

NFPA® 502

**Standard for
Road Tunnels, Bridges,
and Other Limited
Access Highways**

2020



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NFPA® 502

Standard for

Road Tunnels, Bridges, and Other Limited Access Highways

2020 Edition

This edition of NFPA 502, *Standard for Road Tunnels, Bridges, and Other Limited Access Highways*, was prepared by the Technical Committee on Road Tunnel and Highway Fire Protection and acted on by NFPA at its June Association Technical Meeting held June 17–20, 2019, in San Antonio, TX. It was issued by the Standards Council on August 5, 2019, with an effective date of August 25, 2019, and supersedes all previous editions.

This edition of NFPA 502 was approved as an American National Standard on August 25, 2019.

Origin and Development of NFPA 502

A tentative standard, NFPA 502T, *Standard for Limited Access Highways, Tunnels, Bridges, and Elevated Structures*, was prepared by the Technical Committee on Motor Vehicle Fire Protection and was adopted by the National Fire Protection Association on May 16, 1972, at its Annual Meeting in Philadelphia, PA. It was withdrawn in November 1975. In 1980, the committee rewrote the document as a recommended practice and included a chapter on air-right structures. It was adopted at the 1981 NFPA Annual Meeting.

Minor revisions to Chapters 2 through 5, primarily to water supply and fire apparatus requirements, were made in the 1987 edition.

The recommended practice was reconfirmed in 1992.

The 1996 edition incorporated a totally revised chapter on tunnels. Other revisions were made to correlate the new material in tunnel and air-right structure requirements with existing chapters and to update NFPA 502 with respect to current technology and practices.

The 1998 edition was developed by a task group appointed by the chairman of the Technical Committee on Motor Vehicle and Highway Fire Protection. With the planned revision from a recommended practice to a standard, the task group reviewed and completely revised all chapters of the document, with special emphasis on incorporating the lessons learned following completion of the full-scale fire ventilation test program at the Memorial Tunnel in West Virginia. Specific to the Memorial Tunnel Fire Ventilation Test Program, changes were made to Chapter 7, Tunnel Ventilation During Fire Emergencies. The title of the standard was also changed to reflect more accurately the contents and to properly identify the major focus of the standard. The previous title, *Recommended Practice on Fire Protection for Limited Access Highways, Tunnels, Bridges, Elevated Roadways, and Air-Right Structures*, was changed to *Standard for Road Tunnels, Bridges, and Other Limited Access Highways*.

The 2001 edition contained a significant editorial rewrite and reorganization of the document. Technical changes regarding emergency communication, emergency egress and lighting in tunnels, and tunnel ventilation were incorporated into the 2001 edition. Further changes were made to clarify the application of the standard based on tunnel length.

The 2004 edition included new requirements for the protection of concrete and steel tunnel structures, specific requirements for emergency lighting, and clarification of the travel distance to emergency exits in tunnels. The 2004 edition also updated the vehicle tunnel fire data in Annex A to more recent international research.

The 2008 edition added specific requirements for fire tests for tunnel structural elements and included revisions that further clarified the categorization of road tunnels; revisions regarding ventilation, tenable environment, and hazardous goods transport and a revision of the discussion topics in Annex E on fixed fire suppression systems.

The 2011 edition further developed performance-based design approaches for tunnels. Table 7.2 was updated to provide a more comprehensive review of the required systems for tunnels based on tunnel category. Chapter 9 was added to address the design of water-based fire-fighting systems. Additional changes to the document included the addition of system commissioning and periodic testing and updated annex material addressing design factors for life safety and property protection.

The 2014 edition included technical changes regarding emergency ventilation systems, electrical systems, emergency response, and emergency exits and new requirements for flammable and environmental hazards. Table 7.2, the comprehensive review of the required systems for tunnels based on category, was reorganized, updated, and moved to Annex A for ease of use. Additional changes to the document included clarifications for water-based fire-fighting and standpipe systems along with updated annex material corresponding to newly added requirements in the body of the standard.

The 2017 edition of NFPA 502 revised the list of considerations to be taken into account during an engineering analysis and added guidance in the annexes. Integrated testing on fire protection, life safety, and emergency systems, in accordance with NFPA 4, *Standard for Integrated Fire Protection and Life Safety System Testing*, is now required. Requirements for the structural protection of bridges were modified. New to Annex B was guidance on establishing noise levels in order to maintain a minimum level of speech intelligibility through the emergency communication system. The constant K_1 used in the critical velocity equation of Annex D was modified and is no longer a constant for heat release rates (HRR) less than or equal to 100 MW. In Annex E, information was provided regarding the effects of fire suppression on HRR and tunnel ventilation. A new Annex M was added providing guidance on the use of automatic fire detection systems in road tunnels.

The 2020 edition of NFPA 502 includes several revisions. In general requirements, a change was made to ensure that protection methods described assume a single fire event. Section 6.11 now requires an analysis to be performed on joints of nonconventional and nonrigid connections. Fixed water-based fire-fighting systems (FFFS) have been further explained throughout the code, as well as in several annex materials. Structural fire protection material has new requirements per 7.3.4. New references to NFPA 72®, *National Fire Alarm and Signaling Code*®, have been made in Chapter 7 for automatic fire detection systems. A section on Operations Control Centers (OCCs) has been updated in Chapter 13.

Technical Committee on Road Tunnel and Highway Fire Protection

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Port Authority of New York & New Jersey, NY [U]

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Ian E. Barry, IEB Consulting Ltd., United Kingdom [SE]

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Cornelis Kees Both, PRTC Fire Laboratory, Belgium [RT]

Francesco Colella, Exponent, Inc., MA [SE]

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John A. Dalton, GCP-Applied Technologies, MA [M]

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Arnold Dix, School Medicine, UWS, Australia [C]

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Haukur Ingason, SP Technical Research Institute of Sweden, Sweden [RT]

Ahmed Kashef, National Research Council of Canada, Canada [RT]

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Dirk K. Sprakel, FOGTEC Fire Protection GmbH & Co KG, Germany [M]

Peter J. Sturm, Graz University of Technology, Austria [SE]

William Ventura, FDNY, NY [E]

Hadi Wijaya, Land Transport Authority, Singapore, Singapore [U]

Alternates

David Barber, Arup, DC [SE]

(Alt. to Jarrold Alston)

Iain N. R. Bowman, Mott MacDonald Canada Ltd., Canada [SE]

(Alt. to Norris Harvey)

Alan Brinson, European Fire Sprinkler Network, United Kingdom [M]

(Alt. to Russell P. Fleming)

John Celentano, CH2M Hill Consulting Engineers, Scotland [SE]

(Alt. to Ian E. Barry)

Eric Mun Kit Cheong, Land Transport Authority, Singapore, Singapore [U]

(Alt. to Hadi Wijaya)

Robert M. Cordell, Johnson Controls, RI [M]

(Alt. to Zachary L. Magnone)

Daniel T. Dirgins, PB Americas, Inc., MA [SE]

(Alt. to William G. Connell)

Gary L. English, Underground Command And Safety, WA [SE]

(Alt. to Maurice M. Pilette)

Kevin P. Harrison, Fire Department City of New York, NY [E]

(Alt. to William Ventura)

Marc L. Janssens, Southwest Research Institute, TX [RT]

(Alt. to Jason P. Huczek)

Daniel Joyeux, Efectis Nederland, Netherlands [RT]

(Alt. to Tomas Rakovec)

Dimitry Kogan, Port Authority Of NY and NY, NY [U]

(Alt. to Antonino Marino)

Anders Lönnermark, SP Fire Technology, Sweden [RT]

(Alt. to Haukur Ingason)

Robert Schmidt, RSCC Wire & Cable LLC, CT [M]

(Alt. to James S. Conrad)

Nader Shahcheraghi, AECOM, CA [SE]

(Alt. to David M. Plotkin)

Luke C. Woods, UL LLC, MA [RT]

(Alt. to Blake M. Shugarman)

Nonvoting

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(Member Emeritus)

Robert E. Solomon, NFPA Staff Liaison

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Committee Scope: This Committee shall have primary responsibility for documents on fire prevention and fire protection measures to reduce loss of life and property damage for limited access highways, road tunnels, bridges, elevated highways, depressed highways, and roadways that are located beneath air-right structures. Excluded from this scope is the protection for facilities for the storage, repair, and parking of motor vehicles.

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NFPA 502

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2020 Edition

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

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

Chapter 1 Administration

1.1 Scope.

1.1.1 This standard provides fire protection and fire-life safety requirements for limited access highways, road tunnels, bridges, elevated highways, depressed highways, and roadways that are located beneath air-right structures.

1.1.2 This standard establishes minimum requirements for each of the identified facilities.

1.1.3 This standard does not apply to the following structures:

- (1) Parking garages
- (2) Bus terminals
- (3) Truck terminals
- (4) Any other structure in which motor vehicles are stored, repaired, maintained, or parked

1.1.4 This standard shall be applicable where a structure or an element of a structure, including those specified in 1.1.3(1) through 1.1.3(4), is deemed to be a facility by the authority having jurisdiction (AHJ).

1.1.4.1 If any element of a structure cited in 1.1.3 is used to allow only the travel of road vehicles as a means of access to or egress from the structure, then it shall be characterized as a facility and treated as such under this standard.

1.2 Purpose. The purpose of this standard is to establish minimum criteria that provide protection from fire and its related hazards.

1.3 Application.

1.3.1* The provisions of this standard are the minimum necessary to provide protection from loss of life and property from fire.

1.3.2* The AHJ determines the application of this standard to facility alterations and fire protection system upgrades.

1.3.3 The portion of this standard that covers emergency procedures applies to both new and existing facilities.

1.4 Retroactivity. The provisions of this standard reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.4.1 Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard. Where specified, the provisions of this standard shall be retroactive.

1.4.2 In those cases where the AHJ determines that the existing situation presents an unacceptable degree of risk, the AHJ shall be permitted to apply retroactively any portions of this standard deemed appropriate.

1.4.3 The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the AHJ and only where the determined level of life safety and fire protection provisions required is approved.

1.5 Equivalency. Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, reliability, and safety over those prescribed by this standard, provided sufficient technical data demonstrates that the applied method, material, or device is equivalent to, or superior to, the requirements of this standard with respect to fire performance and safety.

1.5.1 Technical documentation shall be submitted to the AHJ to demonstrate equivalency.

1.5.2 The system, method, or device shall be approved for the intended purpose.

1.5.3 Alternative methods or devices approved as equivalent shall be recognized as being in compliance with this standard.

1.6 Units.

1.6.1* Metric units of measure in this standard are in accordance with the modernized metric system known as the International System of Units (SI). The liter unit (L), which is outside of but recognized by SI, is commonly used in the international fire protection industry. The appropriate units and conversion factors are specified in Table A.1.6.1.

1.6.2 If a value for measurement as provided 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 can be an approximation.

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, Quincy, MA 02169-7471.

NFPA 1, *Fire Code*, 2018 edition.

NFPA 3, *Standard for Commissioning of Fire Protection and Life Safety Systems*, 2018 edition.

NFPA 4, *Standard for Integrated Fire Protection and Life Safety System Testing*, 2018 edition.

NFPA 10, *Standard for Portable Fire Extinguishers*, 2018 edition.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, 2016 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2019 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 2019 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 2017 edition.

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, 2019 edition.

NFPA 18, *Standard on Wetting Agents*, 2017 edition.

NFPA 18A, *Standard on Water Additives for Fire Control and Vapor Mitigation*, 2017 edition.

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, 2019 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 2018 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 2019 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 2020 edition.

NFPA 70®, *National Electrical Code®*, 2020 edition.

NFPA 72®, *National Fire Alarm and Signaling Code*, 2019 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives*, 2019 edition.

NFPA 92, *Standard for Smoke Control Systems*, 2018 edition.

NFPA 101®, *Life Safety Code®*, 2018 edition.

NFPA 110, *Standard for Emergency and Standby Power Systems*, 2019 edition.

NFPA 111, *Standard on Stored Electrical Energy Emergency and Standby Power Systems*, 2019 edition.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 2018 edition.

NFPA 262, *Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces*, 2019 edition.

NFPA 750, *Standard on Water Mist Fire Protection Systems*, 2019 edition.

NFPA 820, *Standard for Fire Protection in Wastewater Treatment and Collection Facilities*, 2020 edition.

NFPA 1561, *Standard on Emergency Services Incident Management System and Command Safety*, 2014 edition.

NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*, 2017 edition.

NFPA 1963, *Standard for Fire Hose Connections*, 2019 edition.

2.3 Other Publications.

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

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

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

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

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

2.3.2 CSA Publications. Canadian Standards Association, 178 Rexdale Boulevard, Toronto, Ontario, Canada M9W 1R3.

CSA C22.2 No. 0.3, *Test Methods for Electrical Wires and Cables*, 2009, reaffirmed 2014.

2.3.3 Efectis Publications. Efectis Nederland, Brandpuntlaan Zuid 16, 2665 NZ, Bleiswijk, The Netherlands, www.efectis.com.

2008-Efectis-R0695, "Fire Testing Procedure for Concrete Tunnel Linings," 2008.

2.3.4 FHWA Publications. Federal Highway Administration, 1200 New Jersey Avenue, SE, Washington, DC 20590.

Manual on Uniform Traffic Control Devices (MUTCD), 2012.

2.3.5 IEEE Publications. IEEE, Three Park Avenue, 17th Floor, New York, NY 10016-5997.

FT4/IEEE 1202, *Standard for Flame-Propagation Testing of Wire and Cable*, 2006.

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

ISO 1182, *Reaction to fire tests for products — Non-combustibility test*, 2010.

2.3.7 Military Specifications. Department of Defense Single Stock Point, Document Automation and Production Service, Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-DTL-24643C, *Detail Specification: Cables, Electric, Low Smoke Halogen-Free, for Shipboard Use*, Revision C.

2.3.8 OSHA Publications. Occupational Safety and Health Administration, 200 Constitution Avenue, NW, Washington, DC 20210.

Title 29, Code of Federal Regulations, Part 1910.146, "Permit-Required Confined Spaces."

▲ **2.3.9 UL Publications.** Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

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

UL 1724, *Outline of Investigation for Fire Tests for Electrical Circuit Protective Systems*, 2006.

ANSI/UL 2196, *Standard for Fire Test for Circuit Integrity of Fire-Resistive Power, Instrumentation, Control, and Data Cables*, 2017.

2.3.10 Other Publications.

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

EN 13501-1, *Fire classification of construction products and building elements — Part 1: Classification using data from reaction to fire tests*, 2007 + A1:2010.

2.4 References for Extracts in Mandatory Sections.

NFPA 3, *Recommended Practice for Commissioning of Fire Protection and Life Safety Systems*, 2018 edition.

NFPA 10, *Standard for Portable Fire Extinguishers*, 2018 edition.

NFPA 70®, *National Electrical Code®*, 2020 edition.

NFPA 101®, *Life Safety Code®*, 2018 edition.

NFPA 402, *Guide for Aircraft Rescue and Fire-Fighting Operations*, 2019 edition.

NFPA 472, *Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents*, 2018 edition.

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

NFPA 1142, *Standard on Water Supplies for Suburban and Rural Fire Fighting*, 2017 edition.

NFPA 1901, *Standard for Automotive Fire Apparatus*, 2016 edition.

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

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 defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

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

3.2.3 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.

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

3.3 General Definitions.

3.3.1 Agency. The organization legally established and authorized to operate a facility.

3.3.2 Alteration. For limited access highways, road tunnels, bridges, elevated highways, depressed highways, and roadways that are located beneath air-right structures, a modification, replacement, or other physical change to an existing facility.

3.3.3 Alternative Fuel. A motor vehicle fuel other than gasoline and diesel.

3.3.4 Ancillary Facility. A structure, space, or area that supports the operation of limited access highways, road tunnels, bridges, elevated highways, depressed highways, and roadways that are under air-right structures, that are usually used to house or contain operating, maintenance, or support equipment and functions.

3.3.5* Backlayering. The movement of smoke and hot gases counter to the direction of the ventilation airflow.

3.3.6* Basis of Design (BOD). A document that describes the concepts and decisions used to meet the owner's project requirements and governing laws, regulations, codes, and standards. [3, 2018]

3.3.7 Bridge. A structure spanning and providing a highway across an obstacle such as a waterway, railroad, or another highway.

3.3.8* Building. Any structure used or intended for supporting or sheltering any use or occupancy.

3.3.9 Cable Tray System. A unit or assembly of units or sections and associated fittings forming a structural system used to securely fasten or support cables and raceways. [70:392.2]

3.3.10 Combustible. Capable of undergoing combustion.

3.3.11 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, 2019]

3.3.12 Commissioning. A systematic process that provides documented confirmation that specific and interconnected fire protection, life safety, and emergency systems function according to the intended design criteria set forth in the project documents and satisfy the owner's operational needs, including compliance requirements of any laws, regulations, codes, and standards requiring fire protection, life safety, and emergency systems.

3.3.13 Congestion. A traffic condition characterized by slow speeds or stopped traffic that occurs when volume increases or an incident occurs that impedes traffic flow.

3.3.14 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.

3.3.15 Decibel. The logarithmic units associated with sound pressure level.

3.3.15.1 A-weighted Decibel (dBA). Decibel values with weighting applied over the frequency range of 20 Hz to 20 kHz to reflect human hearing.

3.3.15.2 Un-weighted Decibel (dBZ). Decibel values without weighting applied.

N 3.3.16 Degraded Modes of Operation. Any condition in which fire protection and life safety systems and other related systems are not operating at normal capacity.

3.3.17 Deluge System. An open fixed water-based fire suppression system activated either manually or automatically.

N 3.3.18* Design Fire Scenario. A set of conditions that defines the fire development.

3.3.19 Dry Standpipe. A standpipe system designed to have piping contain water only when the system is being utilized.

3.3.20 Dynamic Vehicle Envelope. The space within the tunnel roadway that is allocated for maximum vehicle movement.

3.3.21* Emergency Communications. Radio and telephone systems located throughout the facility dedicated to provide the ability for direct communications during an emergency.

3.3.22 Emergency Exits. Doors, egress stairs, or egress corridors leading to a point of safety, such as cross-passages leading to an adjacent nonincident tunnel and portals.

3.3.23 Emergency Response Plan. A plan developed by an agency, with the cooperation of all participating agencies, that details specific actions to be performed by all personnel who are expected to respond during an emergency.

3.3.24 Engineering Analysis. An analysis that evaluates all factors that affect the fire safety of a facility or a component of a facility.

3.3.25 Equivalency. An alternative means of providing an equal or greater level of safety than that afforded by strict conformance to prescribed codes and standards.

3.3.26 Facility. A limited access highway, road tunnel, roadway beneath an air-right structure, bridge, or elevated highway.

Δ 3.3.27 Fire Apparatus. A vehicle designed to be used under emergency conditions to transport personnel and equipment to support the suppression of fires or mitigation of other hazardous situations. [1901, 2016]

3.3.28 Fire Department Connection. A connection through which the fire department can pump supplemental water into the fixed water-based fire-fighting system, sprinkler system, standpipe system, or other systems furnishing water for fire suppression and extinguishment to supplement existing water supplies.

Δ 3.3.29 Fire Emergency. The existence of, or threat of, fire or the development of smoke or fumes, or any combination thereof, that demands immediate action to mitigate the condition or situation.

Δ 3.3.30* Fire Growth Rate. Rate of change of the fire's heat release.

N 3.3.31* Fire Risk Assessment. A process to characterize the risk associated with fire, which addresses the design fire scenario or scenarios of concern, their probability, and their potential consequences.

N 3.3.31.1 Risk Acceptance Criteria. The units and threshold values against which a fire risk assessment is judged.

3.3.32 Fire Suppression. The sharp reduction of the rate of heat release of a fire and the prevention of regrowth.

Δ 3.3.33* Fixed Water-Based Fire-Fighting System (FFFS). A system permanently attached to the tunnel that is able to spread a water-based extinguishing agent in all or part of the tunnel.

Δ 3.3.34* Heat Release Rate (HRR). The rate at which heat energy is generated by burning. [921, 2017]

3.3.35 Highway. Any paved facility on which motor vehicles travel.

3.3.35.1* Depressed Highway. An uncovered, below-grade highway or boat section where walls rise to the grade surface and where emergency response access is usually limited.

3.3.35.2 Elevated Highway. A highway that is constructed on a structure that is above the surface but that does not cross over an obstacle as in the case of a bridge.

3.3.35.3 Limited Access Highway. A highway where preference is given to through-traffic by providing access connections that use only selected public roads and by prohibiting crossings at grade and at direct private driveways.

3.3.36 Hose Connection. A combination of equipment provided for the connection of a hose to a standpipe system that includes a hose valve with a threaded outlet.

3.3.37 Hose Valve. The valve to an individual hose connection.

3.3.38* Incident Commander (IC). The individual responsible for all incident activities, including the development of strategies and tactics and the ordering and the release of resources. [472, 2018]

3.3.39* Length of Bridge or Elevated Highway. The linear distance measured along the centerline of a bridge or elevated highway structure from abutment to abutment.

3.3.40 Length of Tunnel. The length from face of portal to face of portal that is measured using the centerline alignment along the tunnel roadway.

3.3.41 Level Equivalent (L_{eq}). The average sound level over time on an acoustical energy basis.

3.3.42 Mandatory Requirement. A requirement prefaced by the word “shall” within the standard.

3.3.42.1 Conditionally Mandatory Requirement. A requirement that is based on the results of an engineering analysis.

3.3.42.2 Nonmandatory Requirement. A requirement that is not prefaced by the word “shall” and most likely contained in an annex, a footnote, or Informational Note of the standard.

3.3.43 Motorist. A vehicle occupant, including the driver and passenger(s).

3.3.44* Noncombustible Material. See Section 4.8.

3.3.45 Operations Control Center. A dedicated location that controls and coordinates the facility operations and from which communication is maintained with the agency’s supervisory and operating personnel and with participating agencies where required.

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

3.3.47* Point of Safety. For road tunnels, bridges, and limited access highways, an exit enclosure 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 motorists.

3.3.48 Portable Fire Extinguisher. A portable device, carried or on wheels and operated by hand, containing an extinguishing agent that can be expelled under pressure for the purpose of suppressing or extinguishing fire. [10, 2018]

3.3.49 Portal. The interface between a tunnel and the atmosphere through which vehicles pass; a connection point to an adjacent structure.

3.3.50 Primary Structural Element. An element of the structure whose failure is expected to result in the collapse of the structure or the inability of the structure to perform its function.

3.3.51 Progressive Structural Collapse. The spread of an initial local failure from element to element resulting in the eventual collapse of an entire structure or a disproportionately large part of it.

3.3.52 Raceway. An enclosed channel of metal or nonmetallic materials designed expressly for holding wires, cables, or busbars, with additional functions as permitted in NFPA 70. Raceways include, but are not limited to, rigid metal conduit, rigid nonmetallic conduit, intermediate metal conduit, liquid-tight flexible conduit, flexible metallic tubing, flexible metal conduit, electrical nonmetallic tubing, electrical metallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways, wireways, and busways.

3.3.53 Road Tunnel. An enclosed roadway for motor vehicle traffic with vehicle access that is limited to portals.

3.3.54 Roadway. The volume of space that is located above the pavement surface through which motor vehicles travel.

3.3.55 Rural. Those areas that are not unsettled wilderness or uninhabitable territory but are sparsely populated with densities below 500 persons per square mile. [1142, 2017]

3.3.56 RWS (Rijkswaterstaat) Time-Temperature Curve. The fire test and time-temperature curve described in the report, Efectis-R0695, 2008.

3.3.57 Self-Rescue. People leaving the hazardous area or dangerous situation without any professional (fire fighters, rescue personnel, etc.) help.

3.3.58 Smoke Release Rate. The rate at which smoke is generated by burning.

3.3.59 Sound Pressure Level. The logarithmic ratio of the root-mean squared sound pressure to the reference sound pressure (2.0×10^{-5} Pascals).

3.3.60 Structure. That which is built or constructed and limited to buildings and non-building structures as defined herein. [5000, 2018]

3.3.60.1* Air-Right Structure. A structure other than a skywalk bridge that is built over a roadway using the roadway’s air rights. [5000, 2018]

3.3.61 Tenable Environment. An environment that permits evacuation or rescue, or both, of occupants for a specific period of time.

3.3.62 Wayfinding. The use of specific means to enhance the identification of the escape path to assist in evacuation.

Chapter 4 General Requirements

4.1* Level of Fire Protection. The level of fire protection necessary for the facility shall be achieved by implementing the requirements of this standard for each subsystem and integrating the use of these systems, features, and materials.

4.1.1 The protection methods described in this standard shall assume a single fire event.

4.2 Safeguards During Construction. During the course of construction, repair, alteration, or demolition of any facility addressed in this standard, the provisions of NFPA 241 shall apply.

4.2.1 Standpipe Installations in Tunnels Under Construction.

4.2.1.1* Where required by the authority having jurisdiction (AHJ), a standpipe system shall be installed, tested, and main-

tained in tunnels under construction in accordance with NFPA 241, NFPA 14, and NFPA 25.

• **4.3 Fire Protection and Fire-Life Safety Factors.** The requirements for ensuring human safety during the evacuation and rescue phases are substantially different from the requirements to protect the structural components of the facility, and shall be separately defined.

4.3.1* Regardless of the length of the facility, at a minimum, the following factors shall be considered as part of a holistic multidisciplinary engineering analysis of the fire protection and life safety requirements for the facilities covered by this standard:

- (1) New facility or alteration of a facility
- (2) Transportation modes using the facility
- (3) Anticipated traffic mix and volume
- (4) Restricted vehicle access and egress
- (5) Fire emergencies ranging from minor incidents to major catastrophes
- (6) Potential fire emergencies including but not limited to the following:
 - (a) At one or more locations inside or on the facility
 - (b) In close proximity to the facility
 - (c) At facilities a long distance from emergency response facilities
- (7) Exposure of emergency systems and structures to elevated temperatures
- (8) Traffic congestion and control requirements during emergencies
- (9) Fire protection features, including but not limited to the following:
 - (a) Fire alarm and detection systems
 - (b) Standpipe systems
 - (c) Water-based fire-fighting systems
 - (d) Ventilation systems
 - (e) Emergency communications systems
 - (f) Protection of structural elements
- (10) Facility components, including emergency systems
- (11) Evacuation and rescue requirements
- (12) Emergency response time
- (13) Emergency vehicle access points
- (14) Emergency communications to appropriate agencies
- (15) Facility location such as urban or rural (risk level and response capacity)
- (16) Physical dimensions, number of traffic lanes, and roadway geometry
- (17) Natural factors, including prevailing wind and pressure conditions
- (18) Anticipated cargo
- (19) Impact to buildings or landmarks near the facility
- (20) Impacts to facility from external conditions and/or incidents
- (21) Traffic operating mode (unidirectional, bidirectional, switchable, or reversible)

4.3.2* Fire Protection, Life Safety, and Emergency Systems Reliability. Regardless of the length or type of facility, the intended function of the fire protection, life safety, or emergency systems that address an emergency shall not be subject to failure as a result of the emergency that those systems are designed to address when working in combination.

4.3.3* Limited Access Highways. Fire protection for limited access highways shall comply with the requirements of Chapter 5.

4.3.4 Bridges and Elevated Highways. Fire protection for bridges and elevated highways shall comply with the requirements of Chapter 6.

4.3.5* Depressed Highways. Standpipe systems or fire extinguishers, or both, shall be installed on depressed highways where physical factors prevent or impede access to an acceptable water supply.

4.3.6* Road Tunnels. Fire protection for road tunnels shall comply with the requirements of Chapter 7.

4.3.7* Roadway Beneath Air-Right Structures. Fire protection for roadways that are located beneath air-right structures shall comply with the requirements of Chapter 8.

4.3.8* Ancillary Facilities. All related ancillary facilities that support the operation of limited access highways, depressed highways, bridges and elevated highways, and road tunnels shall be protected as required by all applicable NFPA standards and applicable building codes except as modified in this standard.

Δ 4.4 Emergency Response Plan.

4.4.1* Emergency traffic-control procedures shall be established to regulate traffic during an emergency.

4.4.1.1 Traffic shall be managed to avoid blocking access to emergency responders or otherwise interfering with the mitigation of the fire or emergency event. Traffic incident management shall be in conformance with Chapter 6I, "Control of Traffic Through Traffic Incident Management Areas," of the *Manual on Uniform Traffic Control Devices (MUTCD)*.

4.4.2 Emergency procedures and the development of an emergency response plan for the facilities covered by this standard shall be completed in accordance with the requirements of Chapter 13.

4.5 Emergency Communications. Emergency communications, where required by the AHJ, shall be provided by the installation of outdoor-type telephone boxes, coded alarm telegraph stations, radio transmitters, or other approved devices that meet the following requirements:

- (1) They shall be made conspicuous by means of indicating lights or other approved methods.
- (2) They shall be identified by a readily visible number plate or other approved device.
- (3) They shall be posted with instructions for use by motorists.
- (4) They shall be located in approved locations so that motorists can park vehicles clear of the travel lanes.
- (5) Emergency communication devices shall be protected from physical damage from vehicle impact.
- (6) Emergency communication devices shall be connected to an approved constantly attended location.

4.6 Signage. Signs, mile markers, or other approved location reference markers shall be installed to provide a means for determining the relative location within or along the facility.

4.7 Commissioning and Integrated Testing.

4.7.1 The agency shall require the development of a commissioning plan and conduct integrated testing to facilitate the verification of the operational readiness of all installed fire protection, life safety, and emergency systems required by this standard, other applicable NFPA standards, and as required within the basis of design (BOD) for construction.

4.7.2 The commissioning plan shall be reviewed and approved by the AHJ where required.

N 4.7.3 Requirements, procedures, and documentation for commissioning shall be in accordance with NFPA 3 and this standard.

4.7.4 Integrated system testing shall be performed on fire protection, life safety, and emergency systems.

4.7.4.1 This testing shall confirm that the operation, interaction, and coordination of multiple individual systems perform their intended function.

4.7.4.2 Requirements, procedures, and documentation shall be in accordance with NFPA 4 and as required by this standard.

4.7.4.3 Results reported shall verify that the systems required to operate together as a whole achieve the overall fire protection and life safety objectives.

4.8* Noncombustible Material. A material that complies with any one of the following shall be considered a noncombustible material:

- (1)* The material, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors, when subjected to fire or heat.
- (2) The material is reported as passing ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*.
- (3) The material is reported as complying with the pass/fail criteria of ASTM E136 when tested in accordance with the test method and procedure in ASTM E2652, *Standard Test Method for Behavior of Materials in a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750°C*.
- (4) The material is reported as complying with the pass/fail criteria of EN 13501-1, *Fire classification of construction products and building elements — Part 1: Classification using data from reaction to fire test, in relation to ISO 1182, Reaction to fire tests for products — Non-combustibility test*.

4.9 Structural Anchorage.

4.9.1 Attachments to the structure that penetrate a passive fire protection system shall not adversely affect the thermal performance of the system.

4.9.2 Passive fire protection systems shall not adversely affect the integrity of attachments to the structure.

Chapter 5 Limited Access Highways

5.1 General. This chapter shall provide fire protection requirements for limited access highways.

5.2 Traffic Control.

5.2.1 Traffic control devices or other approved methods shall be provided at the points of entry to a limited access highway to

allow fire apparatus and other emergency responders to enter unimpeded.

5.3* Fire Apparatus.

5.3.1 Where limited accessibility to a highway or section thereof might prevent or delay an approved emergency response time, emergency response plans shall identify mitigating measures for various levels of emergency.

5.3.2 Where a dedicated means of access for use by emergency responders to enter the facility is provided, procedures for using such access shall be included in the emergency response plan.

5.4 Protection of Structural Elements.

5.4.1 Acceptable means shall be included within the design of the limited access highway to protect structures in accordance with this standard to achieve the following:

- (1) Support fire fighter accessibility
- (2) Mitigate structural damage from fire to prevent progressive structural collapse
- (3) Minimize economic impact

5.4.2 Critical structural members shall be protected from collision and high-temperature exposure that can result in dangerous weakening or complete collapse.

5.5* Incident Detection. (Reserved)

5.6* Fire Hydrants. (Reserved)

5.7 Drainage. On limited access highways, drainage systems to channel and collect surface runoff, which can include spilled hazardous or flammable liquids, shall be designed to direct to areas that do not introduce additional fire hazards on or outside the facility.

Chapter 6 Bridges and Elevated Highways

6.1* General.

6.1.1 This chapter shall provide fire protection requirements for bridges and elevated highways.

6.1.2 Bridges or elevated highways and spaces below bridges and elevated highways that are fully enclosed and meet the definition of a tunnel and the tunnel length requirements of Section 7.2 shall meet the requirements of Chapter 7.

6.2* Application. For the purpose of this standard, length or other elements of engineering analysis of the bridge or elevated highway shall dictate the minimum fire protection requirements.

6.2.1 For bridges or elevated highways less than 300 m (1000 ft) in length, the provisions of this chapter shall not apply.

6.2.2* Where a bridge or elevated highway does not fully enclose the roadway on both sides, the decision to consider it as a road tunnel shall be made by the authority having jurisdiction (AHJ) after an engineering analysis in accordance with 4.3.1.

6.2.3 In rural areas, Sections 6.4 and 6.7 of this standard shall not apply.

6.3 Protection of Structural Elements.

6.3.1* Acceptable means shall be included within the design of the bridge or elevated highway to prevent progressive structural collapse or collapse of primary structural elements.

6.3.1.1 Primary structural elements shall be protected in accordance with this standard in order to achieve the following functional requirements:

- (1) Support fire fighter accessibility
- (2) Minimize economic impact
- (3) Mitigate structural damage

6.3.2* Where it has been determined by engineering analysis that collapse of the bridge or elevated highway will impact life safety or have unacceptable implications, the bridge or elevated highway, including its primary structural elements, shall be protected from collision and capable of withstanding the time-temperature exposure represented by the selected design fire scenario.

6.3.2.1 The design fire scenario shall be used to design a bridge or elevated highway.

6.3.2.2 The selection of the design fire scenario shall consider the types of vehicles passing under and on the bridge or elevated highway.

6.3.3 For through truss bridges, suspension (including cable stay) bridges, or elevated highways, an engineering analysis shall be prepared to determine acceptable risk due to fire, including possible collapse scenarios.

6.4 Incident Detection.

6.4.1 Manual Fire Alarm Boxes.

6.4.1.1 Where the length of a bridge or elevated highway exceeds 3.2 km (2 miles), a manual fire alarm box shall be mounted in a NEMA Enclosure Type 4X or equivalent box at intervals of not more than 1.0 km (0.6 mile).

6.4.1.2 The location of the manual fire alarm boxes shall be approved by the AHJ.

6.4.1.3 The alarm shall indicate the location of the manual fire alarm box at the monitoring station.

6.4.1.4 The system shall be installed, inspected, and maintained in compliance with NFPA 72.

6.4.2 Closed-Circuit Television (CCTV) Systems.

6.4.2.1 Where the length of a bridge or elevated highway exceeds 300 m (1000 ft), a CCTV system shall be installed on the bridge.

6.4.2.2 The CCTV system shall be capable of viewing the entire length of the bridge or elevated highway from a single monitoring station using multiple cameras and camera locations.

6.5 Traffic Control. The decision to require a means to stop traffic from entering a bridge shall be made by the AHJ after an engineering analysis in accordance with 4.3.1.

6.6 Standpipe, Fire Hydrants, and Water Supply.

6.6.1* Applicability. Where the length of a bridge or elevated highway exceeds 300 m (1000 ft), a horizontal standpipe system

shall be installed on the structure in accordance with the requirements of Chapter 10.

6.6.2 Where the transverse width of a bridge or elevated highway exceeds 30 m (100 ft), or the travel direction lanes are physically separated by a barrier, and the structure meets the requirements of 6.6.1 above, the standpipe system shall be installed on each side of the bridge or elevated highway.

6.6.3* Fire Hydrants (Reserved).

6.7 Portable Fire Extinguishers.

6.7.1 Where the length of a bridge or elevated highway exceeds 3.2 km (2 miles), a portable fire extinguisher, with a rating of 2-A:20-B:C mounted in an NFPA 10-compliant cabinet, shall be installed at intervals of not more than 1.0 km (0.6 mile). No portable extinguisher shall be placed within 0.6 km (0.4 mile) of the end of the bridge or elevated highway.

6.7.2 To facilitate safe use by the public, the maximum weight of each extinguisher shall be 9 kg (20 lb).

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

6.7.4 The location of the portable fire extinguishers shall be approved by the AHJ.

6.8 Drainage.

6.8.1 On bridges and elevated highways, drainage systems to channel and collect surface runoff, which can include spilled hazardous or flammable liquids, shall be designed to drain to areas that do not introduce additional fire hazards on or outside the facility.

6.8.2 Expansion joints shall be designed to prevent spillage to the area below the bridge or elevated highway.

6.8.3 Bridges or elevated highways with combustible expansion joint or bearing system material, vulnerable to a spill of flammable liquids, shall have a roadway surface drainage system capable of intercepting a spill.

6.9 Hazardous Locations. Confined spaces meeting the definition of NFPA 1670 shall be labeled in accordance with 29 CFR 1910.146.

6.10 Control of Hazardous Materials. Control of hazardous materials shall be in accordance with the requirements of Chapter 14.

6.11 Joints Between Structural Elements. An analysis shall be performed on joints of nonconventional and nonrigid connections.

Chapter 7 Road Tunnels

7.1* General.

7.1.1* This chapter shall provide fire protection and life safety requirements for road tunnels.

7.1.2* For road tunnels that include either passive fire protection or fixed water-based fire-fighting systems (FFFS), or both, the impact of these systems during a fire on protection of structural elements, the tenable environment within the tunnel, and the tunnel ventilation system shall be evaluated.

7.2* Application. For the purpose of this standard, factors described in 4.3.1 shall dictate fire protection and fire-life safety requirements. The minimum fire protection and fire-life safety requirements, based on tunnel length, are categorized as follows:

- (1) Category X — Where tunnel length is less than 90 m (300 ft), an engineering analysis shall be performed in accordance with 4.3.1, an evaluation of the protection of structural elements shall be conducted in accordance with Section 7.3, and traffic control systems shall be installed in accordance with the requirements of Section 7.6.
- (2) Category A — Where tunnel length is 90 m (300 ft) or greater, an engineering analysis shall be performed in accordance with 4.3.1, an evaluation of the protection of structural elements shall be conducted in accordance with Section 7.3, and a standpipe system and traffic control systems shall be installed in accordance with the requirements of Chapter 10 and Section 7.6.
- (3) Category B — Where tunnel length equals or exceeds 240 m (800 ft) and where the maximum distance from any point within the tunnel to a point of safety exceeds 120 m (400 ft), all provisions of this standard shall apply unless noted otherwise in this document.
- (4) Category C — Where the tunnel length equals or exceeds 300 m (1000 ft), all provisions of this standard shall apply unless noted otherwise in this document.
- (5) Category D — Where the tunnel length equals or exceeds 1000 m (3280 ft), all provisions of this standard shall apply.

7.2.1* Where a roadway or portion of a roadway is not fully enclosed on both sides, is not fully enclosed on top, or any combination thereof, the decision by the authority having jurisdiction (AHJ) to consider the roadway as a road tunnel shall be made after an engineering analysis is performed in accordance with 4.3.1.

7.3 Protection of Structural Elements.

7.3.1* For all tunnel categories, acceptable means shall be included within the design of the tunnel to prevent progressive collapse of primary structural elements and to prevent the failure of support for overhead equipment and systems in accordance with this standard to achieve the following functional requirements in addition to life safety:

- (1) Support fire fighter accessibility
- (2) Minimize economic impact
- (3) Mitigate structural damage

7.3.2* The structure shall be capable of withstanding the temperature exposure represented by the Rijkswaterstaat (RWS) time-temperature curve or other recognized standard time-temperature curve that is acceptable to the AHJ, following an engineering analysis as required in Chapter 4.

7.3.3 During a 120-minute period of fire exposure or other time that is acceptable to the AHJ, the following failure criteria shall be satisfied:

- (1) Regardless of the material the primary structural element is made of, irreversible damage and deformation leading to progressive structural collapse shall be prevented.
- (2)* Tunnels with concrete structural elements shall be designed such that fire-induced spalling, which leads to progressive structural collapse, is prevented.

7.3.4 Structural fire protection material, where provided, shall satisfy the following performance criteria:

- (1) Tunnel structural elements shall be protected to achieve the following for concrete:
 - (a) The concrete is protected such that fire-induced spalling is prevented.
 - (b) The temperature of the concrete surface does not exceed 380°C (716°F).
 - (c) The temperature of the steel reinforcement within the concrete [assuming a minimum cover of 25 mm (1 in.)] does not exceed 250°C (482°F).
- (2) Tunnel structural elements shall be protected to achieve a lining temperature not exceeding 300°C (572°F) for steel or cast iron.
- (3) The material shall be noncombustible in accordance with Section 4.8.
- (4) The material shall have a minimum melting temperature of 1350°C (2462°F).
- (5) The material shall meet the fire protection requirements with less than 5 percent moisture content by weight and when fully saturated with water, in accordance with the approved time-temperature curve.

7.3.5 Joints Between Structural Elements. An analysis shall be performed on joints of nonconventional and nonrigid connections.

7.3.6 All fasteners, intermediate support elements, and anchors that attach equipment and devices not otherwise addressed in other codes and standards to the structure above roadway and walkway surfaces shall be capable of maintaining support during exposure to a minimum of 450°C (842°F) for a minimum of 120 minutes.

7.4 Fire Alarm and Detection.

7.4.1 Tunnels described in categories B, C, and D shall have at least two independent means of identifying and locating a fire.

7.4.2 Tunnels described in categories B, C, and D shall have an automatic fire detection system in accordance with 7.4.6.

7.4.3* Closed-circuit television (CCTV) systems with traffic-flow indication devices or surveillance cameras shall be permitted for use to identify and locate fires in tunnels with 24-hour supervision.

7.4.4 When water-based fire-fighting systems are installed in road tunnels, an automatic fire detection system shall be provided in accordance with 7.4.6.

7.4.5 Ancillary spaces within tunnels defined in categories B, C, and D (such as pump stations and utility rooms) and other areas shall be supervised by automatic fire alarm systems in accordance with 7.4.6.

7.4.6* Automatic Fire Detection Systems.

7.4.6.1* Automatic fire detection systems shall be installed in accordance with Chapter 17 of NFPA 72, or other equivalent international standards, and approved by the AHJ (see also Annex M).

7.4.6.2* Where a fire detection system is installed in accordance with the requirements of 7.4.6.1, signals for the purpose of automatically indicating the direction of evacuation and relocation of occupants shall not be required.

7.4.6.3 The performance of automatic fire detection systems shall include details of the fire signature required to initiate the alarm.

7.4.6.4 Automatic fire detection systems shall be capable of identifying the location of the fire within 15 m (50 ft).

7.4.6.5 Spot detectors shall have a light that remains on until the device is reset.

7.4.6.6 Automatic fire detection systems within a tunnel shall be zoned to correspond with the tunnel ventilation zones and **FFFS** where either, or both, of these systems are provided.

7.4.6.7* Automatic fire detection systems shall be able to provide detection in the early stages of a developing fire within the tunnel under anticipated air velocity.

7.4.7* Fire Alarm Control Panel. Where a fire detection system is installed in accordance with the requirements of 7.4.7.1, an approved fire alarm control panel (FACP) shall be provided in accordance with Chapters 10 and 14 of *NFPA 72*, or other equivalent international standards.

N 7.4.7.1* The FACP shall be used to receive signals from the facilities' automatic fire detection system and to initiate alarms.

7.5* Emergency Communications Systems — Two-Way Radio Communication Enhancement System.

7.5.1 Two-way radio communication enhancement systems shall be installed in new and existing tunnels and ancillary facilities where required by the **AHJ** or by other applicable governing laws, codes, or standards.

7.5.2 Two-way radio communication enhancement systems shall be designed, installed, tested, and maintained in accordance with the provisions of Chapter 24 of *NFPA 72*.

7.6 Tunnel Closure and Traffic Control.

7.6.1 All road tunnels, as defined by this standard, shall be provided with a means to stop approaching traffic.

7.6.2 Road tunnels longer than 240 m (800 ft) shall be provided with means to stop traffic from entering the direct approaches to the tunnel, to control traffic within the tunnel, and to clear traffic downstream of the fire site following activation of a fire alarm within the tunnel. The following requirements shall apply:

- (1) Direct approaches to the tunnel shall be closed following activation of a fire alarm within the tunnel. Approaches shall be closed in such a manner that responding emergency vehicles are not impeded in transit to the fire site.
- (2) Traffic within the tunnel approaching (upstream of) the fire site shall be stopped prior to the fire site until it is safe to proceed as determined by the incident commander.
- (3)* Means shall be provided downstream of an incident site to expedite the flow of vehicles from the tunnel. If it is not possible to provide such means under all traffic conditions, then the tunnel shall be protected by a fixed water-based fire-fighting system or other suitable means to establish a tenable environment to permit safe evacuation and emergency services access.
- (4) Operation shall be returned to normal as determined by the incident commander.

Δ 7.7* Fire Apparatus. (Reserved)

7.8* Standpipe, Fire Hydrants, and Water Supply. Standpipe and water supply systems in road tunnels shall be provided in accordance with the requirements of Chapter 10.

7.9* Portable Fire Extinguishers.

7.9.1 Portable fire extinguishers, with a rating of 2-A:20-B:C, shall be located along the roadway in approved wall cabinets at intervals of not more than 90 m (300 ft).

7.9.2 To facilitate safe use by motorists, the maximum weight of each extinguisher shall be 9 kg (20 lb).

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

7.10 Fixed Water-Based Fire-Fighting Systems. See Chapter 9.

7.10.1 Fixed water-based fire-fighting systems shall be conditionally mandatory in category C and category D tunnels.

7.11 Emergency Ventilation. Tunnel ventilation systems employed during fire emergencies shall comply with the requirements of Chapter 11.

7.12* Tunnel Drainage System.

7.12.1* A drainage system shall be provided in tunnels to collect, store, or discharge effluent from the tunnel, or to perform a combination of these functions.

7.12.2* The drainage collection system shall be designed to capture spills of hazardous or flammable liquids so that they cannot spread or cause flame propagation such that the length of the road surface drain path from any potential spill point to the drain inlet(s) is minimized.

7.12.3 Components of the drainage conveyance and collection system, including the main drain lines, shall be noncombustible (e.g., steel, ductile iron, or concrete).

7.12.4* The drainage system shall be constructed entirely of noncombustible materials.

7.12.5* The drainage conveyance and collection system shall have sufficient capacity to receive, as a minimum, the rate of flow from all design roadway sources without causing flooding of the roadway.

7.12.5.1 The minimum design flow rate shall include, where applicable, the design spill rate for fuel or other hazardous liquids, the standpipe system discharge rate, any fixed water-based fire-fighting system discharge rate, environmental sources (rain, snow, etc.), tunnel washing, and any other catchments sharing the tunnel drainage system piping.

7.12.5.2* Where the tunnel roadway drainage system discharges by gravity or by pumped discharge, it shall be provided with a separator, drainage storage capacity, or combination sufficient for the design spill rate for the hazardous liquids.

7.12.6 Hazardous Locations.

7.12.6.1 Storage tanks and wet wells and service chambers of pump stations shall be classified for hazardous locations in accordance with *NFPA 70* and *NFPA 820*.

7.12.6.2 All motors, starters, level controllers, system controls, and other miscellaneous electrical equipment, such as compo-

nents of the lighting system in the pump station, shall conform to the requirements of the hazard classification.

7.12.7 Hydrocarbon Detection.

7.12.7.1 Storage tanks and pump stations shall be monitored for hydrocarbons.

7.12.7.2 Detection of hydrocarbons in the tunnel drainage effluent shall initiate both a local and a remote alarm.

Δ 7.13* Alternative Fuels. (Reserved)

7.14 Control of Hazardous Materials. Control of hazardous materials shall comply with the requirements of Chapter 14.

7.14.1* Fire size, growth rate, and smoke release rate shall be permitted to be reduced where an engineering analysis can show that the pool size of the combustible or flammable liquid can be limited by proper design of the roadway cross slope, the roadway grade, the drainage inlets, and the drainage conveyance pipe or trough.

7.14.1.1 If fire is to be controlled by drainage method(s), this shall be coordinated with tunnel drainage in accordance with Section 7.12.

7.15* Flammable and Combustible Environmental Hazards.

7.15.1 Design, construction, maintenance, and operation of tunnels shall consider the flammable and combustible risks for both naturally occurring and constructed environmental hazards from outside the road tunnel.

7.15.2 For the identified hazards, an engineering analysis shall be performed of constructed or naturally occurring environmental sources of fire/life safety hazards to determine means and methods for mitigation of identified risks to tunnel fire/life safety.

7.16 Means of Egress.

7.16.1 General.

Δ **7.16.1.1*** The means of egress requirements for all road tunnels and those roadways beneath air-right structures that the AHJ determines are similar to a road tunnel shall be in accordance with NFPA 101, Chapter 7, except as modified by this standard.

7.16.1.2* Reflective or lighted directional signs indicating the distance to the two nearest emergency exits shall be provided on the side walls at distances of no more than 25 m (82 ft).

N **7.16.1.3*** Wayfinding shall be provided to aid evacuation of the tunnel.

N **7.16.1.3.1** The type and extent of wayfinding shall be determined by an engineering analysis.

N **7.16.1.3.2** Where wayfinding lighting is used, it shall be in accordance with Section 12.8.

7.16.2* Tenable Environment. A tenable environment shall be provided in the means of egress during the evacuation phase in accordance with the emergency response plan for a specific incident. The criteria for tenability and time of tenability shall be established.

7.16.3 Maintenance. The means of egress shall be maintained in accordance with NFPA 1.

7.16.4 Walking Surfaces.

7.16.4.1 The walking surfaces of the emergency exits, cross-passageways, and walkways shall be slip resistant.

Δ **7.16.4.2** Changes in elevation, ramps, and stairs shall meet the requirements of Chapter 7 of NFPA 101.

7.16.5 Emergency Exit Doors.

7.16.5.1* Emergency exit doors shall provide protection against fire and ensure pressurization of escape routes.

7.16.5.2 Doors to the emergency exits shall open in the direction of exit travel.

7.16.5.3 Horizontal sliding doors shall have a sign identifying them as horizontal sliding doors and indicating the direction to open.

7.16.5.4* Horizontal sliding doors shall be permitted in emergency exits.

7.16.5.5* Emergency exit door assemblies exposed to the incident tunnel shall be 1½-hour rated, based on the time-temperature curve described in 7.3.2, and shall be installed in accordance with NFPA 80. All other doors in the path of egress shall comply with NFPA 101.

7.16.5.6* The force required to open the doors fully when applied to the latch side shall be as low as possible but shall not exceed 222 N (50 lb). This opening force shall not be exceeded under the worst-case ventilation differential pressure.

7.16.5.7* Emergency exit doors and associated hardware shall be designed to withstand positive and negative pressures created by passing vehicles.

7.16.5.8 Emergency exit doors shall be self-closing door systems and shall not rely on external power.

Δ 7.16.6 Emergency Exits.

7.16.6.1* Emergency exits shall be provided throughout the tunnel.

7.16.6.2* Spacing between exits for protection of tunnel occupants shall not exceed 300 m (1000 ft). Required spacing shall be determined by consideration of the following factors:

- (1) Category, including types and classes of tunnels
- (2) Design fire scenario
- (3) Egress analysis
- (4) Fire/life safety systems analyses to provide tenable environment in tunnel in accordance with 7.16.2 (This includes type and operation of tunnel ventilation, detection, fire protection, and control systems.)
- (5) Traffic management system
- (6) Emergency response plan
- (7) Consideration of uncertainties of people's behavior during a fire event and of those who are unable to self-rescue

7.16.6.3* Egress Pathway.

7.16.6.3.1* The tunnel roadway surface, when supported by a traffic management system, shall be considered as a part of the egress pathway.

7.16.6.3.2 The egress pathway shall have a minimum clear width of 1.12 m (3.7 ft), lead directly to an emergency exit, and be protected from traffic.

7.16.6.4* The emergency exits shall be separated from the tunnel by a minimum of a 2-hour fire-rated construction enclosure, rated based on the time-temperature curve described in 7.3.2.

7.16.6.5 Emergency “exits” shall be pressurized in accordance with NFPA 92 with doors meeting the requirements of 7.16.5.

7.16.6.6* Where portals of the tunnel are below surface grade, surface grade shall be made accessible by a stair, vehicle ramp, or pedestrian ramp.

7.16.6.7 Where cross-passageways are used as an emergency exit, provisions shall be included that stop all traffic operation in the adjacent tunnel.

7.17 Acceptance Test.

7.17.1 Acceptance tests for fire alarm and detection systems shall be performed in accordance with Chapters 7 and 14 of NFPA 72, or other equivalent international standards, including performance requirements specified in the basis of design.

7.17.2 Acceptance tests for standpipe systems shall be performed in accordance with NFPA 14 or other equivalent international standards and performance specified in Chapter 10.

7.17.3 Acceptance tests for water-based fire-fighting systems shall be performed in accordance with NFPA 11, NFPA 13, NFPA 15, NFPA 16, NFPA 18, NFPA 18A, and NFPA 750 or other equivalent international standards as applicable to the system(s) installed, including performance requirements specified in the basis of design.

7.17.4 Acceptance tests for fire hydrants, water mains, and water supply systems shall be performed in accordance with NFPA 22, NFPA 24, or other equivalent international standards as applicable to the system(s) installed and performance specified in Chapter 10.

7.17.5 Acceptance tests for emergency ventilation systems shall be performed in accordance with the basis of design criteria, equipment manufacturers’ specifications, agreed-upon methods acceptable to the AHJ, and performance requirements specified in Chapter 11.

Δ 7.17.6 Acceptance tests for electrical systems (emergency power, emergency lighting, exit signs, etc.) shall be performed in accordance with NFPA 70, NFPA 110, basis of design criteria, equipment manufacturers’ specifications, and performance requirements specified in Chapter 12.

7.17.7 Acceptance tests for communication systems and traffic control systems shall be performed in accordance with the basis of design, equipment manufacturers’ specifications, and agreed-upon methods acceptable to the AHJ.

Chapter 8 Roadways Beneath Air-Right Structures

8.1* General. This chapter shall provide fire protection and life safety requirements for roadways where a structure is built using the air rights above the road.

8.2 Application. Where required by the authority having jurisdiction (AHJ), the requirements of Chapter 4 shall apply.

8.2.1 The limits that an air-right structure imposes on the emergency accessibility and function of the roadway that is located beneath the structure shall be assessed.

8.2.2 Where an air-right structure encloses both sides of a roadway, it shall be considered a road tunnel for fire protection purposes and shall comply with the requirements of Chapter 7.

8.2.3* Where an air-right structure does not fully enclose the roadway on both sides, the decision to consider it as a road tunnel shall be made by the AHJ after an engineering analysis in accordance with 4.3.1.

8.3 Traffic Control.

8.3.1 Where the roadway beneath an air-right structure is considered a road tunnel, the traffic-control requirements of Section 7.6 shall apply.

8.3.2 The traffic-control system shall be interlocked with the fire alarm system in such a manner that the control system can be operated from either a remote source or from either end of the roadway that passes beneath the air-right structure.

8.4 Protection of Structure.

8.4.1 All structural elements that support air-right structures over roadways and all components that provide separation between air-right structures and roadways shall have a minimum 2-hour fire resistance rating in accordance with Section 7.3.

8.4.1.1* An engineering analysis shall be prepared to determine acceptable risk to include possible collapse scenarios of the air-right structure(s).

8.4.2 Structural members shall be protected from physical damage from vehicle impact. An inspection and repair program shall be kept in force to monitor and maintain the structure and its protection.

8.4.3 Maintenance of the structure shall be considered in the design.

8.4.4 Structural support elements shall not be within the dynamic vehicle envelope.

8.4.5 Buildings that are located above roadways shall be designed with consideration of the roadway below an air-right structure as a potential source of heat, smoke, and vehicle emissions.

8.4.6 The structural elements shall be designed to shield the air-right structure and its inhabitants from these potential hazards.

8.4.7 The design of the air-right structure shall neither increase risk nor create any risk to those who use the roadway below.

8.5 Emergency Ventilation.

8.5.1 Chapter 11 shall apply where ventilation during a fire emergency within the roadway beneath an air-right structure is required by Section 7.2.

8.5.2 The prevention or minimization of adverse effects on air-right structures and their occupants from fire products such as heat, smoke, and toxic gases shall be considered in the design of the ventilation system.

8.6 Drainage System. Where required by the AHJ, a drainage system that is designed in accordance with the requirements of Section 7.12 shall be provided for roadways beneath air-right structures.

8.7 Control of Hazardous Materials. Control of hazardous materials shall comply with the requirements of Chapter 14.

8.8 Emergency Response Plan.

8.8.1 Where an air-right structure includes a building or facility, a mutual emergency response plan shall be developed among the operator of the air-right structure, the operator of the roadway, and the local AHJ so that, during an emergency in either the air-right structure or the roadway, the safety of the motorists using the roadway and of the occupants of the air-right structure is enhanced.

8.8.2 Emergency response procedures and the development of emergency response plans shall comply with the requirements of Chapter 13.

8.9* Standpipe, Fire Hydrants, and Water Supply. Where the roadway beneath air-right structure length is 90 m (300 ft) or greater, standpipe and water supply systems shall be provided in accordance with the requirements of Chapter 10.

8.10 Acceptance Test.

8.10.1 Acceptance tests for standpipe systems shall be performed in accordance with NFPA 14 or other equivalent international standards and performance specified in Chapter 10.

8.10.2 Acceptance tests for fire hydrants, water mains, and water supply systems shall be performed in accordance with NFPA 22, NFPA 24, or other equivalent international standards as applicable to the system(s) installed and performance specified in Chapter 10.

8.10.3 Acceptance tests for emergency ventilation systems shall be performed in accordance with the basis of design criteria, equipment manufacturers' specifications, agreed-upon methods acceptable to the AHJ, and performance requirements specified in Chapter 11.

8.10.4 Acceptance tests for communication systems and traffic control systems shall be performed in accordance with the basis of design, equipment manufacturers' specification, and agreed-upon methods acceptable to the AHJ.

Chapter 9 Fixed Water-Based Fire-Fighting Systems

9.1* General.

9.1.1 Fixed water-based fire-fighting systems (FFFS) shall be permitted in road tunnels as part of an integrated approach to the management of fire protection and fire-life safety risks.

9.1.2 When an FFFS is installed in road tunnels, it shall be installed, inspected, and maintained in accordance with NFPA 11, NFPA 13, NFPA 15, NFPA 16, NFPA 18, NFPA 18A, NFPA 25, NFPA 750, or other equivalent international standard.

9.2 Design Objectives.

9.2.1 The goal of an FFFS shall be to slow, stop, or reverse the fire growth rate or otherwise mitigate the impact of fire to improve tenability for tunnel occupants during a fire condi-

tion, enhance the ability of first responders to aid in evacuation and engage in manual fire-fighting activities, and/or protect the major structural elements of a tunnel.

9.2.2* Fixed water-based fire-fighting systems shall be categorized based upon their desired performance objective in 9.2.2.1 through 9.2.2.4.

9.2.2.1* Fire Suppression System. A fire suppression system shall be a fixed water-based system intended to sharply reduce the heat release rate of a fire and prevent its growth by means of direct and sufficient application of extinguishing agent through the fire plume to the burning fuel surface.

9.2.2.2* Fire Control System. A fire control system shall be a fixed water-based system intended to limit the size of a fire by distribution of extinguishing agent to decrease the heat release rate and pre-wet adjacent combustibles while controlling gas temperatures to avoid structural damage.

9.2.2.3* Volume Cooling System. A fixed water-based system shall be designed to provide substantial cooling of products of combustion but is not intended to affect heat release rate directly.

9.2.2.4* Surface Cooling System. A fixed water-based system shall be designed to provide direct cooling of critical structure, equipment, or appurtenances without directly affecting heat release rate.

N 9.3 Water Supply.

N 9.3.1 FFFS shall be connected to an approved water supply that is capable of supplying system demand for a minimum of 1 hour.

N 9.3.2 The water supply demand for a facility with an FFFS shall include the demand for the FFFS and the standpipe system when both systems are provided.

N 9.3.3 Acceptable water supplies shall include the following:

- (1) Municipal or privately owned waterworks systems that have adequate pressure and flow rate and a level of integrity acceptable to the authority having jurisdiction (AHJ)
- (2) Automatic or manually controlled fire pumps that are connected to an approved water source
- (3) Pressure-type or gravity-type storage tanks that are installed, inspected, and maintained in accordance with NFPA 22

9.4 Performance Evaluation.

9.4.1 Fire test protocols shall be designed to address the performance objectives as described in 9.2.2 and the tunnel parameters described in Section 9.5.

9.4.2* Fire test protocols shall be designed to replicate and evaluate the range of the application parameters associated with road tunnels.

9.4.3* System components shall be listed or as approved by the AHJ.

9.4.4 Impact on Other Safety Measures.

9.4.4.1 For the sizing of the emergency ventilation system in accordance with Section 11.4, the effect of the fixed water-based fire-fighting system shall be taken into account.

9.4.4.2 For protection of structural elements, the applicable provisions of Section 7.3 shall apply unless evidence of the

performance of the required structural fire protection by a fixed water-based fire-fighting system is provided and approved by the AHJ.

9.4.5 Layout Parameters. To achieve the design objectives in accordance with 9.2.1, discharge device coverage, spacing, positioning, spray characteristics, working pressure, and flow rates shall be determined by use of applicable codes, standards, or accepted practices, or where necessary, by an engineering analysis considering relevant available data resulting from full-scale tunnel fixed water-based fire-fighting tests of the type of fixed water-based fire-fighting system being used.

9.5 Tunnel Parameters.

9.5.1 Tunnel parameters shall be the features of the tunnel that affect the design of a water-based fire-fighting system.

9.5.2 Tunnel Geometry. The tunnel geometry (width, ceiling height, obstruction location) shall be considered when selecting such parameters as nozzle location and nozzle positioning.

9.5.3 Ventilation. Ventilation considerations shall include natural and fire-induced forced ventilation parameters.

9.5.4 Hazard Analysis. A fire hazard analysis shall be conducted to determine both the design parameters of the water-based fire-fighting system and the type of detection and activation scheme employed. The water-based fire-fighting system shall address the anticipated vehicle types and contents, ease of ignition and re-ignition of the fuel, anticipated fire growth rate, and difficulty of achieving one or more of the performance objectives established in Section 9.2 or as otherwise acceptable to the AHJ.

9.5.5 Obstructions and Shielding. The presence of obstructions and the potential for shielding of water-based fire-fighting system discharge shall be addressed to ensure that system performance is not affected.

9.5.6 Ambient Conditions. The range of ambient conditions that could be experienced in the tunnel shall be identified.

9.6 System Design and Installation Documentation.

9.6.1 The system design and installation documentation shall identify the design objectives and tunnel parameters over which the system performance evaluation is valid.

9.6.2 System documentation shall clearly identify engineering safety factors incorporated into the overall system design. Safety factors shall be required to ensure that installed system performance exceeds the performance of the system as tested in accordance with Section 9.4.

9.6.3 System documentation shall also include recommended testing, inspection, and maintenance procedures and, by reference, the requirements of the relevant NFPA standard or equivalent standard acceptable to the AHJ.

9.7 Engineering Design Requirements.

9.7.1* When an **FFFS** is included in the design of a road tunnel, the impact of this system on other measures that are part of the overall safety concept shall be evaluated. At a minimum, this evaluation shall address the following:

- (1) Impact on drainage requirements
- (2) Impact on tenability, including the following:
 - (a) Increase in humidity

- (b) Reduction (if any) in stratification and visibility
- (3) Integration with other tunnel systems, including the following:
 - (a) Fire detection and alarm system
 - (b) Tunnel ventilation system
 - (c) Traffic control and monitoring systems
 - (d) Visible emergency alarm notification
 - (e) Protection of structural elements
- (4) Incident command structure and procedures, including the following:
 - (a) Procedures for tunnel operators
 - (b) Procedures for first responders
 - (c) Tactical fire-fighting procedures
- (5) Protection and reliability of the **FFFS**, including the following:
 - (a) Impact events
 - (b) Seismic events
 - (c) Redundancy requirements
- (6) Ongoing system maintenance, periodic testing, and service requirements

9.7.2 The engineering analysis shall also address delays in activation.



Chapter 10 Standpipe Systems

10.1 General.

10.1.1 Standpipe systems shall be designed and installed as Class I systems in accordance with NFPA 14, except as modified by this standard.

10.1.2 Standpipe systems shall be inspected and maintained in accordance with NFPA 25.

10.1.3 Standpipe systems shall be either wet or dry, depending on the climatic conditions, the fill times, the requirements of the authority having jurisdiction (AHJ), or any combination thereof.

10.1.4 Areas Subject to Freezing.

10.1.4.1 Where wet standpipes are required in areas subject to freezing conditions, the water shall be heated and circulated.

10.1.4.2 All piping and fittings that are exposed to freezing conditions shall be heat-traced and insulated.

10.1.4.3 Heat trace material shall be listed for the intended purpose and supervised for power loss.

10.1.5* Dry standpipe systems shall be installed in a manner so that the water is delivered to all hose connections on the system in 10 minutes or less.

10.1.6 Combination air relief–vacuum valves shall be installed at each high point on the system.

10.2 Water Supply.

10.2.1 Wet standpipe systems (automatic or semiautomatic) shall be connected to an approved water supply that is capable of supplying the system demand for a minimum of 1 hour.

10.2.2 Dry standpipe systems shall have an approved water supply that is capable of supplying the system demand for a minimum of 1 hour.

10.2.3 Acceptable water supplies shall include the following:

- (1) Municipal or privately owned waterworks systems that have adequate pressure and flow rate and a level of integrity acceptable to the AHJ
- (2) Automatic or manually controlled fire pumps that are connected to an approved water source
- (3) Pressure-type or gravity-type storage tanks that are installed, inspected, and maintained in accordance with NFPA 22

10.3 Fire Department Connections.

10.3.1 Fire department connections shall be of the threaded two-way, three-way, or four-way type or shall consist of at least one minimum 100 mm (4 in.) quick-connect coupling that is accessible and compatible with responding fire department equipment or as approved.

10.3.2 Each independent standpipe system shall have a minimum of two fire department connections that are remotely located from each other.

10.3.3 Fire department connections shall be protected from vehicular damage by means of bollards or other approved barriers.

10.3.4 Fire department connection locations shall be approved and shall be coordinated with emergency access and response locations.

10.4 Hose Connections.

10.4.1 Hose connections shall be spaced so that no location on the protected roadway is more than 45 m (150 ft) from the hose connection.

10.4.2* Hose connection spacing shall not exceed 85 m (275 ft).

10.4.3 Hose connections shall be located so that they are conspicuous and convenient but still reasonably protected from damage by errant vehicles or vandals.

10.4.4 Hose connections shall have 65 mm (2½ in.) external threads in accordance with NFPA 1963 and the AHJ.

10.4.5 Hose connections shall be equipped with caps to protect hose threads.

10.5 Fire Pumps. Fire pumps shall be installed, inspected, and maintained in accordance with NFPA 20.

10.6 Identification Signs.

10.6.1 Identification signage for standpipe systems and components shall be approved by and developed with input from the AHJ.

10.6.2 Identification signage shall, as a minimum, identify the name and limits of the roadway that is served.

10.6.3 Identification signage shall be conspicuous and shall be affixed to, or immediately adjacent to, fire department connections and each roadway hose connection.

Chapter 11 Emergency Ventilation

11.1* General. Emergency ventilation systems and tunnel operating procedures shall be developed to maximize the use of the road tunnel ventilation system for the removal and

control of smoke and heated gases that result from fire emergencies within the tunnel.

11.1.1* Emergency ventilation shall not be required in tunnels less than 1000 m (3280 ft) in length, where it can be shown by an engineering analysis, using the design parameters for a particular tunnel (length, cross-section, grade, prevailing wind, traffic direction, types of cargoes, design, fire size, etc.), that the level of safety provided by a mechanical ventilation system can be equaled or exceeded by enhancing the means of egress, the use of natural ventilation, or the use of smoke storage, and shall be permitted only where approved by the authority having jurisdiction (AHJ).

11.1.2 Emergency ventilation shall be required in tunnels exceeding 1000 m (3280 ft).

11.1.3 For any engineering analysis performed to determine the requirement for tunnel emergency ventilation, potential fires immediately proximate to the tunnel portal, but outside the tunnel, that can have a negative impact on the tunnel environment shall be included in the engineering analysis.

11.1.4* The emergency ventilation operational procedures shall be designed to assist in the evacuation or rescue, or both, of motorists from the tunnel.

11.1.5 Emergency ventilation shall be sized to meet minimum ventilation requirements with one fan out of service or shall provide operational measures to ensure that life safety is not compromised with one fan out of service.

▲ 11.2* Smoke Control.

11.2.1 The emergency ventilation system shall provide a means for controlling smoke.

11.2.2 In all cases, the desired goal shall be to provide an evacuation path for motorists who are exiting from the tunnel and to facilitate fire-fighting operations.

11.2.3 In tunnels with bidirectional traffic where motorists can be on both sides of the fire site, the following objectives shall be met:

- (1) Smoke stratification shall not be disturbed.
- (2) Longitudinal air velocity shall be kept at low magnitudes.
- (3) Smoke extraction through ceiling openings or high openings along the tunnel wall(s) is effective and shall be considered.

▲ **11.2.4*** In tunnels with unidirectional traffic where motorists are likely to be located upstream of the fire site, the following objectives shall be met:

- (1) Longitudinal systems
 - (a)* Prevent backlayering by producing a longitudinal air velocity in the direction of traffic flow.
 - (b) Avoid disruption of the smoke layer initially by not operating jet fans that are located near the fire site; operate fans that are farthest away from the site first.
- (2) Transverse or reversible semitransverse systems
 - (a) Maximize the exhaust rate in the ventilation zone that contains the fire and minimize the amount of outside air that is introduced by a transverse system.
 - (b) Create a longitudinal airflow in the direction of traffic flow by operating the upstream ventilation