crosswalks shall have uniform walking surface at the top of the rail.

6.2.6.9 Walkway continuity shall be maintained at special track sections (e.g., crossovers, pocket tracks).

6.2.6.10 A guard shall not be required on the trackside of raised walkways in trainways.

6.2.6.11 The minimum unobstructed width of egress facilities located within or directly adjacent to the trainway shall be 610 mm (24 in.) measured at the walkway surface and 762 mm (30 in.) measured at a height of 1422 mm (56 in.) above the walkway surface.

6.2.7 Protection.

6.2.7.1 Automatic Fire Detection.

6.2.7.1.1 Heat and smoke detectors shall be installed at traction power substations and signal bungalows and shall be connected to the central supervising station.

6.2.7.1.2 Signals received from such devices shall be identifiable as to origin of signals.

6.2.7.2 Standpipe and Hose Systems.

6.2.7.2.1 Standpipes for Class I or Class III service, as described in NFPA 14, shall be installed in all underground or enclosed trainways according to the calculation in 6.2.7.2.3.

6.2.7.2.2 Standpipes shall be permitted to be of the dry type with the approval of the authority having jurisdiction.

6.2.7.2.3 A fire standpipe system shall be provided for all underground or enclosed trainways if the length of the trainway, L_T, is greater than the length allowable for participating agency personnel to reach every conceivable fire location within the trainway, according to the following calculated length:

$$L_T > L_H - D_P$$

where:

L_H = maximum length of fire hose permitted by the authority having jurisdiction

D_P = maximum of the distances (measured along the route of the hose) from each trainway portal to the nearest fire hydrant or approved water source

6.2.7.2.4 Standpipe lines shall be a minimum size of 101.6 mm (4 in.) in diameter, or sized by hydraulic calculations.

6.2.7.2.4.1 The authority having jurisdiction shall specify the required water flow and pressure.

6.2.7.2.5 Identification numbers and letters conforming to the sectional identification numbers and letters of the fixed guideway transit or passenger trainway system shall be provided at each surface fire department connection and at each hose valve on the standpipe lines.

6.2.7.2.5.1 Identifying numbers and letters shall be on conspicuous, durable, and legible signs affixed to, or immediately adjacent to, ground-level fire department connections.

6.2.7.2.5.2 Identifying signs shall be affixed to underground or enclosed trainway walls at each hose outlet valve or shall be painted directly on the standpipe in white letters next to each hose outlet valve.

6.2.7.2.5.3 Exposed tunnel standpipe lines and identification signs shall be painted as required by the authority having jurisdiction.

6.2.7.3 Standpipe Installations in Tunnels Under Construction.

6.2.7.3.1 A standpipe system, either temporary or permanent in nature, shall be installed in tunnels under construction before the tunnel has exceeded a length of 61 m (200 ft) beyond any access shaft and shall be extended as tunnel work progresses.

6.2.7.3.2 Permanent and temporary standpipes shall conform to NFPA 14, as outlined in 6.2.7.2.

6.2.7.3.3 Temporary standpipes, which might be used by contractors to furnish water for construction purposes, shall be equipped with hose outlets and valves with 63.5 mm (2½ in.) hose thread conforming to NFPA 1963.

6.2.7.3.4 Reducers or adapters shall be provided and attached for connection of the contractor's hose.

6.2.7.3.5 Reducers or adapters shall be readily removable through the use of a fire fighter's hose spanner wrench.

6.2.7.3.6 Permanent standpipes or temporary standpipes installed in tunnels during construction shall be provided with risers to the ground surface level.

6.2.7.3.7 Risers shall be equipped with approved fire department connections.

6.2.7.3.8 Risers shall be identified with signs as outlined in 6.2.7.2.5 of this standard.

6.2.7.3.9 Risers shall be readily accessible for fire department use.

6.2.7.3.10 Risers shall be protected from accidental damage.

6.2.7.3.11 There shall be a check valve and ball drip or a valved drain in the riser at the connection to the standpipe.

6.2.7.3.12 Permanent or temporary standpipes installed during the construction phase shall be supported and capable of withstanding the pressure and thrust forces to which they might be subjected.

6.2.7.3.13 Temporary standpipes shall remain in service until the permanent standpipe installation is in service and operational.

6.2.7.4 Portable Fire Extinguishers. Portable fire extinguishers shall be provided in such numbers, sizes, and types and at such locations in tunnels as determined by the authority having jurisdiction.

6.2.8 Flammable and Combustible Liquids Intrusion.

6.2.8.1 General. Prevention of accidental intrusion of flammable and combustible liquids due to spills shall be provided in accordance with 6.2.8.2 through 6.2.8.7.

6.2.8.2 Vehicle Roadway Terminations. Vent or fan shafts utilized for ventilation of tunnels shall not terminate at grade on any vehicle roadway.

6.2.8.3 Median and Sidewalk Terminations. Vent and fan shafts shall be permitted to terminate in the median strips of divided highways, on sidewalks designed to accept such shafts, or in open space areas provided that the grade level of the median strips, sidewalk, or open space meets the following conditions:

(1) Is at a higher elevation than the surrounding grade level
(2) Is separated from the roadway by a concrete curb at least 152.4 mm (6 in.) in height

6.2.8.4 Aboveground Atmospheric Storage Tanks. Aboveground atmospheric storage tanks storing, handling, or processing Class I flammable liquid or Class II or Class III combustible liquids and related piping shall not be located directly over a subsurface structure or within 7.6 m (25 ft) measured horizontally from the outside wall of such subsurface structure unless provided with an approved leak detection system.

6.2.8.4.1 Where the top of the subsurface trainway or station is more than 15.2 m (50 ft) below the surface of the earth, an engineering analysis to determine the need for the requirement in 6.2.8.4 shall be permitted to be conducted.

6.2.8.5 Underground Storage Tanks. Underground storage tanks for Class I flammable or Class II or Class III combustible liquids and related piping shall not be permitted directly over a subsurface structure or within 7.6 m (25 ft) measured horizontally from the outside wall of such subsurface structure. *(See 6.2.8.7 for tanks in or under existing buildings.)*

6.2.8.5.1 Where the top of the subsurface trainway or station is more than 15.2 m (50 ft) below the surface of the earth an engineering analysis to determine the need for the requirement in 6.2.8.5 shall be permitted to be conducted.

6.2.8.5.2 For underground storage tanks and related piping for Class I flammable or Class II or Class III combustible liquids located in the area between 7.6 m (25 ft) and 30.5 m (100 ft) (measured horizontally) from the outside wall of the subsurface structure and within that same area, such tanks and related piping within 0.61 m (2 ft) (measured vertically) below the lowest point of subsurface structure excavation shall be constructed and installed according to one of the following methods:

(1) For tanks of double-wall construction:
   (a) Tanks shall be equipped with an approved automatic leak detection and monitoring system.
   (b) Tanks shall be provided with an approved corrosion protection system.
   (c) Installation, maintenance, and inspection shall conform to the requirements specified by the authority having jurisdiction.
(2) For tanks installed in a cast-in-place reinforced concrete vault large enough to hold and retain the entire contents of the tank:
   (a) The storage tank shall be completely encompassed by not less than 610 mm (24 in.) of well-tamped, noncorrosive inert material within the vault.
   (b) An approved method for the monitoring of, or testing for, product and enclosure leakage shall be incorporated into the enclosure design.
   (c) The vault lid shall be designed and constructed to withstand anticipated surface loadings and shall not be less than 152.4 mm (6 in.) of reinforced concrete.
   (d) Vault, tank, and piping shall be protected from corrosion.

6.2.8.5.3 All tanks, vaults, and appurtenances used to store Class I flammable and Class II and Class III combustible liquids shall be compatible with the materials stored and shall conform to the provisions of NFPA 30.

6.2.8.6 Service Stations.

6.2.8.6.1 Service stations dispensing Class I flammable liquids and Class II and Class III combustible liquids, and located in the area within 30.5 m (100 ft) (measured horizontally) from the outside wall of the underground structure, shall be required to comply with 6.2.8.6.2 through 6.2.8.6.5.

6.2.8.6.2 The surface around pump islands shall be graded or drained in a manner to divert spills away from the tunnel vent gratings or tunnel entrances or exits.

6.2.8.6.3 Continuous drains across driveways, ramps, or curbs of at least 152.4 mm (6 in.) in height shall separate service station properties from adjacent tunnel vent gratings or tunnel entrances or exits.

6.2.8.6.4 No connection (such as venting or drainage) of any storage tanks and related piping of Class I flammable liquids and Class II and Class III combustible liquids to a subsurface fixed guideway transit structure shall be permitted.

6.2.8.6.5 Dispensing pumps for Class I flammable liquids and Class II and Class III combustible liquids shall not be located less than 7.6 m (25 ft) from the face of such pump to the nearest side of a tunnel vent grating or subway entrance or exit.

6.2.8.7 Existing Storage Tanks in or Under Buildings.

6.2.8.7.1 Existing storage tanks for Class I flammable liquids and Class II and Class III combustible liquids located in or under buildings, and located directly above a subsurface transit structure or within 7.6 m (25 ft) (measured horizontally) from the outside wall of the subsurface transit structure, shall be removed and relocated outside the prohibited area.

6.2.8.7.1.1 Where the top of the subsurface trainway or station is more than 15.2 m (50 ft) below the surface of the earth, an engineering analysis to determine the need for the requirement of 6.2.8.7.1 shall be permitted to be conducted.

6.2.8.7.2 Where it is not possible to remove and relocate tanks for Class I flammable and Class II combustible liquids due to limited space, such underground tanks shall be abandoned in accordance with the provisions of Annex C of NFPA 30.

6.2.8.7.3 Where it is not possible to remove and relocate tanks for Class III combustible liquids located in buildings, such tanks shall be provided with leak detection and a secondary containment system of adequate capacity to contain the contents of the tank.

6.2.8.7.4 Tanks shall be abandoned in accordance with the provisions of Annex C of NFPA 30.

6.2.8.7.5 Where it is not possible to remove and relocate tanks for Class III combustible liquids located under a building, such tanks shall be UL-listed double wall or installed in a cast-in-place reinforced concrete vault and shall be provided with an approved leak detection system.

6.2.8.7.6 Tanks shall be abandoned in accordance with the provisions of Annex C of NFPA 30.

6.2.9 Combustible Components.

6.2.9.1 General. Combustible components not covered in 6.2.1 through 6.2.3.8 shall comply with 6.2.9.

6.2.9.2 Engineering Analysis. An engineering analysis shall be conducted on nonstructural combustible components that includes, as a minimum, an examination of peak heat release rate for combustible elements, total heat released, ignition temperatures, radiant heating view factors, and behavior of the component during internal or external fire scenarios to determine that, if a fire propagates beyond involving the component of fire origin, a level of fire safety is provided within an enclosed trainway commensurate with this standard.

6.2.9.2.1 Computer modeling, material fire testing, or full-scale fire testing shall be conducted to assess durability performance in potential fire scenarios.

6.3 Surface Trainways.

6.3.1 General. Section 6.3 shall apply to any at-grade or unroofed structure other than elevated structures.

6.3.2 Construction Materials. Construction materials shall be not less than Type II (000) approved noncombustible material as defined in NFPA 220, as determined by an engineering analysis of potential fire exposure hazards to the structure.

6.3.3* Traction Power. Subsection 6.3.3 shall apply to life safety and fire protection criteria for the traction power subsystem installed in the trainway.

6.3.3.1 Traction power shall include the wayside pothead, the cable between the pothead and the contact (third) rail or overhead wire, the contact rail supports, and special warning and identification devices.

6.3.3.2 Life safety and fire protection criteria for the subsystem installed in the trainway shall conform to the requirements for underground trainways that are listed in 6.2.5.2.

6.3.4 Electrical Wiring and Cable Requirements. All wiring materials and installations other than those for traction power shall conform to the requirements of NFPA 70.

6.3.5 Emergency Access.

6.3.5.1 If security fences are used along the trainway, access gates shall be provided in security fences, as deemed necessary by the authority having jurisdiction.

6.3.5.2 Access gates shall be a minimum of 1118 mm (44 in.) wide and shall be of the hinged or sliding type.

6.3.5.3 Access gates shall be placed as close as practical to the portals to permit easy access to tunnels.

6.3.5.4 Information that clearly identifies the route and location of each gate shall be provided on the gates or adjacent thereto.

6.3.6 Egress for Passengers.

6.3.6.1 The system shall incorporate means for passengers to evacuate a train at any point along the trainway and reach a point of safety.

6.3.6.2 System egress points shall be illuminated.

6.4 Elevated Structures.

6.4.1 General. Elevated structures are all structures not defined in this standard as surface or underground structures.

6.4.2 Construction Materials. All structures necessary for lineway support and all structures and enclosures on or under trainways shall be of not less than Type I or Type II (000) or combinations of Type I- or Type II-approved noncombustible construction as defined in NFPA 220, as determined by an engineering analysis of potential fire exposure hazards to the structure.

6.4.3* Traction Power. This subsection shall apply to life safety and fire protection criteria for the traction power subsystem installed in the trainway.

6.4.3.1 Traction power shall include the wayside pothead, the cable between the pothead and the contact (third) rail or overhead wire, the contact rail supports walkways, and special warning and identification devices.

6.4.3.2 Life safety and fire protection criteria for the subsystem installed in the trainway shall conform to the requirements for underground trainways that are listed in 6.2.5.2.

6.4.4 Electric Wire and Cable Requirements. All wiring materials and installations other than for traction power shall conform to the requirements of NFPA 70.

6.4.5 Emergency Access.

6.4.5.1 Access to the trainway shall be from stations or by mobile ladder equipment from roadways adjacent to the trackway.

6.4.5.2 If no adjacent or crossing roadways exist, access roads at a maximum of 762 m (2500 ft) intervals shall be required.

6.4.5.3 If security fences are used along the trackway, access gates shall be provided as deemed necessary by the authority having jurisdiction.

6.4.5.4 Information shall be provided adjacent to each blue light station that identifies the route and location of the access.

6.4.5.5 The graphics shall be legible from the ground level outside the trackway.

6.4.6 Egress for Passengers.

6.4.6.1 The system shall incorporate a walk surface or other means for passengers to evacuate a train at any point along the trainway so that they can proceed to the nearest station or other point of safety.

6.4.6.2 System egress points shall be illuminated.

Chapter 7 Emergency Ventilation System

7.1 General.

7.1.1* This chapter defines the requirements for the environmental conditions and the mechanical and nonmechanical ventilation systems used to meet those requirements for a fire emergency in a station or trainway as required by Section 5.3 and 6.2.2.

7.1.2 The requirement for a mechanical or nonmechanical system intended for the purpose of emergency ventilation shall be determined in accordance with 7.1.2.1 through 7.1.2.4.

7.1.2.1 For length determination, include all contiguous enclosed trainway and underground fixed guideway transit station segments between portals.

7.1.2.2 A mechanical emergency ventilation system shall be provided in the following locations:

(1) In an enclosed fixed guideway transit station
(2) In a fixed guideway transit underground or enclosed trainway that is greater in length than 304.8 m (1000 ft)

7.1.2.3 A mechanical emergency ventilation system shall not be required in the following locations:

(1) In an open fixed guideway transit station
(2) Where the length of an underground trainway is less than or equal to 61 m (200 ft)

7.1.2.4 Where supported by engineering analysis, a nonmechanical emergency ventilation system shall be permitted to be provided in lieu of a mechanical emergency ventilation system in the following locations:

(1) Where the length of the underground or enclosed trainway is less than or equal to 304.8 m (1000 ft) and greater than 61 m (200 ft)
(2) In an enclosed station where engineering analysis indicates that a nonmechanical emergency ventilation system supports the tenability criteria of the project.

7.1.2.5 In the event that an engineering analysis is not conducted, or does not support the use of a nonmechanical emergency ventilation system, for the configurations described in 7.1.2.4, a mechanical emergency ventilation system shall be provided.

7.1.3 The engineering analysis of the ventilation system shall include a validated subway analytical simulation program augmented as appropriate by a quantitative analysis of airflow dynamics produced in the fire scenario, such as would result from the application of validated computational fluid dynamics (CFD) techniques. The results of the analysis shall include the no-fire (or cold) air velocities that can be measured during commissioning to confirm that a mechanical ventilation system as built meets the requirements determined by the analysis.

7.1.4 Where required by 7.1.2, the mechanical emergency ventilation system shall make provisions for the protection of passengers, employees, and emergency personnel from fire and smoke during a fire emergency and shall be designed to maintain the required airflow rates for a minimum of 1 hour but not less than the anticipated evacuation time.

7.2 Design.

7.2.1 The emergency ventilation system shall be designed to do the following:

(1) Provide a tenable environment along the path of egress from a fire incident in enclosed stations and enclosed trainways
(2) Produce airflow rates sufficient to prevent backlayering of smoke in the path of egress within enclosed trainways
(3) Be capable of reaching full operational mode within 180 seconds
(4) Address the maximum number of trains that could be between ventilation shafts during an emergency

7.2.2 The design shall encompass the following:

(1) The heat release rate produced by the combustible load of a vehicle and any combustible materials that could contribute to the fire load at the incident site
(2) The fire growth rate
(3) Station and trainway geometries
(4) A system of fans, shafts, and devices for directing airflow in stations and trainways
(5) A program of predetermined emergency response procedures capable of initiating prompt response from the central supervising station in the event of a fire emergency

7.2.3 The design and operation of the signaling system, traction power blocks, and ventilation system shall be coordinated to match the total number of trains that could be between ventilation shafts during an emergency.

7.3 Emergency Ventilation Fans.

7.3.1 The ventilation system fans that are designated for use in fire emergencies shall be capable of satisfying the emergency ventilation requirements in either the supply mode or exhaust mode.

7.3.1.1 Individual emergency ventilation fan motors shall be designed to achieve their full operating speed in no more than 30 seconds from a stopped position when started across the line and in no more than 60 seconds for variable-speed motors.

7.3.2 Emergency ventilation fans, their motors, and all related components exposed to the exhaust airflow shall be designed to operate in an ambient atmosphere of 250°C (482°F) for a minimum of 1 hour.

7.3.2.1 A design analysis shall be permitted to be used to reduce this temperature; however, it shall not be less than 150°C (302°F).

7.3.3 Fans shall be rated in accordance with the ANSI/AMCA 210-99, AMCA 300-96, ASHRAE *Handbook Fundamentals*, and ASHRAE 149-2000.

7.3.4 Local fan motor starters and related operating control devices shall be located away from the direct airstream of the fans to the greatest extent practical.

7.3.4.1 Thermal overload protective devices on motor controls of fans used for emergency ventilation shall not be permitted.

7.3.5 Fans that are associated only with passenger or employee comfort and that are not designed to function as a part of the emergency ventilation system shall shut down automatically on identification and initiation of a fire emergency ventilation program so as not to jeopardize or conflict with emergency airflows.

7.3.5.1 Nonemergency ventilation airflows that do not impact the emergency ventilation airflows shall be permitted to be left operational where identified in the engineering analysis.

7.3.6 Critical fans required in battery rooms or similar spaces where hydrogen gases or other hazardous gases might be released shall be designed to meet the ventilation requirements of NFPA 91.

7.3.6.1 These fans and other critical fans in automatic train control rooms, communications rooms, and so forth, shall be identified in the engineering analysis and shall remain operational as required during the fire emergency.

7.4 Devices.

7.4.1 Devices that are interrelated with the emergency ventilation system and that are required to meet the emergency ventilation system airflows shall be structurally capable of withstanding both maximum repetitive and additive piston pressures of moving trains and emergency airflow velocities.

7.4.2 Devices that are subject to exposure to the fire anticipated in the design of the emergency ventilation system and are critical to its effective functioning in the event of that emergency shall be constructed of noncombustible, fire-resistant materials and shall be designed to operate in an ambient atmosphere of 250°C (482°F) for a minimum of 1 hour.

7.4.2.1 A design analysis shall be permitted to be used to reduce this temperature; however, it shall not be less than 150°C (302°F).

7.4.2.2 Finishes applied to noncombustible devices are not required to meet the provisions of 7.4.2.

7.4.3 Devices shall be designed to operate throughout the maximum anticipated temperature range.

7.5 Shafts.

7.5.1 Shafts that penetrate the surface and that are used for intake and discharge in fire or smoke emergencies shall be positioned or protected to prevent recirculation of smoke into the system through surface openings.

7.5.2 If this is not possible, surface openings shall be protected by other means to prevent smoke from re-entering the system.

7.5.3 Adjacent structures and property uses also shall be considered.

7.6 Emergency Ventilation System Control/Operation.

7.6.1 Operation of the emergency ventilation system components shall be initiated from the central supervising station.

7.6.1.1 The central supervising station shall receive verification of proper response by emergency ventilation fan(s) and interrelated device(s).

7.6.1.2 Local controls shall be permitted to override the central supervising station in all modes in the event the central supervising station becomes inoperative or where the operation of the emergency ventilation system components is specifically redirected to another site.

7.6.2 Operation of the emergency ventilation system shall not be discontinued until directed by the incident commander.

7.7 Power and Wiring.

7.7.1 The power for the emergency ventilation fan plants shall be provided by feeders from two separate and distinct utility substations.

7.7.1.1 If a second feeder is not available, an emergency backup system shall be permitted to provide the second power source if designed to meet the demands of the emergency modes.

7.7.1.2 Where an emergency backup system is utilized, it shall comply with the provisions of NFPA 110.

7.7.2 All wiring materials and installations shall conform to the requirements of NFPA 70 and, in addition, shall satisfy the requirements of 7.7.3 through 7.7.8.

7.7.3 Materials manufactured for use as conduits, raceways, ducts, boxes, cabinets, equipment enclosures, and their surface finish materials shall withstand temperatures up to 500°C (932°F) for 1 hour and shall not support combustion under the same temperature condition. Other materials where encased in concrete shall be acceptable.

7.7.4 All conductors shall be insulated.

7.7.4.1 Ground wires shall be permitted to be bare.

7.7.4.2 All thicknesses of jackets shall conform to NFPA 70.

7.7.5 All insulations shall conform to Article 310 of NFPA 70 and shall be moisture- and heat-resistant types carrying temperature ratings corresponding to the conditions of application and in no case lower than 90°C (194°F).

7.7.6 Wire and cable constructions intended for use in control circuits and power circuits to related emergency devices shall be listed as being resistant to the spread of fire and shall have reduced smoke emissions.

7.7.6.1 Cable shall be permitted to be listed by any of the following methods:

(1) The cable does not spread fire to the top of the tray in the vertical-tray flame test in UL 1581, Section 1160, and the cable exhibits a specific optical density of smoke at 4 minutes into the test that does not exceed 200 (in the flaming mode) or 75 (in the nonflaming mode) when tested in accordance with ASTM E 662.
(2) The cable exhibits damage (char length) that does not exceed 1.5 m (4.9 ft) when the vertical flame test, with cables in cable trays, is performed as described in CSA C22.2 No. 0.3, and the cable exhibits a specific optical density of smoke at 4 minutes into the test that does not exceed 200 (in the flaming mode) or 75 (in the nonflaming mode) when tested in accordance with ASTM E 662.

(3) The cable is listed as a limited smoke cable (/LS) by meeting the cable damage height, total smoke released, and peak smoke release rate criteria required when tested in the vertical tray flame test in UL 1685. The following performance criteria shall be met when testing according to UL 1685:
   (a) When testing in the UL vertical tray flame exposure:
      i. The cable damage height shall be less than 2.44 m (8 ft) when measured from the bottom of the cable tray.
      ii. The total smoke released shall not exceed 95 m^2 (1023.6 ft^2).
      iii. The peak smoke release rate shall not exceed 0.25 m^2/s (2.7 ft^2/s).
   (b) Alternatively, when testing in the IEEE 1202 flame exposure:
      i. The cable damage height shall be less than 1.5 m (4.9 ft) when measured from the lower edge of the burner face.
      ii. The total smoke released shall not exceed 150 m^2 (1615 ft^2).
      iii. The peak smoke release rate shall not exceed 0.40 m^2/s (4.3 ft^2/s).

(4) The cable is listed as having fire-resistant characteristics capable of preventing the carrying of fire from floor to floor, by being capable of passing the requirements of the ANSI/UL 1666, and the cable exhibits a specific optical density of smoke at 4 minutes into the test that does not exceed 200 (in the flaming mode) or 75 (in the nonflaming mode) when tested in accordance with ASTM E 662.

(5) The cable is listed as having adequate fire-resistant and low smoke-producing characteristics, by having a flame travel distance that does not exceed 1.52 m (5 ft), generating a maximum peak optical density of smoke of 0.5 and a maximum average optical density of smoke of 0.15 when tested in accordance with NFPA 262.

7.7.7* All conductors for emergency ventilation fans and related emergency devices shall be protected from physical damage by transit vehicles or other normal system operations and from fires in the system by embedment, encasement, or location.

7.7.7.1 Except in ancillary areas or other nonpublic areas, encased conductors shall be enclosed in their entirety in armor sheaths, conduits, or enclosed raceway boxes and cabinets.

7.7.7.2 Conductors in conduits or raceways shall be permitted to be embedded in concrete or to run in concrete electrical duct banks.

7.7.7.3 Conductors in conduits or raceways shall not be installed exposed or surface mounted in air plenums that might carry elevated temperatures accompanying fire emergency conditions.

7.7.8 Overcurrent elements that are designed to protect conductors serving motors for both emergency fans and related emergency devices that are located in spaces other than the main electrical distribution system equipment rooms shall not depend on thermal properties for operation.

7.7.9 For electrical substations and distribution rooms serving emergency ventilation systems where the local environmental conditions require the use of mechanical ventilation or cooling to maintain the space temperature below the electrical equipment operating limits, such mechanical ventilation or cooling systems shall be designed so that failure of any single air moving or cooling unit does not result in the loss of the electrical supply to the tunnel ventilation fans during the specified period of operation.

Chapter 8 Vehicles

8.1 Applicability.

8.1.1 New Vehicles. All new fixed guideway transit and passenger rail vehicles shall be, at a minimum, designed and constructed to conform to the requirements set forth in this chapter.

8.1.2 Retrofit. Where existing fixed guideway transit and passenger rail vehicles are to be retrofitted, the appropriate sections of this standard shall apply only to the extent of such retrofit.

8.2 Compliance Options.

8.2.1 General. Fixed guideway and passenger rail vehicles meeting the goals and objectives of Sections 4.2 and 4.3 shall meet the requirements of either 8.2.2 or 8.2.3.

8.2.2 Prescriptive-Based Option. The prescriptive-based design option shall be conducted in accordance with Sections 8.2 through 8.10.

8.2.3 Performance-Based Option. The performance-based design option shall be conducted in accordance with Section 8.11.

8.3 Prescriptive-Based Construction Requirements.

8.3.1* General. This chapter describes test procedures and minimum performance requirements for materials used in the construction or retrofit of fixed guideway or passenger rail vehicles.

8.3.2 Equipment Arrangement.

8.3.2.1 Heat-producing equipment or equipment posing an ignition or fire threat in vehicles, including associated electrical services, shall be isolated from passenger and crew compartments by suitable construction.

8.3.2.2* Vehicle design shall arrange equipment apparatus external to the passenger and crew compartment where practical.

8.3.2.3 Materials used for ducting and plenums serving the vehicle interior shall be noncombustible or shall comply with the requirements in Table 8.4 for HVAC ducting materials.

8.3.2.4 Fuel tanks shall be designed to minimize passenger and crew exposure to fuel hazards.

8.4 Fire Propagation Resistance.

8.4.1 Interior Fire Propagation Resistance.

8.4.1.1 Interior materials and finishes shall resist an interior vehicle fire for a nominal time period determined by the authority having jurisdiction.

8.4.1.2 The nominal time period shall be a minimum of at least twice the maximum expected time period under normal circumstances for a vehicle to stop completely and safely from its maximum operating speed, plus the time necessary to evacuate all vehicle occupants to a safe area.

8.4.1.3 The nominal time period shall be consistent with the safe evacuation of a crush load of passengers from the vehicle under worst-case conditions.

Table 8.4 Test Procedures and Performance Criteria for the Flammability and Smoke Emission Characteristics of Materials Used in Fixed Guideway Vehicles and Passenger Rail Cars

Category	Function of Material	Test Method	Performance Criteria
Cushions, mattresses	All [1–8]	ASTM D 3675	$I_s \leq 25$
		ASTM E 662	D_s (1.5) ≤ 100 D_s (4.0) ≤ 175
Fabrics	All [1–3, 6–8]	14 CFR 25, Appendix F, Part I (vertical test)	Flame time ≤ 10 seconds Burn length ≤ 6 in.
		ASTM E 662	D_s (4.0) ≤ 200
Interior vehicle components[9–12]	Seat and mattress frames, wall and ceiling lining and panels, seat and toilet shrouds, trays and other tables, partitions, shelves, opaque windscreens, and combustible signage [1, 2, 9]	ASTM E 162	$I_s \leq 35$
		ASTM E 662	D_s (1.5) ≤ 100 D_s (4.0) ≤ 200
	Flexible cellular foams used in armrest and seat and mattress padding [1–3, 6]	ASTM D 3675	$I_s \leq 25$
		ASTM E 662	D_s (1.5) ≤ 100 D_s (4.0) ≤ 175
	Thermal and acoustical insulation[1, 2]	ASTM E 162	$I_s \leq 25$
		ASTM E 662	D_s (4.0) ≤ 100
	HVAC ducting [1, 2]	ASTM E 162	$I_s \leq 25$
		ASTM E 662	D_s (4.0) ≤ 100
	Floor covering[12, 13]	ASTM E 648	CRF ≥ 5 kW/m^2
		ASTM E 662	D_s (1.5) ≤ 100 D_s (4.0) ≤ 200
	Light diffusers, windows and transparent plastic windscreens [2, 14]	ASTM E 162	$I_s \leq 100$
		ASTM E 662	D_s (1.5) ≤ 100 D_s (4.0) ≤ 200
Elastomers[1, 10]	Window gaskets, door nosings, intercar diaphragms, and roof mats	ASTM C 1166	Pass[15]
		ASTM E 662	D_s (1.5) ≤ 100 D_s (4.0) ≤ 200
Exterior vehicle components[1, 2, 10, 11]	End caps, roof housings, articulation bellows, exterior shells, and component boxes and covers	ASTM E 162	$I_s \leq 35$
		ASTM E 662	D_s (1.5) ≤ 100 D_s (4.0) ≤ 175
Wire and cable	All	UL 1581, CSA C22.2, UL 1685, ANSI/UL 1666, NFPA 262, ASTM E 662[16]	Pass; see 8.5.7.1
	Control and low voltage	ICEA S-19/NEMA WC3, UL 44, UL 83	Pass; see 8.5.7.1.3
	Fire alarm cable	IEC 60331-11	Pass; see 8.5.7.1.4
Structural components[17]	Flooring,[18] other[19]	ASTM E 119	Pass

[1] See 8.4.1.5.1.
[2] See 8.4.1.5.2.
[3] See 8.4.1.5.3.
[4] See 8.4.1.5.4.
[5] See 8.4.1.5.5.
[6] See 8.4.1.5.6.
[7] See 8.4.1.5.7.
[8] See 8.4.1.5.8.
[9] See 8.4.1.5.9.
[10] See 8.4.1.5.10.
[11] See 8.4.1.5.11.
[12] See 8.4.1.5.12.
[13] See 8.4.1.5.13.
[14] See 8.4.1.5.14.
[15] See 8.4.1.5.15.
[16] See 8.4.1.5.16.
[17] See 8.4.1.5.17.
[18] See 8.4.1.5.18.
[19] See 8.4.1.5.19.

8.4.1.4 Such materials and finishes shall, at a minimum, include the following:

(1) Interior walls and ceiling linings
(2) Floor coverings
(3) Seats
(4) Sleeping accommodation
(5) Food service-related components
(6) Shades
(7) Drapes
(8) Curtains
(9) Glazing
(10) Transparencies
(11) Partitions
(12) Elastomer(s)
(13) Thermal and acoustical insulations

8.4.1.5* The test procedures and minimum performance for interior materials and finishes shall be as detailed in Table 8.4.

8.4.1.5.1 Materials tested for surface flammability shall not exhibit any flaming running or dripping unless an appropriate fire hazard analysis is conducted that addresses the location and quantity of the material used and the vulnerability of the materials to ignition and contribution to flame spread. *(See also 8.4.3.)*

8.4.1.5.2 The ASTM E 662 maximum test limits for smoke emission (specific optical density) shall be measured in either the flaming or nonflaming mode, utilizing the mode that generates the most smoke.

8.4.1.5.3* Testing of a complete seat assembly (including cushions, fabric layers, and upholstery) according to ASTM E 1537 using the pass/fail criteria of California Technical Bulletin 133 and testing of a complete mattress assembly (including foam and ticking) according to ASTM E 1590 using the pass/fail criteria of California Technical Bulletin 129 shall be permitted in lieu of the test methods prescribed herein, provided the assembly component units remain unchanged or new (replacement) assembly components possess fire performance properties equivalent to those of the original components tested.

8.4.1.5.3.1 A fire hazard analysis shall also be conducted that considers the operating environment within which the seat or mattress assembly will be used in relation to the risk of vandalism, puncture, cutting, introduction of additional combustibles, or other acts that potentially expose the individual components of the assemblies to an ignition source.

8.4.1.5.3.2 The requirements of 8.4.1.5.5, 8.4.1.5.6, 8.4.1.5.7, and 8.4.1.5.8 shall be met.

8.4.1.5.4 Testing shall be performed without upholstery.

8.4.1.5.5 The surface flammability and smoke emission characteristics shall be demonstrated to be permanent after dynamic testing according to ASTM D 3574, Test I_2 or Test I_3, both using Procedure B, except that the test samples shall be a minimum of 152.4 mm (6 in.) × 457 mm (18 in.) × the thickness used in end-use configuration, or multiples thereof. If Test I_3 is used, the size of the indentor described in Section 96.2 of ASTM D 3574 shall be modified to accommodate the specified test specimen.

8.4.1.5.6 The surface flammability and smoke emission characteristics shall be demonstrated to be permanent by washing, if appropriate.

8.4.1.5.7 The surface flammability and smoke emission characteristics shall be demonstrated to be permanent by dry cleaning, if appropriate, according to ASTM D 2724.

8.4.1.5.8 Materials that cannot be washed or dry-cleaned shall be so labeled and shall meet the applicable performance criteria after being cleaned as recommended by the manufacturer.

• **8.4.1.5.9** Combustible signage shall not be required to meet flame spread or smoke emission requirements if the combustible mass of a single sign does not exceed 0.5 kg (1.1 lb) and the aggregate area of combustible signage does not exceed 10 percent of the wall area of the car, including windows. *(See 8.4.3.)*

8.4.1.5.10 Materials used to fabricate miscellaneous, discontinuous small parts (such as knobs, rollers, fasteners, clips, grommets, and small electrical parts) that will not contribute materially to fire growth in end use configuration are exempt from flammability and smoke emission performance requirements, provided that the surface area of any individual small part is less than 100 cm^2 (16 $in.^2$) in end use configuration and an appropriate fire hazard analysis is conducted that addresses the location and quantity of the materials used and the vulnerability of the materials to ignition and contribution to flame spread.

8.4.1.5.11* If the surface area of any individual small part is less than 100 cm^2 (16 $in.^2$) in end use configuration, materials used to fabricate such a part shall be permitted to be tested in accordance with ASTM E 1354 as an alternative to both the ASTM E 162 flammability test procedure or the appropriate flammability test procedure otherwise specified in Table 8.4 and the ASTM E 662 smoke generation test procedure. Testing shall be at 50 kW/m^2 (4.4 $Btu/sec{\cdot}ft^2$) applied heat flux with a retainer frame. Materials tested in accordance with ASTM E 1354 shall meet the following performance criteria: Materials tested shall meet the performance criteria of 180 second average heat release rate of $q''_{180} < 100$ kW/m^2 (8.8 $Btu/sec{\cdot}ft^2$) and test average smoke extinction area (F_f) < 500 m^2/kg (2441.2 ft^2/lb).

8.4.1.5.12 Carpeting used as a wall or ceiling covering shall be tested according to ASTM E 162 and ASTM E 662 and meet the respective criteria of $I_s \leq 35$, D_s (1.5) ≤ 100, and D_s (4.0) ≤ 200. *(See 8.4.1.5.1 and 8.4.1.5.2.)*

8.4.1.5.13 Floor covering shall be tested with padding in accordance with NFPA 253 or ASTM E 648, if padding is used in the actual installation.

8.4.1.5.14 For double window glazing, only the interior glazing is required to meet the requirements specified in Table 8.4. (The exterior glazing is not required to meet these requirements.)

8.4.1.5.15 Average flame propagation shall be less than 101.6 mm (4 in.), and no specimen shall be completely consumed.

8.4.1.5.16 All wires and cables shall be listed as being resistant to the spread of fire and shall have reduced smoke emissions. *(See 8.5.7.1.1 for requirements.)*

8.4.1.5.17 Penetrations (ducts, etc.) shall be designed against acting as passageways for fire and smoke, and representative penetrations shall be included as part of test assemblies.

8.4.1.5.18* A structural flooring assembly separating the interior of a vehicle from its undercarriage shall meet the performance criteria during a nominal test period as determined by the railroad. The nominal test period shall be twice the maximum expected time period under normal circumstances for a vehicle to stop completely and safely from its maximum operating speed, plus the time necessary to evacuate all the vehicle's occupants to a safe area. The nominal test period shall not be less than 15 minutes. The fire resistance period required shall be consistent with the safe evacuation of a full load of passengers from the vehicle under worst-case conditions.

8.4.1.5.19 Portions of the vehicle body (including equipment-carrying portions of a vehicle's roof and interior floors separating the lower level of a bilevel car, but not including a flooring assembly subject to 8.4.1.5.18) that separate major ignition sources, energy sources, or sources of fuel load from vehicle interiors shall have sufficient fire endurance as determined by a fire hazard analysis that addresses the location and quantity of the materials used, as well as vulnerability of the materials to ignition, flame spread, and smoke generation. In those cases, the use of the ASTM E 119 test procedure shall not be required.

8.4.2 Exterior Fire Propagation Resistance.

8.4.2.1 Exterior materials and finishes shall resist an exterior vehicle fire for a nominal time period determined by the authority having jurisdiction.

8.4.2.2 The nominal time period shall be a minimum of at least twice the maximum expected time period under normal circumstances for a vehicle to stop completely and safely from its maximum operating speed, plus the time necessary to evacuate all vehicle occupants to a safe area.

8.4.2.3 The nominal time period shall be consistent with the safe evacuation of a crush load of passengers from the vehicle under worst-case conditions.

8.4.2.4 Such combustible materials shall, at a minimum, include all categories and functions included in Table 8.4.

8.4.2.5 The test procedures and minimum performance for exterior materials and finishes shall be as detailed in Table 8.4.

8.4.3 Materials not meeting the requirements of Table 8.4 shall be permitted only after an appropriate fire hazard analysis establishes, within the limits of precision, that the material produces a contribution to fire hazard equal to or less than a material meeting the appropriate criteria of Table 8.4, where the alternate material is used in the same location to fulfill a function similar to the candidate material.

8.5 Electrical Fire Safety.

8.5.1 General Construction. All motors, motor control, current collectors, and auxiliaries shall be of a type and construction suitable for use on fixed guideway transit and passenger rail vehicles.

8.5.2 Clearance and Creepage.

8.5.2.1 Electrical Circuit. Electrical circuits and associated cabling shall be designed with clearance and creepage distance between voltage potentials and car body ground considering the environmental conditions to which the circuits and cabling will be subjected.

8.5.2.2* Air Clearance. The air clearance distances between voltage potentials (up to 2000 V) and ground shall comply with the following formula:

$$\text{Clearance (mm)} = 3.175 + (0.0127 \cdot \text{nominal voltage})$$
$$[\text{Clearance (in.)} = 0.125 + (0.0005 \cdot \text{nominal voltage})]$$

8.5.2.3 Creepage Distance. Creepage distance for voltage potentials (up to 2000 V) to ground in ordinary enclosed environments shall comply with the following formula:

$$\text{Creepage (mm)} = 3.175 + (0.047625 \cdot \text{nominal voltage})$$
$$[\text{Creepage (in.)} = 0.125 + (0.001875 \cdot \text{nominal voltage})]$$

8.5.2.3.1* In other than ordinary enclosed environments, creepage distances shall be modified according to the anticipated severity of the environment.

8.5.3 Propulsion Motors.

8.5.3.1 Rotary motors shall be rated and tested in accordance with IEEE 11.

8.5.3.2 Motor leads shall have insulation suitable for the operating environment.

8.5.3.3 Motor leads shall be supported and protected against mechanical damage.

8.5.3.4 Motor leads, where entering the frame, shall be securely clamped and shall fit snugly to prevent moisture from entering the motor case.

8.5.3.5 Drip loops shall be formed in motor leads to minimize water running along the lead onto the motor case.

8.5.3.6 The current value used in determining the minimum size of motor leads shall not be less than 50 percent of the maximum load current seen under the most severe normal duty or as determined by root-mean-square (rms) calculation, whichever is greater.

8.5.3.7 Other car-borne propulsion configurations shall be designed and constructed to provide a similar level of rating and testing as that for rotary motors.

8.5.4 Motor Control.

8.5.4.1 Motor control shall be rated and tested in accordance with IEEE 16.

8.5.4.2 Control equipment enclosures shall be arranged and installed to provide protection against moisture and mechanical damage.

8.5.4.3 Metal enclosures that surround arcing devices shall be lined with insulating material approved by the authority having jurisdiction, unless otherwise permitted in 8.5.4.5.

8.5.4.4 Shields or separations shall be provided to prevent arcing to adjacent equipment and wiring.

8.5.4.5 Metal enclosures shall not be required to be lined where the arc chutes extend through the enclosure and vent the arc to the outside air.

8.5.5 Propulsion and Braking System Resistors.

8.5.5.1 Self-ventilated propulsion and braking resistors shall be mounted with air space between resistor elements and combustible materials.

8.5.5.2 Heat-resisting barriers of at least 6.38 mm (¼ in.) noncombustible insulating material, or sheet metal not less than 1.02 mm (0.04 in.) thickness, shall be installed extending horizontally beyond resistor supports to ensure protection from overheated resistors.

8.5.5.3 Forced ventilated resistors shall be mounted in ducts, enclosures, or compartments of noncombustible material.

8.5.5.3.1 Forced ventilated resistors shall be mounted with air space between the resistor enclosure and combustible materials.

8.5.5.4 Provisions shall be made to filter the air where the operating environment is severe.

8.5.5.5 Power resistor circuits shall incorporate protective devices for the following failures:

(1) Ventilation airflow, if appropriate
(2) Temperature controls, if appropriate
(3) Short circuit in supply wiring, if appropriate

8.5.5.6 Resistor elements, resistor frames, and support shall be electrically insulated from each other.

8.5.5.7 The insulation shall be removed from resistor leads a minimum of 75 mm (3 in.) back from their terminals except where such removal introduces potential grounding conditions.

8.5.5.8 Where forced ventilation is provided, the resistor leads shall be separated, secured, and cleated for protection in the event of loss of air circulation of the ventilating system.

8.5.5.9 Leads shall be so routed or otherwise protected from resistor heat.

8.5.5.10 The current value used in determining the minimum size of resistor leads shall not be less than 110 percent of the load current seen by the lead under the most severe duty cycle or as determined by rms calculation.

8.5.6 Current Collectors.

8.5.6.1 The minimum size of current collector leads shall be determined by adding the maximum auxiliary loads to the propulsion motor loads.

8.5.6.2 The equivalent regenerative load shall be included in the propulsion system equipped with regenerative capability.

8.5.6.3 For vehicles that have more than one current collector, all current-carrying components shall be sized for continuous operation in the event power collection to the vehicle is restricted to a single collector.

8.5.7 Wiring.

8.5.7.1 Electrical Insulation.

8.5.7.1.1 All wires and cables shall be listed as being resistant to the spread of fire and shall have reduced smoke emissions.

8.5.7.1.2 Cable shall be permitted to be listed by any of the following methods:

(1) The cable does not spread fire to the top of the tray in the vertical-tray flame test in UL 1581, Section 1160, and the cable exhibits a specific optical density of smoke at 4 minutes into the test that does not exceed 200 (in the flaming mode) or 75 (in the nonflaming mode) when tested in accordance with ASTM E 662.
(2) The cable exhibits damage (char length) that does not exceed 1.5 m (4.9 ft) when the vertical flame test, with cables in cable trays, is performed as described in CSA C22.2 No. 0.3, and the cable exhibits a specific optical density of smoke at 4 minutes into the test that does not exceed 200 (in the flaming mode) or 75 (in the nonflaming mode) when tested in accordance with ASTM E 662.
(3) The cable is listed as a limited smoke cable (/LS) by meeting the cable damage height, total smoke released, and peak smoke release rate criteria required when tested in the vertical tray flame test in the UL 1685. The following performance criteria shall be met when testing by UL 1685:
   (a) When testing in the UL vertical tray flame exposure:
      i. The cable damage height shall be less than 2.44 m (8 ft) when measured from the bottom of the cable tray.
      ii. The total smoke released shall not exceed 95 m^2 (1023 ft^2).
      iii. The peak smoke release rate shall not exceed 0.25 m^2/s (2.7 ft^2/s).
   (b) Alternatively, when testing in the IEEE 1202 flame exposure:
      i. The cable damage height shall be less than 1.5 m (4.9 ft) when measured from the lower edge of the burner face.
      ii. The total smoke released shall not exceed 150 m^2 (1615 ft^2).
      iii. The peak smoke release rate shall not exceed 0.40 m^2/s (4.3 ft^2/s).
(4) The cable is listed as having fire-resistant characteristics capable of preventing the carrying of fire from floor to floor, by being capable of passing the requirements of ANSI/UL 1666, and the cable exhibits a specific optical density of smoke at 4 minutes into the test that does not exceed 200 (in the flaming mode) or 75 (in the nonflaming mode) when tested in accordance with ASTM E 662.
(5) The cable is listed as having adequate fire-resistant and low smoke-producing characteristics, by having a flame travel distance that does not exceed 1.52 m (5 ft), generating a maximum peak optical density of smoke of 0.5 and a maximum average optical density of smoke of 0.15 when tested in accordance with NFPA 262.

8.5.7.1.3 Wires and cables for control and other low voltage (i.e, less than 100 V ac and 150 V dc) functions shall comply with 8.5.7.1.2 and either of the following:

(1) The physical, mechanical, and electrical property requirements of ICEA S-19/NEMA WC3
(2) UL 44 for thermosetting insulation and UL 83 for thermoplastic insulation

8.5.7.1.4 Wires and cables used for fire alarm cables shall comply with 8.5.7.1.2 and one of the following:

(1) Be capable of having 15 minute circuit integrity when tested in accordance with IEC 60331-11
(2) Demonstrate that, if circuit integrity is tested during the vertical flame test, a current continues operating for at least 5 minutes during the test
(3) Be fire alarm circuit integrity cable in accordance with NFPA 70

8.5.7.2 Minimum Wire Size. In no case shall wire smaller than the following sizes be used:

(1) No. 14 AWG for wire pulled through conduits or wireways or installed exposed between enclosures
(2) No. 22 AWG for wire used on electronic units, cards, and card racks
(3) No. 18 AWG for all other wire, including wire laid in (rather than pulled through) wireways

8.5.7.3 Cable and Wire Sizes.

8.5.7.3.1 Conductor sizes shall be selected on the basis of current-carrying capacity, mechanical strength, temperature and flexibility requirements, and maximum allowable voltage drops.

8.5.7.3.2 Conductors shall be no smaller than the minimum sizes specified in 8.5.7.2.

8.5.7.3.3 Conductors shall be derated for grouping and shall be derated for ambient temperature greater than the manufacturer's design value in accordance with criteria specified by the authority having jurisdiction.

8.5.7.4 Wiring Methods.

8.5.7.4.1 Conductors of all sizes shall be provided with mechanical and environmental protection and shall be installed, with the exception of low-voltage dc circuits, in any one of, or combination of, the following ways:

(1) In raceways: metallic and nonmetallic, rigid or flexible
(2) In enclosures, boxes, or cabinets for apparatus housing
(3) Exposed: cleated, tied, or secured by other means

8.5.7.4.2 Firestops shall be provided in raceways.

8.5.7.4.3 Wires connected to different sources of energy shall not be cabled together or be run in the same conduit, raceway, tubing, junction box, or cable unless all such wires are insulated for the highest rated voltage in such locations.

8.5.7.4.4 Wires connected to electronic control apparatus shall not touch wires connected to a higher voltage source of energy than control voltage.

8.5.7.4.5 Conduits, electrical metallic tubing, nonmetallic ducts or tubing, and all wires with their outer casings shall be extended into devices and cases where practicable.

8.5.7.4.6 Conduits, electrical metallic tubing, nonmetallic ducts or tubing, and all wires with their outer casings shall be rigidly secured in place by means of cleats, straps, or bushings to prevent vibration or movement and to give environmental protection.

8.5.7.4.7 Conduits, electrical metallic tubing, nonmetallic ducts or tubing, and all wires with their outer casings shall be run continuously into junction boxes or enclosing cases and be securely fastened to these devices.

8.5.7.4.8 Splices outside of junction boxes shall be approved by the authority having jurisdiction.

8.5.7.4.9 Connections and terminations shall be made in a manner to ensure their tightness and integrity.

8.5.7.4.10 Conductors and enclosures of any kind shall be protected from the environment and from mechanical damage, including damage from other larger conductors.

8.5.8 Overload Protection.

8.5.8.1 Propulsion Line Breaker.

8.5.8.1.1 A main, automatic circuit line breaker or line switch and overload relay for the protection of the power circuits shall be provided.

8.5.8.1.2 The circuit breaker arc chute shall be vented directly to the outside air.

8.5.8.2 Main Fuse Protection.

8.5.8.2.1 Cartridge-type fuses, if used in addition to the automatic circuit breaker, shall be installed in approved boxes or cabinets.

8.5.8.2.2 Railway-type ribbon fuses, if used, shall be in boxes designed specifically for this purpose and shall be equipped with arc blowout aids.

8.5.8.2.3 Third-rail shoe fuses mounted on the shoe beams shall be mounted to direct the arc away from grounded parts.

8.5.8.3 Auxiliary Circuits.

8.5.8.3.1 Circuits used for purposes other than propelling the vehicle shall be connected to the main cable at a point between the current collector and the protective device for the traction motors.

8.5.8.3.2 Each circuit or group of circuits shall be provided with at least one circuit breaker, fused switch, or fuse located as near as practicable to the point of connection of the auxiliary circuit.

8.5.8.3.2.1 Protection shall be permitted to be omitted in circuits controlling safety devices.

8.5.9 Battery Installation. Battery installations and circuitry shall include the following:

(1) Minimal use of organic materials, particularly those having hygroscopic properties
(2) Fire-retardant treatment for necessary organic materials used
(3) Battery chargers designed for protection against overcharging
(4) Use of smoke and heat detectors, if appropriate
(5) Use of an emergency battery cutoff switch, if appropriate
(6) Isolation of battery compartment from car interior using noncombustible materials, if appropriate

8.6 Structural Fire Resistivity.

8.6.1 General.

8.6.1.1 Portions of the vehicle body separating major ignition, energy, or fuel-loading sources from passenger and crew compartments, including equipment-carrying portions of vehicle roofs, shall have resistance to exterior fire penetration to these compartments for a period of time equal to or exceeding the time for safe evacuation of a crush load of passengers from the vehicle in the worst-case design situation plus an appropriate safety factor.

8.6.1.2 Design of floor systems shall take into account the potential fire hazard associated with operating components of underfloor equipment.

8.6.1.3 Consideration in the design process shall also be given to heat-producing equipment on roofs as well as potential fire propagation of items carried onto a vehicle by riders, and use and right-of-way characteristics that can affect evacuation time for a vehicle consist.

8.6.1.3.1 Table 8.4 contains test procedures and minimum performance requirements for materials used on interior of vehicles meeting the intent of 8.6.1.3.

8.6.2 Structural Component Test Criteria.

8.6.2.1 Where the floor separates major ignition, energy, or fuel-loading sources from the passenger compartment, the floor assembly shall meet the following criteria at the end of a nominal test period when subjected to the fire exposure as defined in NFPA 251 and ASTM E 119.

(1) Transmission of heat through the floor assembly shall not be sufficient to raise the temperature on its unexposed surface more than 139°C (250°F) average and 181°C (325°F) single point.
(2) The floor assembly shall have withstood the fire exposure without the passage of flame or gases hot enough to ignite cotton waste on the unexposed surface of the specimen.
(3) The floor assembly shall be tested with a representative loading consistent with the vehicle design.
(4) At a minimum, the size of the exposed portion of the floor assembly shall be 3.1 m (10 ft) long by the normal width of the vehicle floor. The assembly shall be configured to have at least one representative floor joint if joints are present and one of each type of typical floor penetration (e.g., air duct, wiring conduit). A proportional reduction shall be permitted to be made in the dimensions of the specimen, provided the specimen represents a true test of the ability of the structural flooring assembly to perform as a barrier against undervehicle fires.

8.6.2.2 The nominal test period shall be determined by the authority having jurisdiction to be a minimum of at least twice the maximum expected time period under normal circumstances for a vehicle to stop completely and safely from its maximum operating speed, plus the time necessary to evacuate all vehicle occupants to a safe area.

8.6.2.3 The nominal test period shall not be less than 15 minutes and the fire resistance period required shall be consistent with the safe evacuation of a crush load of passengers from the vehicle under worst-case conditions.

8.6.2.4 Tests for portions of the vehicle body, other than the floor, shall use either the test criteria defined for floors in 8.6.2.1 or criteria appropriate to the physical locations and magnitude of major ignition, energy, or fuel-loading sources.

8.6.2.4.1 Tests for portions of the vehicle body other than the floor shall demonstrate resistance to fire penetration to the interior of the vehicle by an external fire for a period of time equal to or exceeding the time for safe evacuation of a crush load of passengers from the vehicle in the worst-case design situation.

8.6.3 Overhead Power. Where vehicles are powered by overhead supply (e.g., trolley wire, catenary), consideration shall be given in roof design to prevention of arc penetration and to the susceptibility of materials in the roof assembly to ignition and or fire growth and spread.

8.6.4 Penetrations.

8.6.4.1 All floor, wall, and roof openings and penetrations shall be sealed or protected to maintain integrity of the structure against fire and smoke penetration.

8.6.4.2 The design features of 8.6.4.1 shall be in addition to mechanical considerations such as weatherproofing.

8.6.4.3 Test assemblies shall be representative of vehicle construction, including penetrations.

8.6.4.3.1 ASTM E 814 shall be utilized for evaluation of assemblies, including the construction features in 8.6.4.3.

8.7 Ventilation. Vehicles shall have provisions to deactivate all ventilation systems manually or automatically.

8.8 Emergency Egress Facilities.

8.8.1 Each vehicle shall be provided with a minimum of two means of emergency egress located on the sides or at the end(s) installed as remotely as practicable.

8.8.1.1 Alternate means of emergency egress, including roof hatches, as necessary for the type of vehicle shall be approved by the authority having jurisdiction.

8.8.2 A means to allow passengers to evacuate the vehicle safely to a walk surface or other suitable area under the supervision of authorized employees in case of an emergency shall be provided.

8.8.3 Emergency Lighting.

8.8.3.1 Emergency lighting facilities shall be provided such that the level of illumination of the means of egress shall conform to the specified level of illumination determined necessary by the authority having jurisdiction or with the following:

(1) A minimum, average illumination level of 10.76 lx (1 footcandle) measured at the floor level adjacent to each interior door, and each interior door providing access to an exterior door (such as a door opening into a vestibule) or other emergency egress facility
(2) A minimum, average illumination level of 10.76 lx (1 footcandle) measured 635 mm (25 in.) above floor level along the center of each aisle and passageway
(3) A minimum illumination level of 1.076 lx (0.1 foot-candle) measured 635 mm (25 in.) above floor level at any point along the center of each aisle and passageway

8.8.3.2 The emergency lighting system power shall be automatically obtained from storage batteries.

8.8.3.3 The lighting illumination level shall be not less than 60 percent of the minimum light levels specified in 8.8.3.1 after 1 hour of continuous illumination.

8.8.4* Operation of Means of Emergency Egress. Means of emergency egress using doors, windows, or roof hatches shall be capable of being operated manually without special tools from the interior and exterior of the vehicle.

8.8.5* Marking and Instructions for Operation of Means of Emergency Egress.

8.8.5.1 Marking. A sign identifying the means of emergency egress shall be provided adjacent to the means of emergency egress.

8.8.5.2 Instructions. Instructions for the operation of the vehicle means of emergency egress shall be located on photoluminescent material on the inside of the vehicle at or near the means of emergency egress.

8.8.5.2.1 The location and instructions for the operation of vehicle means of emergency access shall be legibly marked on or near the means of emergency egress on the outside of the vehicle with retroreflective material in accordance with ASTM E 810.

8.8.5.2.2 Reflective material shall have minimum color coefficient criteria of (100 to 200 $Cd/fc=ft^2$) for light material and (20 to 40 $Cd/fc=ft^2$) for dark material.

8.9 Protective Devices.

8.9.1 General. During normal vehicle operation, protective devices shall not introduce new hazards.

8.9.2 Communications.

8.9.2.1 Each manually operated vehicle shall be equipped with a communication system consisting of the following:

(1) A PA system whereby the train, crew personnel, and, at the option of the authority, the central supervising station can make announcements to the passengers
(2) A radio system whereby the train operator can communicate with the central supervising station
(3) An intercommunication system whereby the train crew can communicate with one another
(4) At the option of the authority, a device that can be used by passengers to alert the operator of an emergency

8.9.2.2 Each automated guideway transit (AGT) system vehicle shall be equipped with a communication system consisting of the following:

(1) A PA system whereby the central supervising station can make announcements to the passengers
(2) A system whereby the passengers can communicate with the central supervising station

8.9.2.3 Unauthorized opening of doors or emergency exit facilities on vehicles shall be automatically communicated to the central supervising station or train operator.

8.9.3 Portable Fire Extinguishers.

8.9.3.1 Each vehicle or operator's cab shall be equipped with an approved portable fire extinguisher, unless otherwise permitted in 8.9.3.3.

8.9.3.2 Portable fire extinguishers shall be selected, inspected, and maintained in accordance with NFPA 10.

8.9.3.3 Portable fire extinguishers shall not be required in the vehicle or cab where sufficient wayside extinguishers, standpipe systems, or other fire-fighting equipment is available.

8.9.4 Lightning Protection.

8.9.4.1 Each vehicle that is supplied power from the overhead electrical contact wire shall be provided with a suitable and effective lightning arrester for the protection of all electrical circuits.

8.9.4.2 Lightning arresters on vehicles shall have a grounding connection of not less than 6 AWG and be run in as straight a line as possible to the ground.

8.9.4.2.1 Lightning arresters shall be properly protected against mechanical injury.

8.9.4.2.2 The grounding conductor shall not be run in metal conduit unless such conduit is bonded to the grounding conductor at both ends.

8.9.5 Heater Protection.

8.9.5.1 All heater elements shall incorporate protective devices for the following failures:

(1) Ventilation airflow, if appropriate
(2) Failure of temperature controls or occurrence of overtemperature conditions, as appropriate
(3) Short circuits and overloads in supply wiring

8.9.5.2 Heater-forced air distribution ducts and plenums shall incorporate overtemperature sensors, fusible links, airflow devices, or other means to detect overtemperature or lack of airflow.

8.9.6 Testing and Maintenance.

8.9.6.1 Qualification testing shall be performed by the equipment manufacturer in accordance with the following:

(1) IEEE 16
(2) IEEE 11
(3) Any additional tests specified by the authority having jurisdiction

8.9.6.2 Periodic maintenance shall be performed in accordance with maintenance manuals furnished by the equipment manufacturer.

8.9.6.2.1 The degree and frequency of maintenance shall be based on operating experience as determined by the authority.

8.10 Vehicle Support and Guidance System.

8.10.1 The vehicle support and guidance system (i.e., wheels, tires, magnetic or pneumatic levitation) shall be capable of safely supporting and guiding the vehicle in normal service.

8.10.2 Failure of support, guidance, or levitation system shall not result in a condition that is unsafe to passengers.

8.10.3 Under loss of guideway clearance, the system shall be capable of safe operation until such time that the failure is detected by operation or maintenance personnel and the vehicle is taken out of service.

8.11 Performance-Based Requirements.

8.11.1* Application. The requirements of this section shall apply to fixed guideway and passenger rail vehicles designed to the performance-based option permitted by Section 8.2.

8.11.2* Goals and Objectives. The performance-based design shall meet the goals and objectives of this standard in accordance with Sections 4.2 and 4.3.

8.11.3* Approved Qualifications. The performance-based design shall be prepared by a person with qualifications acceptable to the authority having jurisdiction.

8.11.4* Independent Review. The authority having jurisdiction shall at their discretion require an approved, independent third party to review the proposed design to provide an evaluation of the design.

8.11.5 Sources of Data.

8.11.5.1 Data sources used in performance-based design activities shall be identified and documented for each input data requirement that must be met using a source other than a design fire scenario, an assumption, or a vehicle design specification.

8.11.5.2 The degree of conservatism reflected in such data shall be specified, and a justification for the source shall be provided.

8.11.6 Final Determination. The authority having jurisdiction shall make the final determination as to whether performance objectives have been met.

8.11.7* Maintenance of Design Features.

8.11.7.1 The design features required for the fixed guideway or passenger rail vehicle to meet the performance goals and objectives set forth in this standard shall be intrinsic or shall be purposefully maintained for the life of the vehicle.

8.11.7.2 Performance goals and objectives shall include complying with all documented assumptions, design specifications, and operating environment.

8.11.7.3 Any variations from the original features agreed upon shall require the approval of the authority having jurisdiction prior to the actual change.

8.11.7.4 Where compliance with the standard is effected by means of a performance-based design, the operator shall certify compliance annually with the conditions and limitations of the design by submitting an acceptable warrant of fitness if required by the authority having jurisdiction.

8.11.7.4.1 The warrant of fitness shall attest that the vehicle features, systems, operating environment, and use remain consistent with design specification outlined in the documentation required by 8.11.14, that fire safety systems have been inspected in accordance with applicable NFPA standards for those systems, and that they continue to satisfy the goals and objectives specified in Sections 4.2 and 4.3.

8.11.8* Performance Criteria.

8.11.8.1 General. A design shall meet the objectives specified in Section 4.3 only if, for each design fire scenario, assumption, and design specification, the performance criterion in 8.11.8.2 is met.

8.11.8.2* Performance Criterion. Occupants not intimate with ignition shall not be exposed to instantaneous or cumulative untenable conditions.

8.11.9* Retained Prescriptive Requirements.

8.11.9.1* Systems and Features. All fire protection systems and features of the vehicle shall comply with applicable NFPA standards for those systems and features.

8.11.9.2 The design shall comply with the following requirements in addition to the performance criteria of 8.11.8.2 and the methods of 8.11.10 through 8.11.14.

(1) Electrical fire safety requirements — Section 8.5
(2) Structural fire resistivity — Section 8.6, without reference to Table 8.4
(3) Vehicle support and guidance systems — Section 8.10

8.11.10* Design Specification and Other Conditions.

8.11.10.1 Clear Statement. Design specifications and other conditions used in the performance-based design shall be clearly stated and shown to be realistic and sustainable.

8.11.10.2 Assumptions and Design Specifications Data.

8.11.10.2.1 Each assumption and design specification used in the design shall be accurately translated into input data specifications, as appropriate for the calculation method or model used.

8.11.10.2.2 Any assumptions and design specifications that the design analysis does not explicitly address or incorporate and that are, therefore, omitted from input data specifications shall be identified, and a sensitivity analysis of the consequences of that omission shall be performed.

8.11.10.2.3 Any assumptions and design specifications modified in input data specifications, because of limitations in test methods or other data generation procedures, shall be identified, and a sensitivity analysis of the consequences of the modification shall be performed.

8.11.10.3 Vehicle Characteristics. Characteristics of the vehicle and its contents, equipment, operations, or operating environment that are not inherent in the design specifications, but that affect occupant behavior or the rate of hazard development, shall be explicitly identified.

8.11.10.4* Operational Status and Effectiveness of Vehicle Features and Systems. The performance of fire protection systems and vehicle features shall reflect the documented performance of the components of those systems or features unless design specifications are incorporated to modify the expected performance.

8.11.10.5 Occupant Characteristics.

8.11.10.5.1* Approval. The selection of occupant characteristics to be used in the design calculations shall be approved by the authority having jurisdiction and shall provide an accurate reflection of the expected population of the fixed guideway transit or passenger rail system users.

8.11.10.5.2 Profile. Occupant characteristics shall represent the normal occupant profile, unless design specifications are used to modify the expected occupant features.

8.11.10.5.3 Consistency. Occupant characteristics shall not vary across fire scenarios except as authorized by the authority having jurisdiction.

8.11.10.5.4 Response Characteristics. The basic response characteristics of sensibility, reactivity, mobility, and susceptibility shall be evaluated to reflect the expected distribution of characteristics of a population appropriate to the use of the vehicle.

8.11.10.5.4.1 The source of data for these characteristics shall be documented.

8.11.10.5.5 Location. It shall be assumed that in every normally occupied compartment or area at least one person shall be located at the most remote point from the exits.

8.11.10.5.6* Number of Occupants. The design shall be based on the peak hour ridership as commonly projected for design of new systems or as established by survey of similar operating systems.

8.11.10.5.6.1 In the design process, each proposed vehicle design shall be considered as being loaded to the maximum consistent with that vehicle design and its peak hour ridership characteristics.

8.11.10.5.6.2 Where the success or failure of the design is contingent on the number of occupants not exceeding a certain maximum, operational controls shall be developed and specified in the design process to ensure that a greater number of people shall not occupy the vehicle designed in this way.

8.11.10.5.7* Staff Assistance. The abilities and characteristics of train personnel shall be included as part of the fire safety system design and shall be specifically identified and documented.

8.11.10.6 Emergency Response Personnel. Design characteristics or other conditions related to the availability, speed of response, effectiveness, roles, and other characteristics of emergency response personnel shall be specified, estimated, or characterized to a degree sufficient to satisfactorily evaluate accepted designs.

8.11.10.7* Postconstruction Conditions. Design characteristics or other conditions related to activities during the life of vehicle that affect the ability of that vehicle to meet the stated goals and objectives shall be specified, estimated, or characterized sufficiently for evaluation of the design.

8.11.10.8 Offsite Conditions. Design characteristics or other conditions related to resources or conditions outside the property being designed, such as right-of-way characteristics or accessibility to first responders, that potentially affect the ability of the vehicle design to meet the stated goals and objectives shall be specified, estimated, or characterized sufficiently for its comprehensive evaluation.

8.11.10.9* Consistency of Assumptions. The design shall not include mutually inconsistent assumptions, specifications, or statements of conditions.

8.11.10.10* Special Provisions. Additional provisions not covered by the design specifications, conditions, estimations, and assumptions provided in 8.11.10.1 through 8.11.10.9 but that are required for the design to comply with the performance objectives shall be documented.

8.11.11* Design Fire Scenarios.

8.11.11.1 Choice of Design Fire Scenarios. The authority having jurisdiction shall approve the parameters involved in design fire scenarios.

8.11.11.1.1 The proposed design shall be considered to meet the goals and objectives if it achieves the performance criteria for each required design fire scenario.

8.11.11.1.2 Each design fire scenario shall be challenging, but realistic, with respect to at least one of the following scenario specifications:

(1) Initial fire location
(2) Early rate of growth with respect to a specified fire severity
(3) Smoke generation and resulting obscuration and exposures

8.11.11.1.3 The scenario specifications shall be at least as challenging as any that can, to a practical extent, occur in the environment in which the vehicle operates.

8.11.11.2 Required Design Fire Scenarios.

8.11.11.2.1 Scenarios selected as design fire scenarios shall include, but shall not be limited to, those specified in ASTM E 2061, unless otherwise provided for in 8.11.11.2.2.

8.11.11.2.2 Design fire scenarios demonstrated by the design team to be inappropriate for the vehicle use and operating environment, to the satisfaction of the authority having jurisdiction, shall not be required to be evaluated fully.

8.11.11.3* Design Fire Scenario Data.

8.11.11.3.1 Each design fire scenario used in the performance-based design proposal shall be translated into input data specifications, as appropriate for the calculation method or model used.

8.11.11.3.2 Any design fire scenario specifications that the design analyses do not explicitly address or incorporate and that are omitted from input data specifications shall be identified, and a sensitivity analysis of the consequences of that omission shall be performed and results of the omission described in a report.

8.11.11.3.3 Any design fire scenario specifications modified in input data specifications, because of limitations in test methods or other data generation procedures, shall be identified, and a sensitivity analysis of the consequences of the modification shall be performed.

8.11.12* Evaluation of Proposed Designs.

8.11.12.1* General. A proposed design's performance shall be assessed relative to each performance objective in Section 4.3 and each applicable scenario in 8.11.11, with the assessment conducted through the use of appropriate calculation methods.

8.11.12.1.1 The authority having jurisdiction shall approve the choice of assessment methods.

8.11.12.2 Use. The designer shall use the assessment methods chosen to demonstrate that the proposed design will achieve the goals and objectives, as measured by the performance criteria in light of the safety factors and uncertainty analysis, for each scenario, given the assumptions.

8.11.12.3 Input Data.

8.11.12.3.1 Data. Input data for computer fire models shall be obtained in accordance with ASTM E 1591.

8.11.12.3.1.1 Data for use in analytical models that are not computer-based fire models shall be obtained using appropriate measurement, recording, and storage techniques to ensure the applicability of the data to the analytical method being used.

8.11.12.3.2* Uncertainty and Conservatism of Data. Uncertainty in input data shall be analyzed and, as determined appropriate by the authority having jurisdiction, addressed through the use of conservative values.

8.11.12.4 Output Data. The assessment methods used shall accurately and appropriately produce the required output data from input data based on the design specifications, assumptions, and scenarios.

8.11.12.5 Validity. Evidence shall be provided to confirm that the assessment methods are valid and appropriate for the proposed vehicle, use, and conditions.

8.11.13* Safety Factors. Approved safety factors shall be included in the design methods and calculations to reflect uncertainty in the assumptions, data, and other factors associated with the performance-based design.

8.11.14 Documentation Requirements.

8.11.14.1* General. All aspects of the design, including those described in 8.11.10.1 through 8.11.10.10, shall be documented.

8.11.14.1.1 The format and content of the documentation shall be acceptable to the authority having jurisdiction.

8.11.14.2* Technical References and Resources. The authority having jurisdiction shall be provided with sufficient documentation to support the validity, accuracy, relevance, and precision of the proposed methods.

8.11.14.2.1 The engineering standards, calculation methods, and other forms of scientific information provided shall be appropriate for the particular application and methodologies used.

8.11.14.3 Use of Performance-Based Design Option. Design proposals shall include documentation that provides all personnel involved in the ownership or management of the vehicle with notification of the following:

(1) The vehicle was approved as a performance-based design according to the specified design criteria and assumptions.
(2) Any and all remodeling, modification, renovation, change in use, retrofit, or change in the established assumptions associated with the use of the vehicle design in question shall require re-evaluation and reapproval of the original design.

8.11.14.4 Vehicle Design Specifications. All details of the proposed vehicle design that affect the ability of the vehicle to meet the stated goals and objectives shall be documented.

8.11.14.5 Performance Criteria. Performance criteria and sources of performance data shall be documented.

8.11.14.6 Occupant Characteristics. Assumptions related to occupant characteristics shall be documented.

8.11.14.7 Design Fire Scenarios. Descriptions of design fire scenarios used to evaluate the design(s) shall be documented.

8.11.14.8 Input Data. Input data to models and assessment methods, including sensitivity analyses, shall be documented.

8.11.14.8.1 A complete listing of input data requirements for all models, engineering methods, and other calculation or verification methods used as part of the performance-based design shall be included.

8.11.14.9 Output Data. Output data from models and assessment methods, including sensitivity analyses, shall be documented.

8.11.14.10 Safety Factors. The safety factors utilized shall be documented.

8.11.14.11* Prescriptive Requirements. Retained prescriptive requirements shall be documented.

8.11.14.12 Modeling Features.

8.11.14.12.1 Assumptions made by the model user, and descriptions of models and methods used, including known limitations, shall be documented.

8.11.14.12.2 Documentation shall be provided to verify that the assessment methods have been used validly and appropriately to address the design specifications, assumptions, and scenarios.

8.11.14.12.3 Evidence of Modeler Capability. The design team's relevant experience with the models, test methods, databases, and other assessment methods used in the performance-based design proposal shall be documented.

8.11.14.13 Performance Evaluation. The performance evaluation summary shall be documented.

Chapter 9 Vehicle Storage and Maintenance Areas

9.1 Administration.

9.1.1 The following requirements are directed toward maintaining adequate fire protection in all vehicle storage and maintenance areas.

9.1.2 Implementation of these requirements shall be according to the authority having jurisdiction and applicable local codes.

9.2 Open Areas.

9.2.1 Water Supply. An adequate, reliable water supply shall be available for fire protection, including a sufficient number of properly located hydrants, in accordance with NFPA 24.

9.2.2 Emergency Access.

9.2.2.1 Where the authority having jurisdiction deems it necessary, fire lane areas shall be laid out to permit access by mechanized fire-fighting equipment.

9.2.2.2 Access shall include the establishment of clearly marked fire lanes and the provision of a number of entrance gates into the property as determined by the authority having jurisdiction.

9.2.2.2.1 Fire lanes, where provided, shall comply with NFPA 1.

9.2.3 Fire Extinguishers. Fire extinguishers of adequate size and rating shall be provided, suitably housed and spaced in accordance with NFPA 10 and as required by the authority having jurisdiction.

9.2.4 Communications. Provisions shall be made within the property to summon the local fire department in accordance with provisions contained in Chapter 6 of *NFPA 72.*

9.3 Structures.

9.3.1 Structural Requirements. Structures shall be of noncombustible construction in accordance with NFPA 220.

9.3.2 Drainage Systems. All drainage systems shall be designed to reduce fire and explosion hazards by the use of noncombustible piping.

9.3.2.1 Where piping is not enclosed, as direct a routing as possible to a safe outside location shall be provided.

9.3.2.2* Oil separators, grease traps, and sand traps shall be installed on all floor drainage systems that service maintenance and vehicle storage areas.

9.3.2.3 Separators and grease traps shall be of approved design and of sufficient capacity to meet the level of waste discharged from the areas.

9.3.2.4 The separator storage capacity shall be of sufficient size to retain all the sludge between cleanings.

9.3.2.5 Periodic maintenance checks and flushing shall be conducted on all drains, oil separators, and grease traps to ensure that they are clear of obstructions and that they perform their designed function.

9.3.2.6 Any flammable liquids and greases shall be removed to an area approved for disposal.

9.3.3 Floors. The surface of the grade floor of storage or maintenance areas shall be of noncombustible material.

9.3.4 Roofs. Roof deck coverings shall be listed Class A or Class B in accordance with NFPA 256.

9.3.5 Electrical Requirements.

9.3.5.1 Application. The installation of electric wiring for structure light and power and the installation of all electrical devices not supplying traction power shall be in accordance with NFPA 70, ANSI C2, and applicable local codes as called for by the authority having jurisdiction.

9.3.5.2 Traction Power.

9.3.5.2.1 Overhead Conductors. Nonconducting material shall be used as a runway on which to mount overhead feed trolley wires.

9.3.5.2.1.1 Overhead trolley power installations shall have a minimum height of 3.05 m (10 ft) for isolation of the power lines from shop and storage activity unless an enclosed feed rail system is used with portable cord connectors that have insulated plugs and similar safety features.

9.3.5.2.2 Power Rail Conductors. Power rails (i.e., dc or ac power supplied to the vehicle for propulsion and other loads) shall be secured to suitable insulating supports, properly bonded at joints, and properly guarded to prevent contact with personnel.

9.3.5.2.3 Emergency Power Shutoff. All traction power conductors shall have emergency power shutoff devices or means in accessible locations.

9.3.6 Maintenance Pit Areas.

9.3.6.1 The authority having jurisdiction shall determine whether pit areas and associated access areas below floor level must be designed on the basis that flammable liquids and vapor will be present at times.

9.3.6.1.1 Pits shall be noncombustible and equipment shall be made of noncombustible construction. *(See also 9.3.8.1.)*

9.3.6.2 Walls, floors, and piers shall be constructed of masonry or concrete.

9.3.6.3 Pits shall have at least two exits.

9.3.6.4 Steps shall be noncombustible and constructed with no free space underneath.

9.3.6.5 Pits and subfloor work areas shall be kept clean.

9.3.6.6 Smoking shall be prohibited in pits and subfloor maintenance areas.

9.3.7 Overhead Cranes. All overhead cranes installed in the maintenance area shall adhere to the standard for cranes and monorails as required by NFPA 70.

9.3.8 Ventilation.

9.3.8.1 Underfloor Ventilation. In all pit areas where undercar maintenance can generate fumes of a combustible nature (e.g., blowdowns of transit vehicles), a positive mechanical exhaust ventilation system shall be provided that is capable of air changes at the rate of either 10 per hour or 0.005 $m^3/(s\text{-}m^2)$ (1 cfm per sq ft) of pit floor area, whichever is greater, during normal operation and shall be designed to discharge to the outside atmosphere.

9.3.8.2 Abovefloor Ventilation. Where a mechanical ventilating system is employed in shop maintenance areas, the ventilating system shall be installed in accordance with NFPA 90A.

9.3.8.2.1 Where blower and exhaust systems are installed for vapor removal, the systems shall be installed in accordance with NFPA 91.

9.3.9 Draft Stops.

9.3.9.1* Permanent draft stops in sprinklered buildings shall be installed in structures having a height of more than 7.6 m (25 ft) to the top of roof trusses.

9.3.9.2 Draft stops shall be constructed of rigidly supported noncombustible material. The authority having jurisdiction shall be consulted regarding the exact location of these draft stops.

9.4 Fire Protection Suppression Systems.

9.4.1 Automatic Suppression Systems.

9.4.1.1 An approved automatic sprinkler system shall be installed in all areas of enclosed structures used for storage and maintenance of vehicles.

9.4.1.2 The sprinkler system shall be of a closed-head type for ordinary hazard classification installed in accordance with NFPA 13.

9.4.1.3 A sprinkler system water flow alarm and supervisory signal service shall be installed in accordance with *NFPA 72*.

9.4.2 Protective Signaling Systems.

9.4.2.1 Nonsprinklered covered vehicle storage areas shall be equipped with an automatic fire detection system.

9.4.2.2 A signal of a fire shall be relayed to the supervising station or directly to the fire department.

9.4.2.3 The system shall comply with *NFPA 72*.

9.4.3 Standpipe and Hose Systems. Where standpipes and connections are required, the complete installation, including water supply, shall comply with NFPA 14.

9.4.4 Portable Fire Extinguishers.

9.4.4.1 General. Fire-extinguishing equipment and devices shall be provided in accordance with NFPA 10, subject to the provisions of 9.4.4.2 through 9.4.4.5.

9.4.4.2 Number and Capacity. The number and capacity of such units shall be determined by the authority having jurisdiction.

9.4.4.3 Offices and Storerooms. Offices and storerooms, other than those containing flammable liquids and greases, shall be provided with listed Class A extinguishers.

9.4.4.4 Hazardous Areas. Areas in which flammable or combustible liquids, greases, or chemicals are used or stored shall be provided with listed extinguishers for Class A, Class B, and Class C fires.

9.4.4.5 Additional Locations. Where cranes or monorails are installed inside structures for hoisting or transporting heavy rail equipment, fire extinguishers suitable for Class B and Class C fires shall be located as defined by the authority having jurisdiction.

9.5 Operations and Maintenance.

9.5.1 Vehicle Placement.

9.5.1.1 Vehicles shall be placed and tracks shall be arranged to allow a minimum clearance of 914 mm (36 in.) between the sides of adjacent vehicles.

9.5.1.2 The means of egress shall be in accordance with NFPA *101*.

9.5.2 Vehicle Maintenance.

9.5.2.1 Vehicle Electrical Systems. Vehicle electrical systems, including battery circuits, shall be de-energized except in those cases in which an energized circuit is necessary to accomplish the required maintenance.

9.5.2.2* Batteries. Vehicle batteries shall be disconnected or removed during maintenance operations that require the deenergizing of all electrical circuits.

9.5.2.2.1 Batteries shall be permitted to remain connected where the vehicle is equipped with a battery cutout switch that fully isolates the battery and is physically located immediately adjacent to the battery.

9.5.2.2.2 Areas wherein batteries are charged shall be ventilated to the outside to ensure that the maximum hydrogen-air mixture generated during charging is held below the lower explosive limits.

9.5.2.2.2.1 Where mechanical ventilation systems are required, they shall be installed in accordance with NFPA 91.

9.5.2.2.2.2 The battery exhaust ventilation system shall be provided with electrical power and airflow interlocks that will prevent operation of the battery charger if the ventilation fan motor is not energized or the air velocity in the exhaust duct is less than the designed velocity.

9.5.2.2.2.3 The entire electrical system shall be in accordance with NFPA 70.

9.5.2.2.3 Batteries shall be charged at a rate (i.e., amperage and length of charge) that will not produce a dangerous concentration of hydrogen or excessive heat.

9.5.2.2.3.1* Batteries shall be charged in accordance with the following safety practices:

(1) Access to battery rooms shall be limited to qualified personnel.
(2) Smoking shall be prohibited, and open flames, sparks, arcs, and other sources of ignition shall be kept away from the immediate vicinity of batteries that are being charged.
(3) Appropriate warning signs shall be displayed prominently.
(4) Brushes used to clean batteries shall have neither a metal frame nor wire bristles.

9.5.3 Painting, Cleaning, and Paint Removal.

9.5.3.1 Materials for cleaning and paint removal purposes shall be nonflammable wherever possible.

9.5.3.1.1 The use of flammable or combustible cleaning agents shall be in accordance with NFPA 30.

9.5.3.2 A location in which painting or cleaning is to be done shall be chosen that will provide good general ventilation, ease of cleanup, and convenience.

9.5.3.3 Where major cleaning, painting, and paint removal operations are being conducted, no concurrent potentially hazardous operations shall be conducted within 15.2 m (50 ft) of the area being worked on.

9.5.3.3.1 For touchup operations, any ignition sources within the areas being worked on shall be eliminated; such areas shall be maintained hazard free during the work period.

9.5.3.4 The use of heat lamps to accelerate the drying of painted surfaces shall be prohibited unless used as part of an approved drying booth or enclosure in accordance with NFPA 33.

9.5.3.5 Where cleaning or paint removal agents are applied through spray nozzles under pressure, the nozzle shall be of the self-closing type so that when the hand of the operator is removed the nozzle will close automatically.

9.5.4 Storage of Painting and Cleaning Liquids. Storage of painting and cleaning liquids shall be in accordance with NFPA 30.

9.5.5 Welding.

9.5.5.1 All welding operations performed on component vehicle parts shall be in accordance with NFPA 51B.

9.5.5.2 Welding shall not be done in an area that contains fuel or other flammable or combustible liquids or vapors.

9.5.5.3 No other work shall be permitted within a 10.7 m (35 ft) radius of the location of any gas-shielded arc welding operation unless the welding area is vented and enclosed in an approved manner to prohibit flammable and combustible vapors from entering the work area.

9.5.5.4 Welding equipment shall have no electrical components other than flexible lead cables within 457 mm (18 in.) of the floor.

9.5.5.5 Only qualified welders trained in the techniques and familiar with the hazards involved shall be permitted to do this work.

9.5.6 Industrial Trucks. Industrial trucks (i.e., fork trucks, tractors, platform lift trucks, and other specialized industrial trucks) and their operation and usage shall be in accordance with NFPA 505 and ANSI B56.1 and as determined by the authority having jurisdiction.

9.5.6.1 Fuel Handling. The storage and handling of liquefied petroleum gas (LP-Gas) shall be in accordance with NFPA 58.

9.5.6.2 The storage and handling of liquid fuels (e.g., gasoline and diesel) shall be in accordance with NFPA 30 and with local codes.

Chapter 10 Emergency Procedures

10.1 General.

10.1.1 The authority that is responsible for the safe and efficient operation of a fixed guideway transit or passenger rail system shall anticipate and plan for emergencies that could involve the system.

10.1.2 Participating agencies shall be invited to assist with the preparations of the emergency procedure plan.

10.2 Emergency Management.

10.2.1 Operational procedures for the management of emergency situations shall be predefined for situations within the fixed guideway transit or passenger rail system.

10.2.2 Operational procedures shall be recorded, accessible, and managed from a dedicated source at the central supervising station.

10.2.3 Passengers shall be advised and informed during an emergency, to discourage panic or stress during adverse circumstances.

10.2.4 Personnel whose duties take them onto the operational system shall be trained for emergency response pending the arrival of jurisdictional personnel.

10.2.5 Emergency personnel training shall be kept current through periodic drills and review courses.

10.3 Emergencies. The emergency management plan shall address the following types of emergencies:

(1) Fire or smoke conditions within the system structures including stations, guideways (revenue or nonrevenue), and support facilities
(2) Collision or derailment involving the following:
  (a) Rail vehicles on the guideway
  (b) Rail vehicles with privately owned vehicles
  (c) Intrusion into the right-of-way from adjacent roads or properties
(3) Loss of primary power source resulting in stalled trains, loss of illumination, and availability of emergency power
(4) Evacuation of passengers from a train to all right-of-way configurations under circumstances where assistance is required
(5) Passenger panic
(6) Disabled, stalled, or stopped trains due to adverse personnel/passenger emergency conditions
(7) Tunnel flooding from internal or external sources
(8) Disruption of service due to disasters or dangerous conditions adjacent to the system, such as hazardous spills on adjacent roads or police activities or pursuits dangerously close to the operational system
(9) Structural collapse or imminent collapse of the authority property or adjacent property that threatens safe operations of the system
(10) Hazardous materials accidentally or intentionally released into the system
(11) Serious vandalism or criminal acts, including terrorism
(12) First aid or medical care for passengers on trains and in stations
(13) Extreme weather conditions, such as heavy snows, high or low temperatures, sleet, or ice
(14) Earthquake
(15) Any other emergency as determined by the authority having jurisdiction

10.4* Emergency Procedures. An emergency procedure shall be developed to address specifically the various types of emergencies that might be experienced on the system and shall include, but not be limited to, the following:

(1) Identification of the type of emergency, name of authority, and the date the plan was adopted (or reviewed or revised, as applicable)
(2) Policy, purpose, scope, and definitions
(3) Participating agencies and area of responsibility, including governing officials and signatures of executives signing for each agency
(4) Safety procedures to be implemented specific to each type of emergency operation
(5) Purpose and operations of the central supervising station and alternate central supervising station, as applicable
(6) Command post and auxiliary command post, their purpose, and operational procedures, as applicable
(7) Communications, types of communications available, procedures to maintain safe operation, and equipment to interface with responding agencies
(8) Fire and smoke emergency information and procedures to be provided, including the following:
  (a) Location of fire in station or support facility
  (b) Location of train in tunnel and fire location on train
  (c) Fire detection systems/zones in stations
  (d) Fire protection systems and devices and their location/point of initiating operation
  (e) Exit/entrance locations to the incident site, including vehicular routes
  (f) Emergency ventilation system components and locations of equipment and local controls
  (g) Special equipment locations/cabinets
  (h) Agency(ies) to be notified and their phone numbers
  (i) Agency in command prior to and after the arrival of the local jurisdiction emergency response personnel
  (j) The ventilation system preplanned mode of fan operation (exhaust or supply)
  (k) Preplanned passenger evacuation direction as coordinated with fan mode operation
  (l) Fire and emergency incidents on adjoining properties
(9) Procedures typically implemented by responding jurisdictions for various types of emergencies as appropriate to site configuration
(10) Maps or plans of complex areas of the system at a minimum, such as underwater tubes, multilevel stations, adjacencies to places of large public assembly, or other unique areas
(11) Any other information or data that participating agencies determine to be necessary to provide effective response

10.5* Participating Agencies. Participating agencies to be summoned by operators of a fixed guideway transit or passenger rail system to cooperate and assist depending on the nature of an emergency shall include the following:

(1) Ambulance service
(2) Building department
(3) Fire department
(4) Medical service
(5) Police department
(6) Public works (i.e., bridges, streets, sewers)
(7) Sanitation department
(8) Utility companies (i.e., gas, electricity, telephone, steam)
(9) Water department (i.e., water supply)
(10) Local transportation companies
(11) Red Cross, Salvation Army, and similar agencies

10.6 Central Supervising Station (CSS).

10.6.1 The authority shall operate a CSS for the operation and supervision of the system.

10.6.2 The CSS shall be staffed by trained and qualified personnel.

10.6.3 The CSS shall have the essential apparatus and equipment to communicate with, supervise, and coordinate all personnel and trains operating in the system.

10.6.4 The CSS shall provide the capability to communicate with participating agencies.

10.6.4.1 Agencies such as fire, police, ambulance, and medical service shall have direct telephone lines or designated telephone numbers used for emergencies involving the system.

10.6.5 Equipment shall be available and used for recording radio and telephone communications during an emergency.

10.6.6 CSS personnel shall be thoroughly conversant with the emergency procedure plan and shall be trained to employ it effectively whenever required.

10.6.7 An alternate site(s) to function efficiently during an emergency in the event the CSS is out of service for any reason shall be selected and equipped or shall have equipment readily available.

10.6.8 The CSS shall be located in an area separated from other occupancies by 2-hour fire resistance construction.

10.6.9 The area shall be used for the CSS and similar activities and shall not be jeopardized by adjoining or adjacent occupancies.

10.6.10* The CSS shall be protected by fire detection, protection, and extinguishing equipment so that there shall be early detection and extinguishment of any fire in the CSS.

10.7 Liaison.

10.7.1 An up-to-date listing of all liaison personnel from participating agencies shall be maintained by the authority and shall be part of the emergency procedure plan.

10.7.2 The listing shall include the full name, title, agency, business telephone number(s), and home telephone number of the liaison. An alternate liaison with the same information also shall be listed.

10.7.3 At least once every 3 months, the list shall be reviewed and tested to determine the ability to contact the liaison without delay.

10.8 Command Post.

10.8.1* During an emergency on the system that requires invoking the emergency procedure plan, a command post shall be established by the incident commander for the supervision and coordination of all personnel, equipment, and resources at the scene of the emergency.

10.8.2 The emergency procedure plan shall clearly delineate the authority or participating agency that is in command and that is responsible for supervision, correction, or alleviation of the emergency.

10.8.3 Participating agencies shall each assign a liaison to the command post.

10.8.4 Radio, telephone, and messenger service shall be used to communicate with participating agencies operating at an emergency.

10.8.5* Approved markers shall be used to identify the command post.

10.8.6 The emergency procedure plan shall prescribe the specific identification markers to be used for the command post and for personnel assigned thereto.

10.9* Auxiliary Command Post. When an emergency operation requires an auxiliary command post because of the extent of the operation, the person in command shall establish an auxiliary command post(s) that will function as a subordinate control.

10.10 Training, Exercises, Drills, and Critiques.

10.10.1 The authority and participating agency personnel shall be trained to function efficiently during an emergency.

10.10.1.1 The training shall cover all aspects of the emergency procedure plan.

10.10.2 Exercises and drills shall be conducted at least twice per year to prepare the authority and participating agency personnel for emergencies.

10.10.3 Critiques shall be held after the exercises, drills, and actual emergencies.

10.10.4 Drills shall be conducted at various locations on the system as well as at various times of the day so as to familiarize as many emergency response personnel as possible.

10.11 Records. Written records and telephone and radio recordings shall be kept at the CSS, and written records shall be kept at the command post and auxiliary command post(s) during fire emergencies, exercises, and drills.

10.12 Removing and Restoring Traction Power.

10.12.1 During an emergency, the authority and participating agency personnel shall be supervised so that only the minimum number of essential persons operate on the trainway.

10.12.2 The emergency procedure plan shall have a defined procedure for removing and restoring traction power.

10.12.3 Prior to participating agency personnel operating on the trainway, the traction power shall be removed.

10.12.4 When traction power is removed by activation of an emergency traction power disconnect switch, the CSS shall be contacted by telephone or radio and given the full name, title, agency, and reason for removal of the traction power by the person responsible.

10.12.5 When shutdown of traction power is no longer required by a participating agency, control of such power shall be released to the authority.

Chapter 11 Communications

11.1* General. A communication systems shall be established in accordance with this chapter.

11.2 Central Supervising Station (CSS) and Command Post Relationship.

11.2.1 During normal operations, the CSS shall be the primary control for the system.

11.2.2 During emergency operations, the command post established at the scene of the emergency shall be responsible for controlling, supervising, and coordinating personnel and equipment working to correct or alleviate the emergency.

11.2.3 The command post and CSS shall cooperate and coordinate to have an efficient operation.

11.2.4 The CSS shall be responsible for operation of the system except for the immediate emergency area.

11.3 Radio Communication.

11.3.1 A fixed guideway transit or passenger rail system shall have at least one radio network that is capable of two-way communication with personnel on trains, motor vehicles, and all locations of the system.

11.3.2 Wherever necessary for dependable and reliable communications, a separate radio network capable of two-way radio communication for fire department personnel to the fire department communication center shall be provided.

11.3.3 A radio network shall comprise base transmitters and receivers, antennas, mobile transmitters and receivers, portable transmitters and receivers, and ancillary equipment.

11.4 Telephone.

11.4.1 An emergency telephone (ETEL) shall be provided along the trainway at each blue light station and at other locations deemed necessary by the authority having jurisdiction.

11.4.2 The system shall have a telephone network of fixed telephone lines and handsets capable of communication with all stations, fire command centers, structures, offices, power stations and substations, control towers, ancillary rooms and spaces, and locations along the trainway in accordance with *NFPA 72*.

11.4.3 The location and spacing of telephones along the trainway shall be determined by the authority having jurisdiction.

11.4.4 Telephones along the trainway shall have distinctive signs and/or lights for identification.

11.5 Portable Telephones and Lines.

11.5.1 The authority shall maintain portable communications equipment and arrange for the dispatch to an emergency scene when required for emergency operations or requested by emergency responders.

11.5.2 The authority having jurisdiction shall approve the type of communication equipment.

11.6 Public Address (PA) System.

11.6.1 All stations, as determined by the authority having jurisdiction, shall have a PA system for communicating with passengers and employees. *(For communication requirements for vehicles, see 8.9.2.)*

11.6.2 The CSS shall have the capability of using the PA system to make announcements throughout stations.

11.6.3 Authority supervisory employees and emergency response personnel at stations shall have the capability of making announcements throughout public areas on the PA system.

11.6.4 During interruptions of train service or delays for any reason associated with an emergency, fire, or smoke, the passengers and employees shall be kept informed by means of the PA system.

11.6.5 At times of emergency, the PA system shall be used to communicate with passengers, employees, and participating agency personnel.

11.7 Portable Powered Speakers (Audiohailers). During emergency operations, portable powered speakers shall be made available by the authority where other forms of communication are not available.

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction. The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.3.3.11 Critical Radiant Flux. Critical radiant flux is the property determined by the test procedure in NFPA 253. The unit of measurement of critical radiant flux is watts per square centimeter (W/cm^2).

A.5.1.1 This chapter is written for fixed guideway transit stations but can be useful for passenger rail stations.

A.5.2.3.5.1 Because of the difference in the potential level of hazard between various stations (i.e., open stations as compared to enclosed stations), alternative methods to fire separation could be considered.

A.5.5.1.1 At multilevel stations, it can be reasonable to consider only entraining (or entraining plus detraining) loads for nonincident levels for determining required egress capacity at points where egress routes converge. Nonincident platform loads that do not adversely impact the egress route need not be considered.

A.5.5.2.5 Consideration of control of access to platforms might be necessary to provide the appropriate level of safety.

A.5.5.2.8.2(1) The surge factor of 1.3 is typical based on surveys of transit system patronage data obtained from four transit systems from 1972 through 1981. Additional surge factors from 1.15 through 2.75 have been reported.

A.5.5.2.8.3(1) The surge factor of 1.3 is typical based on surveys of transit system patronage data obtained from four transit systems from 1972 through 1981. Additional surge factors from 1.15 through 2.75 have been reported.

A.5.5.2.8.4 The maximum for a calculated train load should be the most passengers capable of occupying the largest train.

A.5.5.3.3.2 Stairs should be positioned in close proximity to, but not necessarily adjacent to, escalators to allow emergency exiting no matter in which direction the escalator(s) is operating.

A.5.5.4.1(1) It is intended that escalators be as noncombustible as possible, realizing that certain components such as rollers or headrails might not currently be available in noncombustible materials. The authority having jurisdiction should review each installation proposal for compliance to the greatest extent possible.

A.5.7.1.2 Discrete zone indications are desirable for unmanned stations.

A.5.7.1.4 Separate zones on the annunciator panel to monitor main control valves on standpipe systems should be established.

A.5.7.4.3 It is desirable to locate fire department connections near one or more station access points.

A.5.7.6 Where an underground station is part of another building or building complex, consideration should be given to creating a combined fire command center.

A.6.1.1 This chapter is written for fixed guideway transit trainways but can be useful for passenger rail stations.

A.6.1.4.1 The placement of blue light stations at the ends of station platforms should be governed by actual need. For instance, an at-grade system that has stations in dedicated streets and overhead power supply would not need blue light stations at the ends of platforms.

A.6.2.3.6 The trainway, although used for ventilation, should not be considered as an air plenum for purposes of mounting electrical appurtenances.

A.6.2.4.2 Previous editions of NFPA 130 addressed this requirement by prescribing the maximum travel distance to an exit. The intent of this requirement was often misinterpreted. NFPA *101* requires, at a minimum, two means of egress be provided within a building or structure and prescribes the maximum travel distance to an exit. This same requirement is applied in NFPA 130. Where two means of egress are required, the maximum travel distance to an exit occurs at the midpoint. For example, in a building with two exits, in the event of a fire adjacent to an exit rendering that exit unavailable, NFPA *101* recognizes that an individual in proximity to the affected exit must travel twice the prescribed exit travel distance to the alternate exit. Since two means of egress are required at any one point in a tunnel, the exits cannot be more than twice the travel distance, or 762 m (2500 ft) apart.

A.6.2.4.5.3 Where exit hatches are installed in spaces such as walkways or access areas, appropriate design features such as readily visible signs, markings, or bollards should be provided to prevent blockage of the exit hatch. In addition, provisions should be included in the design to protect the exterior side of the hatch, including the outside latch, from accumulation of ice and snow, which could render the hatch inoperable.

A.6.2.4.7.5 This value is a minimum maintained point measured at any location on the walkway, taking into account the total light loss factor (dirt depreciation, lumen depreciation, etc.) that will be experienced by the luminiare.

A.6.2.4.8 Directional signs are provided to assist emergency evacuation of passengers. The signs should be of reflective or illuminated materials and readily visible by passengers within the trainway. Inclusion of distance to the station or portal is discouraged since that might influence passenger evacuation route, which could contradict the emergency evacuation strategy.

A.6.2.5.1.1 The primary hazards presented by the electrified third rail in the trainway are electrical shock to employees and other personnel in the trainway and the heat and smoke generated by the cable or third rail caused by combustion resulting from grounding or arcing.

The life safety and fire protection requirements for the traction power substations, tie breaker stations, and power distribution and control cabling are described in other parts of this standard.

A.6.3.3 The life safety and fire protection requirements for the traction power substations, tie breaker stations, and power distribution and control cabling are described in other parts of this standard.

A.6.4.3 The life safety and fire protection requirements for the traction power substations, tie breaker stations, and power distribution and control cabling are described in other parts of this standard.

A.7.1.1 Separate ventilation systems for tunnels and underground stations can be provided, but are not required. Annex B provides information on types of mechanical systems for normal ventilation of fixed guideway transit systems and information for determining a tenable environment.

A.7.7.7 The trainway, although used for ventilation, should not be considered as an air plenum for purposes of mounting electrical appurtenances.

A.8.3.1 It is recognized that the tests cited in this chapter might not accurately predict the behavior of materials under hostile fire conditions. Therefore, the use of tests that evaluate materials in subassemblies and full-scale configurations is encouraged where such tests are more representative of foreseeable fire sources, heat flux levels, and surface area-to-volume ratios found in vehicles designed in conjunction with this standard.

A.8.3.2.2 The purpose of this requirement is to isolate potential ignition sources from fuel and combustible material and to control fire and smoke propagation.

A.8.4.1.5 Annex E contains additional guidance describing the overall process that could be used to conduct a performance-based hazard analysis, using the test procedures included in Annex D.

A.8.4.1.5.3 The test methods in ASTM E 1537 (for upholstered furniture, 19 kW exposure) and ASTM E 1590 (for mattresses, 18 kW exposure) are deemed to be adequate procedures for testing individual items of upholstered furniture or mattresses for purposes of fire hazard assessment in some public occupancies. However, such individual stand-alone (not fixed in place) items are not those normally present in rail transportation vehicles. Thus, the applicability of the test methods to rail transportation vehicles has not been validated, and they probably are not sufficiently representative of the situation and might require some modifications for better applicability. The use of alternative ignition sources (by varying the location, the gas flow intensity, or the exposure time) for ASTM E 1537 or ASTM E 1590 might be a means of addressing some very high challenge fire scenarios potentially present in rail transportation vehicles. Examples of more powerful ignition sources that could be used include a 50 kW gas burner [Hirschler, 1997], shown to be relevant to detention mattresses or the oil burner used for aircraft seat cushions [FAR 25.853(c)], but the measurements should involve the same fire properties as in ASTM E 1537 or ASTM E 1590. If the ignition source used for a test method is inadequate, the result can be misleading; it has been shown that upholstered furniture and mattresses that are totally consumed when using the appropriate ignition source appear to perform well when using the ignition sources in ASTM E 1537 and ASTM E 1590, respectively.

A.8.4.1.5.11 Testing for heat release and smoke obscuration by using NFPA 271 or ASTM E 1354 is required only as an alternate approach to testing by the test methods for flammability and smoke obscuration in Table 8.4.

A.8.4.1.5.18 Only one specimen need be tested. A proportional reduction can be made in the dimensions of the specimen, provided the specimen represents a true test of the ability of the structural flooring assembly to perform as a barrier against undervehicle fires.

A.8.5.2.2 In selecting air clearance distances, special consideration should be given to the presence of contaminants encroaching on the air clearances.

A.8.5.2.3.1 Appropriate creepage distances can be selected from Annex F.

A.8.8.4 Previous editions of NFPA 130 did not address means of emergency egress from the rail vehicles. Several emergency incidents have occurred that demonstrated the necessity to provide passengers with a means to manually operate, without tools, means of emergency egress in the event of a power failure. Operational issues to be considered include the need to discourage use under nonemergency conditions while permitting effective passenger use in an emergency, particularly if members of the train crew are injured or otherwise unavailable.

Since 1980, the Federal Railroad Administration (FRA) has required that each rail passenger car be provided with at least four emergency window exits. In 1999, the FRA issued a passenger equipment rule that required each intercity and commuter rail car to be equipped with a minimum number of two side doors per car and at least four emergency window exits for each main level. Each sleeping compartment must also be provided with an emergency window exit. Because fixed guideway vehicles historically have been provided with at least two sets of bileaf side doors, one on each side, emergency exit windows usually are not provided.

NFPA 130 did not previously address marking of the location of means of emergency egress and instructions for the operation of egress (access) facilities for fixed guideway transit and passenger rail vehicles from the interior.

A.8.8.5 The United States Federal Aviation Administration (FAA) requires the installation of independently powered floor proximity path marking to delineate the path to emergency exits. The American Public Transportation Association (APTA) has also issued a standard that requires this same concept of marking to be installed in intercity and commuter rail cars.

The Federal Railroad Administration (FRA) issued a rule in 1998 that required marking and instructions for the operation of emergency exit windows and doors used for emergency egress. Although the FRA requires that the marking be conspicuous and legible, specific objective performance criteria were not included.

APTA has issued a standard that contains extensive provisions for the marking of and instructions for emergency egress facilities that are operated from the inside of the vehicle. These minimum performance criteria include letter height, color contrast, and luminance levels.

The APTA standard requires that marking and instructions use either electrically powered or high-performance photo luminescent (HPPL) material. The HPPL material must be charged with an adequate light [53.8 1x (5 foot-candles) for at least 1 hour] but offers the advantage of providing a far greater luminance (brightness) over a far longer time period, while not being dependent on emergency power. The HPPL material has been certified by the FAA for use as floor proximity path marking on certain aircraft.

A.8.11.1 Annex E includes comments and information useful in considering application of this design approach. Chapter 8 presents and describes requirements for use of performance-based life safety design that can be used to develop fixed guideway transit and passenger rail vehicles for use in specified/specific operating environments. The criteria associated with the life safety goals that must be attained are stated in Section 4.2.

The performance option of this standard establishes acceptable levels of risk to occupants of vehicles. This was addressed in earlier versions of NFPA 130 in what was then Chapter 5. While the recently developed performance option of this standard does contain goals, objectives, and performance criteria necessary to provide an acceptable level of risk to occupants, it does not describe how to meet the goals, objectives, and performance criteria. That is up to the fire science engineer practitioner to accomplish. Design and engineering expertise are needed to develop solutions that meet the provisions of Chapter 8. The *SFPE Engineering Guide to Performance-based Protection Analysis and Design of Buildings* provides a framework for these assessments. Other useful references include ASTM E 2061 and APTA's *Recommended Practice for Fire Safety Analysis of Existing Passenger Rail Equipment*.

Scenarios are used to assess the adequacy of designs considered and ultimately selected. As such, initiating events as referenced from ASTM E 2061 are specified for study for which ensuing outcomes must be satisfactory. Approaches and considerations found in APTA's *Recommended Practice for Fire Safety Analysis of Existing Passenger Rail Equipment* are also worthy of consideration.

If the outcome predicted by evaluation of the scenarios is bound by the performance criteria stated, then the objectives will have been met, and the life safety characteristics of a proposed design should be considered to be consistent with the goals of this standard. Although not explicitly part of this standard, it must be assumed that if a design fails to comply with these goals, it will be changed and reassessed iteratively until satisfactory performance levels are attained.

Documentation of assessment parameters such as those used with scenarios is critical. The approval and acceptance of a life safety design are dependent on the quality of the documentation used in this process.

A.8.11.2 Section 4.3 includes specific objectives necessary to achieve desired goals.

A.8.11.3 This requirement considers the qualifications of those being considered to conduct performance-based design activities. These qualifications should include professional experience, education, and credentials that demonstrate knowledgeable and responsible use of applicable models and methods, as well as necessary experience with fixed guideway and passenger rail systems.

A.8.11.4 This provides qualifications of a third-party or peer reviewer, which should be a qualified person or group of persons chosen by the authority having jurisdiction to review proposed performance-based designs.

A.8.11.7 This subsection addresses continued compliance with the goals and objectives of the standard, which entails ensuring that cars will be maintained consistent with the original design requirements for fire safety. In practice, such compliance involves numerous important factors and all efforts must be directed at ensuring that the fire performance of the design selected will not diminish due to either foreseeable aging or activities related to maintenance [or lack thereof]. This is difficult, if not impossible, to mandate in a construction standard but still must be addressed.

Vehicle construction — including doors or other emergency exists, interior finish, and fire- and smoke-resistive construction — and the vehicle and fire protection systems must be maintained to retain the same level of performance as is provided for in the original, accepted design parameters. As with any other fire safety application, such as change of occupancy, vehicle use should not be changed to any degree without being addressed immediately. As such, changes that comprise original assumptions made with respect to occupant characteristics, combustibility of furnishings, train crew and first responder characteristics, and existence of a comprehensive in-place system safety plan must not be made. Also, actions needed to maintain the reliability of all associated systems at the anticipated level to meet the initial design criteria must be memorialized and made known to the AHJ and the system operator.

A.8.11.8 This subsection specifies measures that must be addressed in determining whether the objectives are or have been met by a particular design or designs.

A.8.11.8.2 This paragraph addresses the need to avoid exposing occupants to untenable conditions. It is of extreme importance especially for vehicles operated in tunnels or right-of-ways, where exiting from vehicles might be difficult or impossible.

To make the needed assessment, the design team might wish to set detailed performance criteria that ensure that occupants are not incapacitated by fire effects, the limits of which are a fairly contentious issue technically at present. The *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* describes a process of establishing such tenability limits, although the exact limits used are subject to change based on research currently under way in the United States and the European Union. The practitioner is urged to consult this literature directly.

Conversely, to be successful the design team can demonstrate that for each design fire scenario and the design specifications, conditions, and assumptions, each compartment or area of affected vehicles will be fully evacuated before the smoke and toxic gas layer in that compartment descends to a level lower than 1.8 m (6 ft) above the floor. It is implicit in such a finding that the timing of an evacuation must be such that no occupant is exposed to fire effects. Such an evacuation requires calculation of the locations, movement, and behavior of occupants, because fire effects and occupants are kept separate by moving the occupants. A level of 1.52 m (5 ft) is often used in calculations, but at that level, a large fraction of the population would not be able to stand, walk, or run normally and still avoid inhalation of toxic gases. They would have to bend over or otherwise move their heads closer to the floor level.

Alternatively, for each design fire scenario and the design specifications and assumptions, the design team can demonstrate that the smoke and toxic gas layer will not descend to a level lower than 1.8 m (6 ft) above the floor in any occupied compartment. The advantage of this procedure is that it conservatively requires that no occupant be exposed to fire effects, regardless of where occupants are or where they move. This removes the need to make any calculations regarding occupants, including their behavior, movement locations, prefire characteristics, and reactions to fire effects. This procedure is even more conservative and simpler than the procedure described in the preceding paragraph because it does not allow fire effects in occupied rooms to develop to a point where people could be affected at any time during the fire.

Finally, for each design fire scenario and the design specifications and assumptions, the design team can demonstrate that no fire effects will reach any occupied compartment. The advantage of this procedure is that it removes the need to make any calculations regarding occupants, including their behavior, movement, locations, prefire characteristics, and reactions to fire effects. A further advantage is that it also removes the need for some of the modeling of fire effects, because it is not necessary to model the filling of rooms, only the spread of fire effects to those rooms. This procedure is even more conservative and simpler than both of the preceding procedures because it does not allow any fire effects in occupied rooms.

The last three approaches are generally preferable, inasmuch as they are free of the complex technical issues involved in calculating reliable incapacitation data directly.

A.8.11.9 This subsection describes input needed for design specifications and includes the observation that certain retained prescriptive requirements are included.

A.8.11.9.1 The requirements apply to systems and features required by the standard that reference applicable standards and to any additional systems or features included in the design at the discretion of the design team. The referenced standards are expected to state maintenance, testing, and other requirements required or necessary to provide positive assurance of an acceptable level of reliability. The referenced standards themselves can be prescriptive based or performance based.

A.8.11.10 This subsection indicates that all assumptions related to the life safety design and the probable response of vehicles and occupants to a fire-related emergency must be clearly stated.

Design specifications and other conditions will form the input to evaluation of proposed designs as relates to 8.11.12. Where a specification or condition is not known, a reasonable estimation is permitted. However, the design team will need to take steps to ensure that the estimation is valid during the life of the vehicle, and any and all such estimations must be documented according to 8.11.14.

A.8.11.10.4 This paragraph addresses life safety systems such as automatic fire suppression and fire alarm systems. Performance issues that need to be documented include response time indexes, discharge densities, and distribution patterns. Calculations should address amounts of extinguishing agent and, for example, must not include an unlimited supply of extinguishing agent if only a limited supply will be carried by an "affected" vehicle.

A.8.11.10.5.1 This paragraph addresses features that might be incorporated in a car design to modify expected occupant behavior characteristics. The type of ridership as well as available staffing impacts such features.

Such features might include addressing crew issues as part of the design process or hardware built in to be used for emergencies. Examples of crew issues include training crew or staff and developing crew or staff activities to be undertaken in emergencies to assist passengers and to provide notification. An example of hardware might be the type of notification appliance(s) used.

Human factors constitute a large body of knowledge that can be applied in considering design issues. Four basic characteristics are considered to be a minimum set of mutually exclusive human performance characteristics that can affect the ability of a fire safety system to meet life safety objectives:

(1) Sensibility to physical cues, especially the sounding of an alarm
(2) Reactivity, or the ability to correctly interpret cues and take appropriate action
(3) Mobility, or the speed of movement
(4) Susceptibility to products of combustion

In applying those four characteristics to emergency situations, assumptions can be used to address a larger number of factors that are components of these basic performance characteristics. Examples of characteristics that have an impact on individual and group performance include the following:

(1) *Alertness:* Awake/asleep, can depend on time of day
(2) *Responsiveness:* Ability to sense cues and react
(3) *Commitment:* Degree to which occupant is committed to an activity underway before the alarm
(4) *Focal point*: Point at which an occupant's attention is focused, for example, to the front of a classroom, a stage, or server in business environment; hand of cards in a gambling casino
(5) *Physical and mental capabilities:* Can affect ability to sense, respond, and react to cues; might be related to age or disability
(6) *Role:* Can determine whether occupant will lead or follow others
(7) *Familiarity with environment:* Can depend on time spent in vehicle prior to emergency or prior participation in emergency training
(8) *Social affiliation:* Extent to which an occupant will act/react as an individual or as a member of a group
(9) *Condition:* Over the course of the fire, the effects — both physiological and psychological — of the fire and its combustion products on each occupant

A.8.11.10.5.6 This paragraph relates to a vehicle's capacity, which should represent the maximum number of people expected that will be contained in a compartment or area. Capacity should be based on the peak hour or crush load patronage anticipated for each design's worst-case or most conservative loading.

A.8.11.10.5.7 This paragraph addresses the staff characteristics that should be considered, such as number and types of personnel, their location and their quality, and frequency of training. Both onboard and station personnel should be considered.

A.8.11.10.7 This paragraph addresses design proposals and requires that the proposals explicitly state all design specifications or requirements regarding system safety program plans, inspection programs, or other ongoing programs associated with the performance-based design agreed upon. These data are crucial to meet the stated goals and objectives, and their reliable performance is necessary for occupied and operational vehicles.

Examples of such programs include maintenance, training, labeling, or certification programs required to ensure operational status or reliability in vehicle systems or features.

A.8.11.10.9 This paragraph refers to interrelations assumed among the performance of vehicle elements and systems, occupant behavior, or emergency response actions that might conflict with each other. For each fire scenario considered, it is necessary to ensure that conflicts in actions do not occur. Typical conflicts could include the following:

(1) Assuming a door will remain closed during the fire to contain smoke, while occupants use the same door during egress from the area
(2) Assuming fire apparatus will arrive immediately from a distant location to provide water to fire department connections and similar situations

A.8.11.10.10 This paragraph addresses provisions that exceed basic requirements covered by referenced codes and standards, typical design requirements, and operating procedures. It includes provisions such as more frequent periodic testing and maintenance to increase the reliability of fire protection systems, redundant systems to increase reliability, onboard guard service to enhance detection of fires and aid in fire response procedures, additional staff training to address hazards particular to a given right-of-way, and availability and performance of emergency response personnel.

A.8.11.11 This paragraph addresses design fire scenarios that define the challenge a vehicle is expected to withstand. Design fire scenarios are used to capture and limit value judgments on the type and severity of the fire challenge to which a proposed fire safety system needs to respond. The system considered must include any and all aspects of the proposed design that are intended to mitigate the effects of a fire, such as egress, automatic detection and suppression, barriers, staff training, and placement of manual extinguishers, and unusual right-of-way characteristics.

Design fire scenarios can come from two sources: those that are specified in 8.11.11.3 and those that are developed by the design team based on the unique characteristics of the vehicle as required by 8.11.11.2. In all cases, it will be necessary to test vehicle design against more than one design fire scenario.

Once the set of design fire scenarios is established for a given project, each scenario needs to be quantified into a format that can be used for the evaluation of proposed designs. The *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* and the ASTM's *Guide for Fire Hazard Assessment of Rail Transportation Vehicles* outline processes and identify tools and references that can be used at each step of this process.

A.8.11.11.3 This subsection addresses the desirability of considering a range of fire scenarios to evaluate the life safety capabilities of vehicle designs. Fire scenarios should not be limited to worst-case fire scenarios but should address the range of situations that an operating system might encounter and should take into account detection and suppression capabilities as well.

Descriptive terms used to indicate the rate of fire growth for the scenarios are intended to be generic, and the exception in this section is for application to each active or passive fire protection system individually. Two characteristics of the design must be evaluated and approved by the authority having jurisdiction:

(1) System reliability
(2) Design performance in the absence of the system being analyzed

In these cases, acceptable performance does not require fully meeting the stated goals and objectives. Analysis might show, for example, that it might not be possible to fully meet all goals and objectives if a key system is unavailable, and yet no system is totally reliable. The authority having jurisdiction will determine what level of performance, possibly short of the stated goals and objectives, is acceptable, given the very low probability (i.e., the system's unreliability probability) that the system will not be available. Such a process is described in APTA's *Recommended Practice for Fire Safety Analysis of Existing Passenger Rail Equipment*.

A.8.11.12 This subsection directs that appropriate methods for assessing performance must be used. This requirement considers that satisfactory assessment methods translate input data, which might include test specifications, parameters or variables for modeling, or other data, into output data, which are specifically measured against stated performance criteria. Computer fire models used for such applications should be evaluated for their predictive capability in accordance with ASTM E 1355.

A.8.11.12.1 *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* outlines a process for evaluating whether trial designs meet the performance criteria during the design fire scenarios. ASTM E 2061 also describes specific steps necessary to conduct a fire hazard analysis for a vehicle.

APTA's *Recommended Practice for Fire Safety Analysis of Existing Passenger Rail Equipment* provides a step-by-step procedure for use in identifying and prioritizing important fire risks for passenger rail systems.

The procedures described in 8.11.8 and 8.11.10 identify required worst-case design fire scenarios among the design fire scenarios within which a proposed fire safety design is required to perform. As such it will also define associated untenable conditions that are to be avoided to maintain life safety. Subsection 8.11.12 discusses methods that form the link from the scenarios and criteria to the goals and objectives.

Assessment methods that are used to demonstrate that a particular proposed design would achieve the stated goals and objectives can be assessed by providing information indicating that the performance criteria of 8.11.8 can be adequately met. Assessment methods for testing the hypotheses used are permitted to be either tests of particular properties of systems or subsystems or hazard modeling of scenarios of interest.

Test results can be directly used to assess a fire safety design when they accurately represent applicable scenarios developed by using 8.11.10. At the same time, they must also provide output data matching the performance criteria in 8.11.8.

Standardized tests are conducted on various systems and components to determine whether they meet some predetermined, typically prescriptive criteria. Results are given on a pass/fail basis: the test specimen either does or does not meet the pre-established criteria.

The scale of tests conducted can be small, intermediate, or full. The latter can include tests such as the ASTM E 119/NFPA 263 fire endurance tests or room fire tests run according to criteria found in guidance documents such as ASTM E 603 for room fire tests.

Data obtained from standardized tests have at least three potential uses for verification purposes:

(1) Test results can be used instead of a model. This use is typically the role of full-scale test results.
(2) Test results can be used as a basis for validating results obtained by a particular model if model predictions match well with the test results. In that case, it can be verified that the model can be used to simulate situations similar to those represented by the particular test scenario.
(3) Test results can be used as input to models. This typically involves use of small-scale test results, specifically flammability tests.

Startup test results can be used to demonstrate that the fire safety system performs as designed for a system design based on modeling. If the startup test indicates a deficiency, then the system needs to be adjusted and retested until it can be demonstrated that the design can meet the performance criteria. Typically, startup tests apply only to the installation specifically designed.

Experimental data from nonstandard tests can be used when the specified scenario and the experimental setup are similar. Typically, experimental data are applicable to a greater variety of scenarios than are standardized test results.

Human and Organizational Performance Tests. Certain tests determine whether inputs used to determine human performance criteria remain valid during the lifetime of a vehicle. Tests of human and organizational performance might include any of the following:

(1) Evacuation times measured during fire drills
(2) Querying emergency response team members to determine whether they know required procedures
(3) Field tests to ensure that emergency response team members can execute tasks within predetermined times and accuracy limits

Design proposals should include descriptions of any tests utilized to determine that stated goals, objectives, and performance criteria are met.

Modeling. Models are frequently referred to somewhat generically, although these vary widely. A specific type of model might be used to establish hazard levels and hazard characteristics for a given class of vehicle operating under a given set of right-of-way and passenger loading characteristics, while calculational fire models can be used to predict the performance of a given vehicle when a given initial fire size, growth rate, ventilation criteria, and the like, are specified under a given specific scenario.

Because of the limitations on the use of tests results alone — not the least of which are costs and lack of varied scenarios for testing, especially for standard testing — computer models are expected to be used in most, if not all, performance-based design assessments.

Fire models do not model fires, they model the effects of a user-specified fire in a given specified environment. Effects of fire and related products of combustion on the occupants can be modeled, as can the movement and behavior of occupants during the fire. The term *evacuation model* can be used to describe models that predict the location and movements of occupants, and the term *tenability model* is used to describe models that predict the effects on occupants of specified levels of exposure to fire effects.

Fire models are used to predict a variety of fire-related performance criteria through calculation. Fire models can be either probabilistic or deterministic. Several types of deterministic models are available: computational fluid dynamics (CFD), or field, models; zone models; purpose-built models; and hand calculations. Probabilistic fire models also are available but are less likely to be used for this purpose.

Probabilistic fire models use the probabilities as well as the severity of various events as the basis of evaluation. Some probabilistic models incorporate deterministic models, but this is not a requirement. Probabilistic models attempt to predict the likelihood or probability that events or severity associated with an unwanted fire will occur or the "expected" loss, which can be thought of as the probability-weighted average severity across all possible scenarios. Probabilistic models can be manifested as fault or event trees or other system models that use frequency or probability data as input. These models tend to be manifested as computer software, but this is not a requirement. Furthermore, the discussion in the following paragraph about sources of models can be applied to probabilistic models, although it concentrates on deterministic models.

There are various sources of fire models. Compendia of computer fire models are found in Friedman's *Survey of Computer Models for Fire and Smoke* and the *SFPE Computer Software Directory*. Within these references are models that were developed by the Building Fire Research Laboratory of the National Institute of Standards and Technology (NIST), which can be downloaded from the Internet at http://fire.nist.gov. Evacuation models in all three categories are discussed in the *SFPE Handbook of Fire Protection Engineering* and the NFPA *Fire Protection Handbook*. ASTM E 2061 also describes calculation methods appropriate to conduct a fire hazard analysis for a vehicle.

Both design professionals and the authority having jurisdiction should consider the strength of the evidence presented for the validity, accuracy, relevance, and precision of any proposed modeling methods. One element in establishing the strength of scientific evidence is the extent of external review and acceptance of the evidence by peers of the authors of that evidence.

When fire growth modeling is conducted, material properties are usually needed for all fuel items, both initial and secondary, and the enclosure surfaces of involved rooms or spaces. For all fires of consequence, it is reasonable to assume that the fire being modeled will receive adequate ventilation. If there is insufficient oxygen, the fire will not be sustained and the heat release rate will be low.

The room dimensions affect the time required for a compartment to come to flashover, as does the arrangement of individual fuel packages in a given compartment. For a given amount and type of fuel, under the same ventilation conditions, a small room will flash over before a large room. In a large room with a small amount of fuel, a fire will behave as if it is burning outside, that is, adequate oxygen for burning and no concentration of heat exist. If the fuel package is unchanged but the dimensions of the room are decreased, then the room will begin to have an effect on the fire, assuming adequate ventilation. The presence of the relatively smaller enclosure results in the buildup of a hot layer of smoke and other products of combustion under the ceiling. This buildup, in turn, feeds more heat back to the seat of the fire, which results in an increase in the pyrolysis rate of the fuel and thus increases the amount of heat energy released by the fire. The room enclosure surfaces themselves also contribute to this radiation feedback effect.

A.8.11.12.3.2 This requirement stresses that procedures used to develop input data required must preserve the intended conservatism of all scenarios and assumptions. Conservatism is only one means to address uncertainty inherent in calculations. Use of conservative approaches does not remove the need to consider safety factors, sensitivity analysis, and other methods of dealing with uncertainty. The *SPFE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* outlines a process for identifying and treating uncertainty.

A.8.11.13 This requirement specifies that safety factors be applied to account for uncertainties in the assessment. It considers assessment of precision required in 8.11.14.2, which mandates a sensitivity and uncertainty analysis. These can be translated into safety factors necessary for the analysis. The discussion that follows considers both sensitivity and characteristics of output that will have meaning in considering various performance-based design options.

Sensitivity Analysis. To conduct a successful analysis, the model user should not rely on a single run as the basis for any performance-based fire safety system design. As such, the first run made should be considered the base case and labeled as such. Successive runs and calculation variables or parameters used to develop the nominal input data set should be evaluated through multiple runs, as should combinations of key variables and parameters. As part of this process, a sensitivity analysis should be conducted that provides the model user with data that indicate how foreseeable fires might vary, how their effects would be manifest, and how the response of the proposed fire safety design might vary under a wide range of fire conditions.

Reasonableness Check. The model user should first try to determine whether the predictions actually make sense, that is, that they do not upset intuition or preconceived expectations. Most likely, if the results don't pass this test, an input error has been committed. Sometimes predictions appear to be reasonable but are, in fact, incorrect. For example, a model can predict higher temperatures farther from the fire than closer to it. The values themselves might be reasonable (e.g., they are not hotter than the fire), but they do not "flow" down the energy as expected.

Margin of Safety. A margin of safety can be developed using the results of the sensitivity analysis in conjunction with the performance criteria to provide the possible range of time during which a condition is estimated to occur. Safety factors and margin of safety are two concepts used to quantify the amount of uncertainty in engineering analyses. Safety factors are used to provide a margin of safety and represent, or address, the gap in knowledge between the theoretically perfect model, that is, reality, and the engineering models that can only partially represent reality.

Safety Factors. These can be applied to either the predicted level of a physical condition or to the time at which the condition is predicted to occur. Thus, a physical or a temporal safety factor, or both, can be applied to any predicted condition. A predicted condition (i.e., a parameter's value) and the time at which it occurs are best represented as distributions. Ideally, a computer fire model predicts the expected or nominal value of the distribution. Safety factors are intended to represent the spread of these distributions.

Given the uncertainty associated with data acquisition and reduction, and the limitations of computer modeling, any condition predicted by a computer model can be thought of as an expected or nominal value within a broader range. For example, an upper layer temperature of 600°C (1112°F) is predicted at a given time. If the modeled scenario is then tested (i.e., a full-scale experiment based on the computer model's input data), the actual temperature at the given time could be 640°C (1184°F) or 585°C (1085°F). Therefore, the temperature should be reported as 600°C +40°C, −15°C (1112°F +104°F, −5°F) or a range of 585°C (1085°F) to 640°C (1184°F).

Ideally, predictions are reported as a nominal value, a percentage, or an absolute value. As an example, an upper layer temperature prediction could be reported as "600°C, 30°C (1112°F, 86°F)" or as "600°C (1112°F), 5 percent." In this case, the physical safety factor is 0.05 (i.e., the amount by which the nominal value should be degraded and enhanced). Given the state-of-the-art of computer fire modeling, this is a very low safety factor. Physical safety factors tend to be on the order of tens of percent. A safety factor of 50 percent is not unheard of.

One problem in establishing safety factors is the difficulty in stating the percentage or range of a property that is appropriate. These values can be obtained when the computer model predictions are compared to test data. However, using computer fire models in a design mode does not facilitate this for two reasons:

(1) The compartment being analyzed has not yet been built.
(2) Test scenarios do not necessarily depict or address the intended design.

A sensitivity analysis should be performed based on the assumptions that affect the condition of interest. A base case that uses all nominal values for input parameters should be developed. The input parameters should be varied over reasonable ranges and the variation in predicted output should be noted. This output variation can then become the basis for physical safety factors.

The temporal safety factor addresses the issue of when a condition is predicted and is a function of the rate at which processes are expected to occur. If a condition is predicted to occur 2 minutes after the start of the fire, then this can be used as a nominal value. A process similar to that described above for physical safety factors can also be employed to develop temporal safety factors. In this case, however, the rates (e.g., of heat release and toxic product generation) will be varied instead of absolute values (e.g., material properties).

The margin of safety can be thought of as a reflection of societal values and can be imposed by the authority having jurisdiction for that purpose. Since the time for which a condition is predicted will most likely be the focus of the authority having jurisdiction (e.g., the model predicts occupants will have 5 minutes to safely evacuate), the margin of safety will be characterized by temporal aspects and explicitly applied to the physical margin of safety present.

Escaping the harmful effects of fire (or mitigating them) is, effectively, a race against time. When assessing fire safety system designs based on computer model predictions, the choice of an acceptable time is important. When an authority having jurisdiction is faced with the predicted time of untenability, a decision must be made regarding whether sufficient time is available to ensure the safety of vehicle occupants. The authority having jurisdiction is assessing the margin of safety. Is there sufficient time to get everyone out safely? If the authority having jurisdiction feels that the predicted egress time is too close to the time of untenability, then the authority having jurisdiction can impose an additional time that the designer will have to incorporate into the system design. In other words, the authority having jurisdiction can impose a greater margin of safety than that originally proposed by the designer.

Documentation is considered in 8.11.14.1. The *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* describes the documentation that should be provided for a performance-based design.

Proper documentation of a performance design is critical to the design acceptance and construction. Proper documentation will also ensure that all parties involved understand what is necessary for the design implementation, maintenance, and continuity of the fire protection design. If attention to details is maintained in the documentation, there should be little dispute during approval, construction, startup, and use.

Poor documentation could result in rejection of an otherwise good design, poor implementation of the design, inadequate system maintenance and reliability, and an incomplete record for future changes or for testing the design forensically.

A.8.11.14.1 This section specifies the minimum set of documentation that must accompany a performance-based design submission.

A.8.11.14.2 This requirement stresses that the sources, methodologies, and data used in performance-based designs should be based on technical references that are widely accepted and used by the appropriate professions and professional groups. In turn, acceptance of reference documents is often related to the sources or processes by which such documents are developed. This can include review and validation as part of consensus standards development, peer review to technical (not popular) publications, monographs and recognized handbooks prepared by professional societies, and recognized standard practices prepared by professional groups.

In many cases, an analysis used for a project will be built from and include numerous component analyses. These component analyses should be evaluated using the same factors that are applied to the overall method.

Technical references and methodologies used in a performance-based design should be closely evaluated by the design team, the authority having jurisdiction, and possibly a third-party reviewer. Strength of the technical justifications should be judged using criteria such as those described above. Such justifications can be strengthened by the presence of data obtained from fire testing to assess a particular property or properties under well-defined conditions.

A.8.11.14.11 The documentation for modeling should conform to ASTM E 1472.

A.9.3.2.2 This requirement provides for the extraction of oil, grease, sand, and other substances that are harmful or hazardous to the structure or public drainage systems.

A.9.3.9.1 See NFPA 204.

A.9.5.2.2 When moving batteries, including removal and replacement, precautions should be taken to prevent short circuits, which can result in fires or explosions.

A.9.5.2.2.3.1 Precautions should be observed while working near battery terminals. Wrenches and other hand tools should be used carefully to avoid short circuits.

A.10.4 Tunnels over 610 m (2000 ft) in length should be equipped with emergency tunnel evacuation carts (ETECs) at locations to be determined by the authority having jurisdiction.

ETECs should be capable of carrying a capacity of at least four stretchers and a total weight capacity of at least 453.5 kg (1000 lb). ETECs should be constructed of corrosion-resistant materials, be equipped with a "deadman" brake, and safely operate on the rail tracks in the tunnel.

A.10.5 The agencies and names might vary depending on the governmental structure and laws of the community.

A.10.6.10 Fan units serving train control and communications rooms should be protected by fire detection, protection, and extinguishing equipment so that there will be early detection and extinguishment of any fire involving these units.

A.10.8.1 The command post should be located at a site that is convenient for responding personnel, easily identifiable, and suitable for supervising, coordinating, and communicating with participating agencies.

A.10.8.5 Signs should be designed to be visible during day or night and under bad weather conditions.

A.10.9 Any emergency response agency can establish an auxiliary command post to assist with the supervision and coordination of their personnel and equipment. This is in addition to providing a liaison at the command post.

A.11.1 Comprehensive and dependable communications are essential for an effective and efficiently operated fixed guideway transit system during emergencies.

Annex B Ventilation

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 General. The purpose of this annex is to provide guidelines for the potential compatibility of the emergency ventilation system with the system employed with normal ventilation of trainways and stations. This annex does not present all factors to be considered in the normal ventilation criteria. For normal ventilation, refer to the *Subway Environmental Design Handbook* (SEDH) and the ASHRAE Handbook series (*Fundamentals, Applications, Systems and Equipment*). Current technology is capable of analyzing and evaluating all unique conditions of each property to provide proper ventilation for normal operating conditions and for preidentified emergency conditions. The same ventilating devices might or might not serve both normal operating conditions and preidentified emergency requirements. The goals of the subway ventilation system, in addition to addressing fire and smoke emergencies, are to assist in the containment and purging of hazardous gases and aerosols such as those that could result from a chemical/biological release.

B.2 Tenable Environments.

B.2.1 Environmental Conditions. Some factors that should be considered in maintaining a tenable environment for periods of short duration are defined in B.2.1.1 through B.2.1.5.

B.2.1.1 Heat Effects. Exposure to heat can lead to life threat three basic ways:

(1) Hyperthermia
(2) Body surface burns
(3) Respiratory tract burns

For use in the modeling of life threat due to heat exposure in fires, it is necessary to consider only two criteria—the threshold of burning of the skin and the exposure at which hyperthermia is sufficient to cause mental deterioration and thereby threaten survival.

Note that thermal burns to the respiratory tract from inhalation of air containing less than 10 percent by volume of water vapor do not occur in the absence of burns to the skin or the face; thus, tenability limits with regard to skin burns normally are lower than for burns to the respiratory tract. However, thermal burns to the respiratory tract can occur upon inhalation of air above 60°C (140°F) that is saturated with water vapor.

The tenability limit for exposure of skin to radiant heat is approximately 2.5 $kW \cdot m^{-2}$. Below this incident heat flux level, exposure can be tolerated for 30 minutes or longer without significantly affecting the time available for escape. Above this threshold value, the time to burning of skin due to radiant heat decreases rapidly according to equation (1).

$$t_{Irad} = 4q^{-1.35} \qquad (1)$$

where:
t = time in minutes
q = radiant heat flux in kW/m^2

As with toxic gases, an exposed occupant can be considered to accumulate a dose of radiant heat over a period of time. The fraction equivalent dose (FED) of radiant heat accumulated per minute is the reciprocal of t_{Irad}.

Radiant heat tends to be directional, producing localized heating of particular areas of skin even though the air temperature in contact with other parts of the body might be relatively low. Skin temperature depends on the balance between the rate of heat applied to the skin surface and the removal of heat subcutaneously by the blood. Thus, there is a threshold radiant flux below which significant heating of the skin is prevented but above which rapid heating occurs.

Based on the preceding information, it is estimated that the uncertainty associated with the use of equation (1) is ±25 percent. Moreover, an irradiance of 2.5 $kW \cdot m^{-2}$ would correspond to a source surface temperature of approximately 200°C, which is most likely to be exceeded near the fire, where conditions are changing rapidly.

Calculation of the time to incapacitation under conditions of exposure to convected heat from air containing less than 10 percent by volume of water vapor can be made using either equation (2) or equation (3).

As with toxic gases, an exposed occupant can be considered to accumulate a dose of convected heat over a period of time. The FED of convected heat accumulated per minute is the reciprocal of t_{Iconv}.

Convected heat accumulated per minute depends on the extent to which an exposed occupant is clothed and the nature of the clothing. For fully clothed subjects, equation (2) is suggested:

$$t_{Iconv} = \left(4.1 \cdot 10^{8}\right) T^{-3.61} \qquad (2)$$

where:
t_{Iconv} = time in minutes
T = temperature in °C

For unclothed or lightly clothed subjects, it might be more appropriate to use equation (3):

$$t_{Iconv} = \left(5 \cdot 10^{7}\right) T^{-3.4} \qquad (3)$$

where:
t_{Iconv} = time in minutes
T = temperature in °C

Equations (2) and (3) are empirical fits to human data. It is estimated that the uncertainty is ±25 percent.

Thermal tolerance data for unprotected human skin suggest a limit of about 120°C (248°F) for convected heat, above which there is, within minutes, onset of considerable pain along with the production of burns. Depending on the length of exposure, convective heat below this temperature can also cause hyperthermia.

The body of an exposed occupant can be regarded as acquiring a "dose" of heat over a period of time. A short exposure to a high radiant heat flux or temperature generally is less tolerable than a longer exposure to a lower temperature or heat flux. A methodology based on additive FEDs similar to that used with toxic gases can be applied. Providing that the temperature in the fire is stable or increasing, the total fractional effective dose of heat acquired during an exposure can be calculated using equation (4):

$$\text{FED} = \sum_{t_1}^{t_2} \left(1/t_{Irad} + 1/t_{Iconv}\right)\Delta t \quad \textbf{(4)}$$

Note 1: In areas within an occupancy where the radiant flux to the skin is under 2.5 kW · m^{-2}, the first term in equation (4) is to be set at zero.

Note 2: The uncertainty associated with the use of this last equation would be dependent on the uncertainties with the use of the three earlier equations.

The time at which the FED accumulated sum exceeds an incapacitating threshold value of 0.3 represents the time available for escape for the chosen radiant and convective heat exposures.

B.2.1.2 Air Carbon Monoxide Content. Air carbon monoxide (CO) content is as follows:

(1) Maximum of 2000 ppm for a few seconds
(2) Averaging 1500 ppm or less for the first 6 minutes of the exposure
(3) Averaging 800 ppm or less for the first 15 minutes of the exposure
(4) Averaging 50 ppm or less for the remainder of the exposure

These values should be adjusted for altitudes above 984 m (3000 ft).

B.2.1.3 Smoke Obscuration Levels. Smoke obscuration levels should be continuously maintained below the point at which a sign internally illuminated at 80 lx (7.5 ft-candles) is discernible at 30 m (100 ft) and doors and walls are discernible at 10 m (33 ft). This is equivalent to a light attenuation coefficient of 0.267 per m (0.06 per ft).

B.2.1.4 Air Velocities. Air velocities in the enclosed trainway should be greater than or equal to 0.82 m/s (150 fpm) and less than or equal to 11.1 m/s (2200 fpm).

B.2.1.5 Noise Levels. Noise levels should be a maximum of 115 dBa for a few seconds and a maximum of 92 dBa for the remainder of the exposure.

B.2.2 Geometric Considerations. Some factors that should be considered in establishing a tenable environment in stations are as follows.

(1) The evacuation path requires a height clear of smoke of at least 2.0 m (6.56 ft). The current precision of modeling methods is within 25 percent. Therefore, in modeling methods a height of at least 2.5 m (8.2 ft) should be maintained above any point along the surface of the evacuation pathway.
(2) The application of tenability criteria at the perimeter of a fire is impractical. The zone of tenability should be defined to apply outside a boundary away from the perimeter of the fire. This distance will be dependent on the fire heat release rate and could be as much as 30 m (100 ft).

B.2.3 Time Considerations. The project should develop a time-of-tenability criterion for stations with the approval of the authority having jurisdiction. Some factors that should be considered in establishing this criterion are as follows:

(1) The time for fire to ignite and become established
(2) The time for fire to be noticed and reported
(3) The time for the entity receiving the fire report to confirm existence of fire and initiate response
(4) The time for all people who can self-rescue to evacuate to a point of safety
(5) The time for emergency personnel to arrive at the station platform
(6) The time for emergency personnel to search, locate, and evacuate all those who can not self-rescue
(7) The time for fire fighters to began to suppress the fire

If a project does not establish a time-of-tenability criterion, the system should be designed to maintain the tenable conditions indefinitely.

B.3 Configurations. Configurations can vary among properties, but engineering principles remain constant. The application of those principles should reflect the unique geometries and characteristics of each property.

Enclosed stations and trainways might be configured with the following characteristics:

(1) High or low ceilings
(2) Open or doored entrances
(3) Open or screened platform edges
(4) End-of-station or midtunnel fan shafts
(5) End-of-station or midtunnel vent shafts
(6) Single, double, or varying combinations of tracks in tunnels
(7) Intersecting tunnels
(8) Multilevel stations
(9) Multilevel tunnels
(10) Varying depths below the surface
(11) Varying grades and curvatures of tracks and tunnels
(12) Varying blockage ratios of vehicles to tunnel cross section
(13) Varying surface ambient conditions
(14) Varying exit points to surface or points of safety

B.4 Draft Control.

B.4.1 For patron comfort in stations, the air velocities induced by train motion should be evaluated carefully by designers. Infrequent exposure to higher velocities can be tolerated briefly but are to be avoided wherever possible. *[Refer to the Subway Environmental Design Handbook (SEDH); the ASHRAE Handbook Fundamentals; and the Beaufort Scale.]*

B.4.2 Draft control can be achieved by the placement of shafts along the tunnel length between stations. Shafts can be arranged with the fan shafts at the ends of stations with vent shafts midtunnel if required or with vent shafts at the ends of stations and fan shafts midtunnel. End-of-station shaft configurations should be related to the station geometries when considering patron comfort in the station relative to train piston draft effects.

B.5 Temperature Control.

B.5.1 Temperature control for patron comfort in the station can be achieved by circulating ambient air in moderate climates or by providing heating and/or cooling in more extreme regions. Preferred temperature goals should be defined in the criteria developed for the design of an individual property relative to the local climate and the length of station occupancy, such as train headways specific to the property during which the patron would be exposed to the station temperatures.

B.5.2 Temperature control and ventilation for ancillary areas housing special equipment should reflect the optimum operating conditions for the specific equipment to ensure the availability of critical equipment and should also give consideration for intermittent occupancy by maintenance personnel. These systems should be separate from the emergency ventilation system for stations and tunnels and should be considered when designing the emergency ventilation system.

B.6 Under-Platform Ventilation System.

B.6.1 An under-platform ventilation system should be considered for the extraction of heat from traction and braking devices. Intakes should be provided below the platform level and should be situated relative to the heat-producing devices on a train berthed in a station.

B.6.2 Ceiling ventilation, by powered or gravity design, to aid in the removal of smoke and/or heat should be considered.

B.7 Platform Edge Screens.

B.7.1 The inclusion of platform edge screens is a design option that is effective for comfort control in stations as well as for smoke control in tunnels. When used, the screens should meet both fire resistivity and structural strengths relative to the train and ventilation system drafts and the operational efficiency requirements.

B.7.2 In a tunnel-to-station evacuation scenario, access to the platform level from the track level should be considered.

B.8 Nonfire Tunnel Ventilation. Where trains might be stopped or delayed in a tunnel for a period of time, the vehicle ventilation system should be capable of maintaining an acceptable level of patron comfort. If not operating in a fire emergency scenario, the tunnel ventilation fans can be used to augment the vehicle system capability. Velocities should consider the comfort levels of employees required to be in the tunnels.

Annex C Emergency Egress

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 Transit Station Occupant Load. Transit station dimensions are determined as a function of the length of trains employed in a transit system. Thus the areas of station platforms in light density outlying stations will be equal to those of heavy density downtown central business district transit stations. Consequently, occupancy loads in rapid transit stations, based on the emergency condition requiring evacuation of that station to a point of safety, are a function of the train-carrying capacities rather than platform areas categorized as a *place of assembly*. The tunnel can be considered as an auxiliary exit from the station under certain fire scenarios.

C.1.1 Calculating Occupant Load. The occupant load, as used in this section, is the basis on which most new or expanding transit systems are designed. The methodology for determining passenger use of transit systems varies considerably between specific systems, but a study usually will permit a determination of *peak hour loads*. Most systems also will determine *peak hour reversal* from morning to afternoon to reflect commuter loads.

The basis on which the occupant load data is determined should be considered carefully in establishing the need for emergency egress. In new transit systems, a survey of actual usage should be made within 2 years of completion of the project to verify design predictions. In operating systems, predicted passenger loads should be established to determine the need for expansion of the system or significant operating changes. Verification by survey should be made following any extension or significant operating change or at a maximum of 5-year intervals.

The basis for calculating occupant loads should be the peak hour patronage figures as commonly projected for design of new transit systems or as established by survey for operating systems.

For new transit systems, the projected peak hour passenger figures can be converted to the peak 15-minute loads by dividing by 4 and multiplying by the system surge factor. The system surge factor is a distribution curve correction and can be varied for a particular system if sufficient data are available for verification. Both link loads (the number of passengers traveling between two stations over a given period) and entraining loads (the number of passengers entering a station to board trains during a given period) are converted in this manner.

For existing transit systems, where actual patronage data are available, statistical methods can be used to calculate occupant load data. The use of statistical methods for calculation of *calculated train loads* and *calculated entraining loads* will provide a more accurate indication of exiting needs.

The station occupant load is composed of two parts: the entraining load and the calculated train load. The entraining load as used for exit calculations is calculated from the peak 15-minute entraining loads by dividing by 15 minutes and multiplying by two times the headway.

Where trains arrive at a platform from only one direction, the calculated train load as used for exit calculations is calculated from the peak 15-minute link load by dividing the number of trains arriving at the station during 15 minutes based on headways and multiplying by 2 to allow for one missed headway. The maximum for the calculated train load should be the most passengers capable of occupying a train.

Where trains arrive at a platform from more than one direction, the entraining load and calculated train load for the peak direction are computed as described in the preceding paragraph. In the off-peak direction, the entraining load and the calculated train load are computed from the peak 15-minute entraining load and the peak 15-minute link load, respectively, by dividing by the number of trains arriving at the station during a 15-minute period, based on headway.

C.1.2 Calculating Evacuation Time. The total evacuation time is the sum of the walking travel time for the longest exit route plus the waiting times at the various circulation elements.

The following methodology is intended to be used to calculate the evacuation time for all platform occupants from the most remote point on the station platform to the point of safety. The examples given measure evacuation time to the street. However, as noted in 5.5.3.2.2, where the point of safety is determined to be the concourse or some other floor area in the station, the example calculations should be modified accordingly.

The walking travel time is calculated using station geometry data and the travel speeds indicated in 5.5.3.3. The exit route is broken down into sequential horizontal and vertical segments and then tabulated. The travel distance for each segment is then divided by the appropriate travel speed to determine the time needed to traverse each segment. The walking travel time is the sum of the times for each segment.

The flow time (the time for the last person to pass through the particular element) for each of the various circulation elements (e.g., platform exits, fare barriers, concourse exits) is calculated using the capacities and conditions specified in 5.5.3 through 5.5.5 along with the calculated occupant load. Care should be taken to ensure that the most restrictive elements are included in the calculations.

For instance, a nominal 914 mm (36 in.) wide door provides access to a 1118 mm (44 in.) wide stair, and the clear width of the door opening, with the door in the fully open position, is usually about 813 mm (32 in.). Using the capacities specified in 5.5.3.3, the door has a capacity of 0.0819 p/mm-min (2.08 pim) or 67 p/min. The stair has a capacity of 0.0516 p/mm-min (1.31 pim) or 58 p/min. In this case, the stair is more restrictive than the door, meaning that the stair should be used in the capacity calculations. If the stair were wider, 1422 mm (56 in.), the capacity of the stair would be 73 p/min. The door capacity would then be more restrictive in either case, meaning that the door capacity should be used.

Where exit paths divide (i.e., where a choice of exit paths is presented), it is presumed (as it is in the model codes) that the passengers will divide into groups roughly in proportion to the exit capacity provided by the various paths at the decision point. It also is presumed that passengers, once having selected an exit path, will stay on that path until another decision point is reached or egress is achieved.

The waiting time at each of the various circulation elements is calculated as follows:

(1) For the platform exits, by subtracting the walking travel time on the platform from the platform exits flow time
(2) For each of the remaining circulation elements, by subtracting the maximum of all previous element flow times

The symbols used in the sample calculations in this annex represent the walking times, flow times, and waiting times as follows:

T = total walking travel time for the longest exit route
T_p = walking travel time on the platform
T_X = walking travel time for the Xth segment of the exit route
F_p = platform exits flow time
F_{fb} = fare barrier flow time
F_c = concourse exits flow time
F_N = flow time for any additional circulation element
$W_p = F_p - T_p$ = waiting time at platform exits
$W_{fb} = F_{fb} - T_{fb}$ = waiting time at fare barriers
$W_c = F_c - \max(F_p \text{ or } F_{fb})$ = waiting time at concourse exits
$W_N = F_N - \max(F_c, F_{fb}, \text{ or } F_p)$ = waiting time at any additional circulation element

Note that the waiting time at any circulation element cannot be less than zero.

C.1.3 Center-Platform Station Sample Calculation. The sample center-platform station is an elevated station with the platform above the concourse, which is at grade *(see Figure C.1.3)*. The platform is 183 m (600 ft) long to accommodate the train length. The vertical distance from the platform to the concourse is 9 m (30 ft).

The station has one paid area separated from the outside by a fare array containing four electronic fare gates and one 1.22 m (48 in.) handicapped/service gate. In addition, two 1.83 m (72 in.) wide emergency exits are provided. Six open wells communicate between the platform and the concourse. Each well contains one stair or one escalator. Station ancillary spaces are located at the concourse level.

Elevators (not shown in Figure C.1.3) are provided for use by handicapped persons or service personnel. Open emergency stairs are provided at each end of the platform and discharge directly to grade through grille doors with panic hardware.

Escalators are nominal 1.22 m (48 in.) wide. Stairs regularly used by patrons are 1.83 m (72 in.) wide; emergency stairs are 1.22 m (48 in.) wide. Gates to emergency stairs are 1.22 m (48 in.) wide.

The station occupant load is 2314 persons.

Table C.1.3 lists the data for the exiting analysis of the sample center platform.

In Test No. 1, the time to clear the platform is found to be 3.80 minutes. This meets the requirement of 5.5.3.1.

In Test No. 2, the time to reach a point outside any enclosing structure is found to be 4.85 minutes. This meets the requirement of 5.5.3.2.

Test No. 1. Evacuate platform occupant load(s) from platform(s) in 4 minutes or less.

$$F_p \text{ (time to clear platform)} = \frac{\text{Platform occupant load}}{\text{Platform exit capacity}}$$

$$F_p = \frac{2314}{609}$$

$$F_p = 3.80 \text{ minutes}$$

Test No. 2. Evacuate platform occupant load from most remote point on platform to a point of safety in 6 minutes or less.

Wp (waiting time at platform exits) = $F_p - T_1$
$Wp = 3.80 - 1.09 = 2.71$ minutes
Concourse occupant load =
Platform occupant load − (F_p · emergency stair capacity)
Concourse occupant load = 2314 − 513
Concourse occupant load = 1801 persons
W_{fb} (waiting time at fare barriers) = $F_f - F_p$

$$F_{fb}\text{(fare barrier flow time)} = \frac{\text{Concourse occupant load}}{\text{Fare barrier exit capacity}}$$

$$F_{fb} = \frac{1801}{600} = 3.0$$

$W_c = F_{fb} - F_p$
$W_c = 3.0 - 3.80 = 0.000$ minutes
W_c (waiting time at concourse exits) = $[F_c - \max(F_{fb} \text{ or } F_p)]$

$$F_c\text{(concourse exit flow time)} = \frac{\text{Concourse occupant load}}{\text{Concourse exit capacity}}$$

$$F_c = \frac{1801}{0} = 0.000 \text{ minutes}$$

$W_c = F_c - \max(F_{fb} \text{ or } F_p)$
$Wc = 0.000 - 3.80 = 0.000$ minutes
Total exit time = $T + W_p + W_f + W_c$
Total exit time = 2.14 + 2.71 + 0.000 + 0.000
Total exit time = 4.85 minutes

Table C.1.3 NFPA 130 Exiting Analysis of Sample Center-Platform Station

Egress Element	mm	in.	p/mm-min	pim	p/min
Platform to concourse (downward)					
Stairs (4)	7315	288	0.0555	1.41	406
Escalators (2*)	1219	48	0.0555	1.41	68
Emergency stairs (2)	2438	96	0.0555	1.41	135
Escalator test: 8.67% (Not > 50%)					609
Throughfare barriers					
Fare gates (4) (capacity = 50 per gate)					200
Service gates (1)	1219	48	0.0819	2.08	100
Emergency exit doors (2)	3658	144	0.0819	2.08	300
					600
Fare barriers to safe area (fare barriers discharge to outside)					
Stairs	0	0	0.0555	1.41	0
Escalators	0	0	0.0555	1.41	0
Emergency stairs	0	0	0.0555	1.41	0
Escalator test: 0.00% (Not > 50%)					0

Walking Time for Longest Exit Route	m	ft	m/min	fpm	minutes
Platform to safe area					
On platform, T_1	41.4	136	37.7	124	1.09
Platform to concourse, T_2	9.1	30	14.6	48	0.62
On concourse, T_3	16.4	54	37.7	124	0.43
Concourse to grade, T_4	0	0	14.6	48	0
On grade to safe area, T_5	3.05	10	37.7	124	0.08
Total walking time, $T = T_1 + T_2 + T_3 + T_4 + T_5$					2.14

*One escalator discounted.

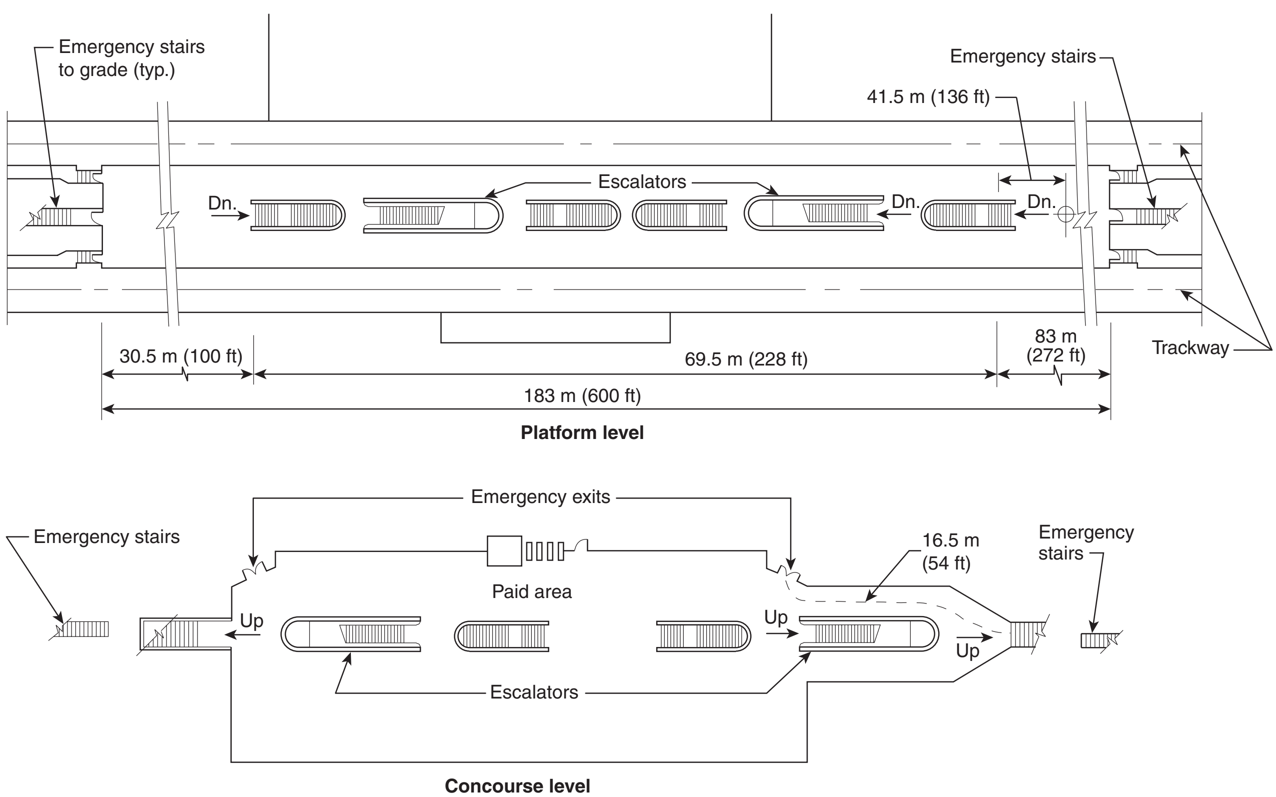

FIGURE C.1.3 Center-Platform Station.

If the concourse of this station is considered to meet the point of safety definition by the authority having jurisdiction, the calculation for Test No. 2 would be modified. The time to reach a point of safety would include the walking travel time from the remote point on the platform to the concourse only, plus the waiting time at the platform exits. The area of the concourse would have to be large enough to accommodate the concourse occupant load calculated in Test No. 2.

C.1.4 Side-Platform Station Sample Calculation. The sample side-platform station is a subway station with a concourse above the platform level but below grade. *(See Figure C.1.4.)* The platform is 183 m (600 ft) long to accommodate the train length. The vertical distance from grade to concourse is 8 m (26 ft). The concourse is 5.5 m (18 ft) above the platform.

The station has two entrances normally used by patrons, each containing one escalator and one stair. The entrances are covered at grade level to a point 3 m (10 ft) beyond the top of the stairs.

The concourse is divided into two free areas and one paid area separated by fare arrays. Each fare array contains 12 fare gates of the turnstile type and one swinging service gate, 1.22 m (48 in.) wide, equipped with panic hardware for use by handicapped persons and service personnel. Three open wells, containing two stairs and one escalator, communicate between each platform and the concourse.

Elevators are provided from grade level to concourse and from the concourse to each platform for use by handicapped persons and service personnel. Station ancillary spaces are located at concourse level.

Enclosed emergency stairs, discharging directly to grade, are provided at both ends of each platform. Escalators are nominal 1.22 m (48 in.) wide. Stairs regularly used by patrons are 1.83 m (72 in.) wide. Emergency stairs are 1.22 m (48 in.) wide. Doors to emergency stairs are 1.22 m (48 in.) wide.

The station occupant load is 1600 persons, 228 on the outbound platform and 1372 on the inbound platform.

The sample calculation shown is one of several that needs to be done to properly analyze this type of station. The sample calculation shows the effect of discounting one of the escalators from concourse to grade. The egress capacity from platform to concourse meets the criteria of 5.5.3.1 in Test No. 1, where the time to clear the platform is found to be 3.66 minutes for the inbound platform and 0.61 minute for the outbound platform.

However, in Test No. 2, the total exit time (i.e., the maximum exit time for the two paths examined) is found to be 7.83 minutes. This does not meet the criteria of 5.5.3.2; therefore, additional egress capacity is needed from concourse to grade.

Additional calculations should be made to examine the results of discounting an escalator between platform and concourse (rather than an escalator between concourse and grade) to verify that the inbound platform can still be cleared in 4 minutes or less under this condition.

Table C.1.4 lists the data for the existing analysis of the sample side-platform station.

Test No. 1. Evacuate platform occupant load(s) from platform(s) in 4 minutes or less.

Inbound platform:

$$F_{p-i}\left(\text{time to clear platform}\right) = \frac{\text{Platform occupant load}}{\text{Platform egress capacity}}$$

$$F_{p-i} = \frac{1372}{375}$$

$F_{p-i} = 3.66$ minutes

Outbound platform:

$$F_{p-o}\left(\text{time to clear platform}\right) = \frac{\text{Platform occupant load}}{\text{Platform egress capacity}}$$

$$F_{p-o} = \frac{228}{375}$$

$F_{p-o} = 0.61$ minutes

F_p for inbound and outbound occupant loads satisfies the criterion of 4 minutes.

Test No. 2. Evacuate platform occupant load from most remote point on platform to a point of safety in 6 minutes or less.

Inbound platform:
W_{p-i} (waiting time at platform egress elements) = $F_{p-i} - T_{1-in.}$
$W_{p-i} = 3.66 - 1.34 = 2.32$ minutes
Concourse occupant load =
Platform occupant load – F_{p-i} · emergency stair capacity)
Concourse occupant load =
Platform occupant load – F_{p-i} · emergency stair capacity)
Concourse occupant load = 1372 – 458
Total concourse occupant load = 914 persons

Outbound platform:
W_{p-o} (waiting time at platform egress elements) = $F_{p-o} - T_{1-out}$
$W_{p-o} = 0.61 - 0.49 = 0.12$ minute
Concourse occupant load =
Platform occupant load – (F_{p-o} · emergency stair capacity)
Concourse occupant load = 228 – 77
Concourse occupant load = 151 persons
Total concourse occupant load =
Concourse load (inbound) + Concourse load (outbound)
Total concourse occupant load = 914 + 151 = 1065 persons

Inbound platform:
W_{fb} (waiting time at fare barriers) = $F_{fb} - F_{p-i}$

$$F_{fb} = \frac{\text{Concourse occupant load}}{\text{Fare barrier egress capacity}}$$

$$F_{fb} = \frac{533}{399}$$

$F_{fb} = 1.34$ minutes
$W_{fb} = F_{fb} - F_{p-i}$
$W_{fb} = 1.34 - 3.66 = 0.00$ minutes
W_c (waiting time at concourse egress elements) =
$F_c - \max(F_{fb} \text{ or } F_{p-i})$

$$F_c\left(\text{concourse flow time}\right) = \frac{\text{Concourse occupant load}}{\text{Concourse egress capacity}}$$

$$F_c = \frac{533}{94}$$

$F_c = 5.68$ minutes
$W_c = F_c - \max(F_{fb} \text{ or } F_{p-i})$
$W_c = 5.68 - 3.66 = 2.02$ minutes

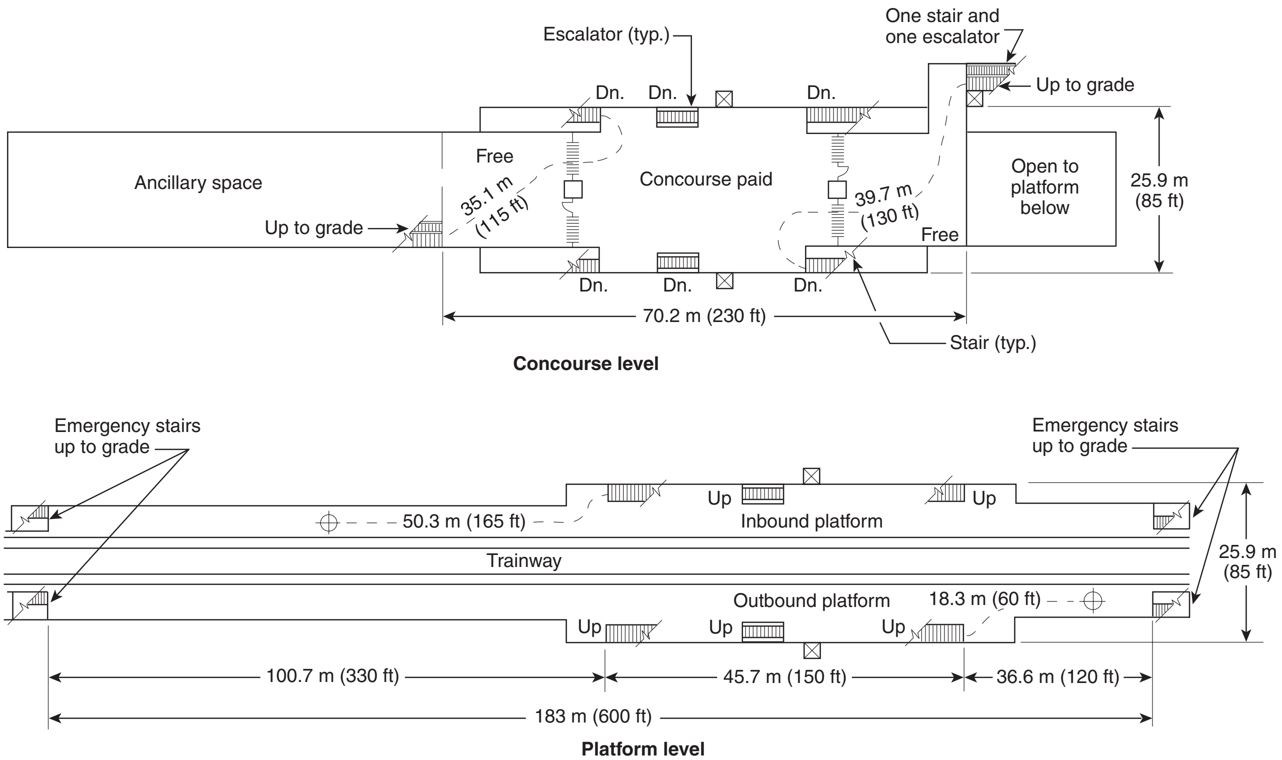

FIGURE C.1.4 Side-Platform Station.

Outbound platform:

W_{fb} (waiting time at fare barriers) = $F_{fb} - F_{p-o}$

$$F_{fb} = \frac{\text{Concourse occupant load}}{\text{Fare barrier egress capacity}}$$

$$F_{fb} = \frac{533}{399}$$

F_{fb} = 1.34 minutes

$W_{fb} = F_{fb} - F_{p-o}$

W_{fb} = 1.34 – 0.61 = 0.73

W_c (waiting time at concourse egress elements) = $F_c - \max(F_{fb} \text{ or } F_{p-o})$

$$F_c = (\text{concourse flow time}) = \frac{\text{Concourse occupant load}}{\text{Concourse egress capacity}}$$

$$F_c = \frac{533}{156}$$

F_c = 3.42 minutes

$W_c = F_c - \max(F_{fb} \text{ or } F_{p-o})$

W_c = 3.42 – 1.34 = 2.08 minutes

Total egress time = $T + W_p + W_{fg} + W_c$

Inbound platform:

Total = 3.49 + 2.32 + 0.00 + 2.02

Total = 7.83 minutes

Outbound platform:

Total = 2.76 + 0.12 + 0.73 + 2.08

Total = 5.69 minutes

C.1.5 Multilevel-Platform Stations. The procedures for calculating exiting times for multilevel platform stations are similar to the sample calculations in C.1.3 and C.1.4. The changes in the exiting calculations are for multilevel-platform stations primarily a function of the concurrent occupancy load determinations for the two platform levels.

The step-by-step procedure relating to the occupancy load calculations generally is recommended as follows:

(1) Calculate the occupancy load for each platform level as in the appropriate examples in C.1.3 and C.1.4 for the same assumed time(s) of day.
(2) If the fire is on the upper-level platform (for an underground station), an assumption can be made as to the percentage of occupants who might be expected to evacuate the lower level through the normal egress routes versus those who might be expected to exit via emergency stairs. These assumptions will be unique for each system as a function of various parameters, including physical configuration of stations, means of egress, and location of emergency exits; communications facilities to advise passengers, both verbal and signing; level of transit personnel working in stations; and transit personnel emergency procedure responsibilities established for the transit operating authority.
(3) The upper-level occupant load is increased by the people evacuating from the lower level through the normal egress routes in accordance with C.1.5(2).
(4) For a fire on the lower level, appropriate assumptions relative to the distribution of the occupancy loads to the available means of egress are calculated in a fashion similar to the procedures described above.

The remainder of the exiting calculations essentially are unchanged from the other sample calculations in C.1.3 and C.1.4.

Table C.1.4 Exiting Analysis of Sample Side-Platform Station

Egress Element	mm	in.	p/mm-min	pim	p/min
Inbound platform to concourse (upward)					
Stairs (2)	3658	144	0.0516	1.31	185
Escalators (1*)	1219	48	0.0516	1.31	62
Emergency stairs (2)	2438	96	0.0516	1.31	125
					375
Throughfare barriers					
Turnstiles (12) (capacity = 25 p/min)					300
Service gate (1)	1219	48	0.0819	2.08	99
					399
Fare barriers to safe area					
Stairs (1)	1829	72	0.0516	1.31	94
Escalator* (0)	0	0	0.0516	1.31	0
					94
Walking Time for Longest Exit Route	**m**	**ft**	**m/min**	**fpm**	**minutes**
Inbound platform					
On platform, T_1	50.3	165	37.7	124	1.34
Platform to concourse, T_2	5.5	18	12.1	40	0.46
On concourse, T_3	35.1	115	37.7	124	0.94
Concourse to grade, T_4	7.9	26	12.1	40	0.66
On grade to safe area, T_5	3.05	10	37.7	124	0.09
Total walking time, $T = T_1 + T_2 + T_3 + T_4 + T_5$					3.49
Element	**mm**	**in.**	**p/mm-min**	**pim**	**p/min**
Outbound platform to concourse (upward)					
Stairs (2)	3658	144	0.0516	1.31	188
Escalators (1*)	1219	48	0.0516	1.31	62
Emergency stairs (2)	2438	96	0.0516	1.31	125
					375
Throughfare barriers					
Turnstiles (12) (capacity = 25 p/min)					300
Service gate (1)	1219	48	0.0819	2.08	99
					399
Fare barriers to safe area					
Stairs	1829	72	0.0516	1.31	94
Escalator	1219	48	0.0516	1.31	62
					156
Walking Time for Longest Exit Route	**m**	**ft**	**m/min**	**fpm**	**minutes**
Outbound platform					
On platform, T_1	18.2	60	37.7	124	0.49
Platform to concourse, T_2	5.5	18	12.1	40	0.46
On concourse, T_3	39.6	130	37.7	124	1.06
Concourse to grade, T_4	7.9	26	12.1	40	0.66
On grade to safe area, T_5	3.05	10	37.7	24	0.09
Total walking time, $T = T_1 + T_2 + T_3 + T_4 + T_5$					2.76

*Worst case: escalator-out-of-service test (5.5.3.3.2.2).

C.2 Escalators. ANSI/ASME A17.1, which governs the design of escalators, is generally recognized as one of the strictest consensus standards. However, considering the critical operational nature of the escalators in rapid transit stations, specially designed units with additional safety features should be provided.

The number of flat steps at the upper landings should be increased in proportion to the vertical rise of the escalator. For a rise up to 6.1 m (20 ft), use the manufacturers' standard number of flat steps. From 6.1 m (20 ft) to 18.3 m (60 ft) rise, use three flat steps; over 18.3 m (60 ft) rise, use four flat steps.

A remote monitoring panel should be provided in the station that displays the following for each escalator:

(1) Direction of travel
(2) Operating speed (if more than one)
(3) Out-of-service status
(4) Flashing light that indicates the escalator is stopped because of activation of a safety device

A remote stopping device should be provided only if the entire escalator is visible from the remote location or a stop is delayed until it is preceded by an appropriate warning.

Annex D Suggested Test Procedures for Fire Hazard Assessment

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

D.1 General. The two most important features in fire safety design of a fixed guideway transit or passenger rail vehicle are to provide sufficient time for evacuation in the event of a fire before the vehicle compartment becomes untenable and to prevent a self-propagating fire.

D.1.1 Modeling has the capability of providing an evaluation of a fire system. A model can predict what effect the use of various combinations of materials will have in preventing fully developed fires in a specific situation.

D.2 Hazard Load Calculations. Hazard load calculations provide a way to examine the potential fire hazard of the products used in a transit vehicle interior and of their component materials. Using the example in Table D.2(a), the selection of the seating materials can seriously affect the loading in a vehicle. A self-propagating fire depends on the size of the initiating fire; therefore, the heat flux or exposing fire used to evaluate materials or products at their location in the fire system is important. In a critical series of tests on heat release on materials, minimum incident heat flux values of 35 kW/m^2 were used. The value of incident heat flux required for testing different products (or their component materials) should be a function of the product being assessed, including its location in the rail transportation vehicle. Hazard load values are useful in determining if a self-propagating fire is possible. The hazard load analysis is one of the methods that can be used for comparing release rate information used to determine the level of safety selected. The release rate information in Table D.2(b) is based on the 3 minute release determined at the exposure identified in Table D.2(b). However, it must be recognized that hazard load calculations cannot take into account the distribution of products within the rail transportation vehicle, a factor that can critically affect fire hazard. Table D.2(c) and Table D.2(d) show the calculations for best loading and worst loading based on the information in Table D.2(a) and Table D.2(b).

Table D.2(a) Hazard Load Calculations

	Hazard Load Calculations	
Exposed Surface Areas	**ft^2**	**m^2**
Seating		
Padded (bottom and back)	365	33.9
Hardback (seat backs)	133	12.4
Windows [(65 ft · 7 ft) · 40% · 2]	365	33.9
Lower walls [(65 ft · 7 ft) · 60% · 2]	546	50.7
Light fixture covers [(65 ft · 0.83 ft) · 2]	108	10
Floor (65 ft · 9 ft)	585	54.3
Ceiling (65 ft · 9 ft)	585	54.3

Note: Interior volume of a rail vehicle is 4095 ft^3 (115.9 m^3).

Table D.2(b) Release Rate Data

		"Best" 3 Minute Release		"Worst" 3 Minute Release	
Transit Vehicle Interior Material	**Area (ft^2)**	**Heat (Btu/ft^2)**	**Smoke (particles[a]/ft^2)**	**Heat (Btu/ft^2)**	**Smoke (particles[b]/ft^2)**
Seating at 1.0 W/cm^2					
Padded	365	90	2,100	2,400	10,140
Hardback	133	150	330	300	2,500
Windows at 1.5 W/cm^2	365	60	165	1,500	600
Lower walls at 1.5 W/cm^2	546	150	330	300	2,500
Light fixture covers at 1.5 W/cm^2	108	85	275	860	200
Floor at 1.0 W/cm^2	585	0	0	75	90
Ceiling at 3.5 W/cm^2	585	0[b]	0[b]	1,150	30

[a]A *particle* of smoke is as defined by ASTM E 906.
[b] Assumed noncombustible aluminum panels.