First Revision No. 27-NFPA 502-2023 [Chapter 2]

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,* ~~2021~~ 2024 edition.

NFPA 3, *Standard for Commissioning of Fire Protection and Life Safety Systems,* ~~2021~~ 2024 edition.

NFPA 4, *Standard for Integrated Fire Protection and Life Safety System Testing,* ~~2021~~ 2024 edition.

NFPA 10, *Standard for Portable Fire Extinguishers,* ~~2022~~ 2026 edition.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam,* ~~2021~~ 2024 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* ~~2022~~ 2025 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* ~~2019~~ 2024 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 2022 edition.

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

~~NFPA 18, *Standard on Wetting Agents,* 2021 edition.~~

~~NFPA 18A, *Standard on Water Additives for Fire Control and Vapor Mitigation,* 2022 edition.~~

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection,* ~~2022~~ 2025 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection,* ~~2018~~ 2023 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances,* ~~2022~~ 2025 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* ~~2023~~ 2026 edition.

NFPA 70®, *National Electrical Code*®, ~~2023~~ 2026 edition.

NFPA 72®, *National Fire Alarm and Signaling Code*®, ~~2022~~ 2025 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* ~~2022~~ 2025 edition.

NFPA 92, *Standard for Smoke Control Systems,* ~~2021~~ 2024 edition.

NFPA *101*®, *Life Safety Code*®, ~~2021~~ 2024 edition.

NFPA 110, *Standard for Emergency and Standby Power Systems,* ~~2022~~ 2025 edition.

NFPA 111, *Standard on Stored Electrical Energy Emergency and Standby Power Systems,* ~~2022~~ 2025 edition.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations,* 2022 edition.

NFPA 262, *Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces,* ~~2019~~ 2023 edition.

NFPA 350, *Guide for Safe Confined Space Entry and Work,* 2022 edition.

NFPA 750, *Standard on Water Mist Fire Protection Systems,* 2023 edition.

NFPA 820, *Standard for Fire Protection in Wastewater Treatment and Collection Facilities,* ~~2020~~ 2024 edition.

NFPA 1561, *Standard on Emergency Services Incident Management System and Command Safety,* 2020 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.

NFPA 2500, *Standard for Operations and Training for Technical Search and Rescue Incidents and Life Safety Rope and Equipment for Emergency Services,* 2022 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*, ~~2021a~~ 2023b .

~~ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials* , 2020.~~

ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace, at 750°C*, ~~2019a~~ 2022 .

ASTM E2652, *Standard Test Method for Assessing Combustibility of Materials Using a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750°C*, ~~2018~~ 2022 .

ASTM E3134, *Standard Specification for Transportation Tunnel Structural Components and Passive Fire Protection Systems*, 2020.

~~**2.3.2** BSI Publications.~~

~~BSI British Standards, 12110 Sunset Hills Road, Suite 200, Reston, VA 20190-5902.~~

~~BS 476-4, *Fire tests on building materials and structures — Part 4: Non-combustibility test for materials* , 1970, corrigendum, 2012 .~~

2.3.2 CSA Publications.

CSA Group, 178 Rexdale Blvd., Toronto, ON, M9W 1R3, Canada.

CSA C22.2 No. 0.3, *Test Methods for Electrical Wires and Cables*, 2009, reaffirmed 2019.

2.3.3 FHWA Publications.

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

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

2.3.4 IEEE Publications.

IEEE~~, 3 Park Avenue, 17th Floor, New York, NY 10016-5997~~ Operations Center, 445 Hoes Lane, Piscataway, NJ 08854-4141 .

IEEE 1202, *Standard for Flame-Propagation Testing of Wire and Cable*, 2006, Corrigendum 1, 2012 .

IEEE 2412, *Standard Test Procedure for Determining Circuit Integrity Performance of Fire Resistive Cable Systems in Passenger Rail and Road Tunnels* , 2023.

2.3.5 ISO Publications.

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

ISO 1182, *Reaction to fire tests for products — Non-combustibility test*, 2020.

ISO 1716, *Reaction to fire tests for products — Determination of the gross heat of combustion (calorific value)*, 2018.

2.3.6 Military Specifications.

~~Department of Defense Single Stock Point, Document Automation and Production Service, Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094~~ Defense Standardization Program Office, 8725 John J Kingman Road, Stop 5100, Fort Belvoir, VA 22060-6220 .

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

2.3.7 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."

2.3.8 UL Publications.

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

UL 723, *Test for Surface Burning Characteristics of Building Materials*, 2018, revised 2023 .

~~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.

UL 2196, *Fire Test for Circuit Integrity of Fire-Resistive Power, Instrumentation, Control, and Data Cables*, 2017, revised 2020 .

UL 2556, *Wire and Cable Test Methods* , 2021.

2.3.9 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, ~~2003~~ 2020 .

BS EN 13501-1, *Fire classification of construction products and building elements — Part 1: Classification using data from reaction to fire tests*,2019.

IEC 61508, *Standard for Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems*, 2010.

2.4 References for Extracts in Mandatory Sections.

NFPA 3, *Standard for Commissioning of Fire Protection and Life Safety Systems,* ~~2021~~ 2024 edition.

NFPA 10, *Standard for Portable Fire Extinguishers,* ~~2021~~ 2022 edition.

NFPA 70®, *National Electrical Code®,* ~~2020~~ 2023 edition.

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

NFPA 440, *Guide for Aircraft Rescue and Firefighting Operations and Airport/Community Emergency Planning,* 2024 edition.

NFPA 470, *Hazardous Materials/Weapons of Mass Destruction (WMD) Standard for Responders,* 2022 edition.

NFPA 921, *Guide for Fire and Explosion Investigations,* 2021 edition.

NFPA 1142, *Standard on Water Supplies for Suburban and Rural Firefighting,* 2022 edition.

NFPA 1900, *Standard for Aircraft Rescue and Firefighting Vehicles, Automotive Fire Apparatus, Wildland Fire Apparatus, and Automotive Ambulances,* 2024 edition.

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

NFPA 5000®, *Building Construction and Safety Code®,* ~~2021~~ 2024 edition.

Supplemental Information

File Name	Description	Approved
502_A2025_FDM_Ch2.doc.docx	Attached Word Document with Track Changes contains various updates to this Chapter.	

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Fri Sep 29 06:26:50 EDT 2023

Committee Statement

Committee Statement: Updated references to the most current edition. Incorporated reference changes due to NFPA Emergency Response and Responder Safety (ERRS) Consolidation Project. Updates to addresses for various Publications. Incorporated reference as per various First Revisions. Attached word document with track changes shows all the updates.

Response Message: FR-27-NFPA 502-2023

Public Input No. 6-NFPA 502-2023 [Section No. 2.3.1]

Public Input No. 9-NFPA 502-2023 [Section No. 2.3.2]

Public Input No. 23-NFPA 502-2023 [Section No. 2.3.9]

First Revision No. 17-NFPA 502-2023 [Section No. 3.3.9]

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~~ 2023]

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 11:37:26 EDT 2023

Committee Statement

Committee Statement: Reorganization of NFPA 70, moved definitions to Article 100. Extract tags were updated accordingly.

Response Message: FR-17-NFPA 502-2023

First Revision No. 18-NFPA 502-2023 [Section No. 3.3.11]

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~~ 440 ,~~2019~~ 2024]

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 11:38:53 EDT 2023

Committee Statement

Committee Statement: NFPA's Emergency Response and Responder Safety Consolidation (ERRS) Project consolidated NFPA 402 into NFPA 440. Extract tag was updated to reflect change.

Response Message: FR-18-NFPA 502-2023

First Revision No. 19-NFPA 502-2023 [Section No. 3.3.28]

3.3.28 Fire Apparatus.

A vehicle designed to be used under emergency conditions to transport personnel and equipment or to support the suppression of fires or mitigation of other hazardous situations. [~~1901~~ **1900** , ~~2016~~ 2024]

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 11:40:51 EDT 2023

Committee Statement

Committee Statement: NFPA's Emergency Response and Responder Safety Consolidation (ERRS) Project consolidated NFPA 1901 into NFPA 1900. Extract tag was updated to reflect change. Text was also revised to match source document.

Response Message: FR-19-NFPA 502-2023

First Revision No. 25-NFPA 502-2023 [New Section after 4.2.1.1]

4.3 Confined Spaces.

During confined space entry and work, the provisions of NFPA 350 shall apply.

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 14:49:47 EDT 2023

Committee Statement

Committee Statement: NFPA 350 - Guide for Safe Confined Space Entry and Work needs to be followed while performing work in confined spaces for the safety of the workers. Subsequent sections should be renumbered.

Response Message: FR-25-NFPA 502-2023

First Revision No. 2-NFPA 502-2023 [New Section after 4.4.1.1]

4.4.2*

The local responding fire department(s) and other emergency response agencies, which might be expected to respond to fires or other emergency incidents, shall be given opportunities to provide input on the project design and operational intent during the design and planning phases to ensure the emergency response will be effective and feasible.

A.4.4.2

Historically, where the project design and operational intent have progressed without responder input, beyond the point where the essential changes are readily possible, responders and AHJs have required changes which could have been resolved with earlier responder input with less impact to the project schedule and additional costs.

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Wed Sep 27 13:59:35 EDT 2023

Committee Statement

Committee Statement: Although emergency response agencies may comment on emergency plans, and may, at the owner/designer discretion be invited to comment on design and operational intent, there is no requirement for this to occur. This language makes this a requirement. In some cases, lack of early input results in final design being completed without responder agencies input. Lacking early input, the design and response plans may not allow effective responder actions. This lack of input has resulted in responder or local AHJ requiring changes to design with resultant unnecessary delays and additional costs. Subsequent sections to be renumbered.

Response Message: FR-2-NFPA 502-2023

Public Input No. 36-NFPA 502-2023 [New Section after A.4.4.1]

Public Input No. 35-NFPA 502-2023 [New Section after 4.4.1]

First Revision No. 11-NFPA 502-2023 [Section No. 4.8]

4.9* 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 Assessing Combustibility of Materials Using 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 Assessing Combustibility of Materials Using a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750°C*.

(4)* The material is reported as complying with the pass/fail criteria for Class A1 of ~~either of the following:~~ BS EN 13501-1, *Fire classification of construction products and building elements — Part 1: Classification using data from reaction to fire tests*, in relation to ISO 1182, *Reaction to fire tests for products — Non-combustibility test*, and ISO 1716, *Reaction to fire tests for products — Determination of the gross heat of combustion (calorific value)*.

~~EN 13501-1, *Fire classification of construction products and building elements — Part 1: Classification using data from reaction to fire tests*, in relation to ISO 1182, *Reaction to fire tests for products — Non-combustibility test*, and ISO 1716, *Reaction to fire tests for products — Determination of the gross heat of combustion (calorific value)*~~

~~BS 476-4, *Fire tests on building materials and structures — Part 4: Non-combustibility test for materials*~~

A.4.9

The provisions of Section 4.9 do not require inherently noncombustible materials to be tested in order to be classified as noncombustible materials. Examples of such materials include steel, concrete, masonry, and glass.

ASTM E136 and ASTM E2652, which are referenced in Section 4.9, are not the only standards used for assessing the combustibility of materials. ISO 1182 (most recently updated in 2020) and BS 476-4 are also used for the purpose of assessing whether a material is combustible. BS 476-4 contains acceptance criteria, but it is not in common use and has not been updated since 1970. ASTM E2652 uses the same test equipment as older editions of ISO 1182, but the 2020 edition of ISO 1182 revised the test equipment. Neither ASTM E2652 nor ISO 1182 contain acceptance criteria. The European Union scheme for classification of materials based on reaction-to-fire tests (BS EN 13501-1) uses ISO 1182 and ISO 1716 for determining whether a material is noncombustible and includes its own acceptance criteria. BS EN 13501-1 contains two sets of acceptance criteria based on ISO 1182 and ISO 1716 for Class A1 and Class A2 materials (the Class A1 acceptance criteria are more stringent). ASTM E136 allows for the use of the ASTM E2652 test apparatus but requires the same set of acceptance criteria irrespective of the test apparatus used.

Supplemental Information

File Name	Description	Approved
PI_25_Text.docx	Word file with Track Changes showing updates	

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 09:53:16 EDT 2023

Committee Statement

Committee Statement: BS 476-4 is superseded by BS EN ISO 1182 (ISO 1182 is referenced in EN 13501-1) and as a consequence should not be applied. Application of BS 476-4 cannot lead to an A1 classification.

Editorial change to update correct reference for Annex from (3) to (4).

Response Message: FR-11-NFPA 502-2023

Public Input No. 25-NFPA 502-2023 [Section No. 4.8]

First Revision No. 7-NFPA 502-2023 [Section No. 5.4.1]

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 firefighter ~~accessibility~~ operations

(2) Mitigate structural damage from fire to prevent progressive structural collapse

(3) Minimize economic impact

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 08:17:05 EDT 2023

Committee Statement

Committee Statement: Accessibility is limited to "entering" the facility or structure. The terminology was modified to "operations" instead of "activities" since operations encompasses the entire emergency response. The intent of the change (from accessibility to operations) is to draw attention also to safe operations as well as departure of fire fighters after finishing their operations (in other words: the entire period of time the fire fighters are active in the facility or structure).

Response Message: FR-7-NFPA 502-2023

Public Input No. 16-NFPA 502-2023 [Section No. 5.4.1]

First Revision No. 8-NFPA 502-2023 [Section No. 6.3.1.1]

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 firefighter ~~accessibility~~ operations

(2) Minimize economic impact

(3) Mitigate structural damage

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 08:24:06 EDT 2023

Committee Statement

Committee Statement: Accessibility is limited to "entering" the facility or structure. "Operations" encompasses the entire emergency response.

The intent of the change (from accessibility to operations) is to draw attention also to safe operations as well as departure of fire fighters after finishing their operations (in other words: the entire period of time the fire fighters are active in the facility or structure).

Response Message: FR-8-NFPA 502-2023

First Revision No. 20-NFPA 502-2023 [Section No. 6.9]

6.9 Hazardous Locations.

Confined spaces meeting the definition of ~~NFPA 1670~~ NFPA 2500 shall be labeled in accordance with 29 CFR 1910.146.

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 11:44:09 EDT 2023

Committee Statement

Committee Statement: NFPA's Emergency Response and Responder Safety Consolidation (ERRS) Project consolidated NFPA 1670 into NFPA 2500. Reference was updated to new standard.

Response Message: FR-20-NFPA 502-2023

First Revision No. 14-NFPA 502-2023 [Section No. 7.2.1]

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, or parts thereof, as a road tunnel shall be made after an engineering analysis is performed in accordance with 4.4.1.

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 10:43:19 EDT 2023

Committee Statement

Committee Statement: The aim of the proposed change is to avoid a compromise for the entire roadway under consideration, but allow for differentiation for individual segments of the not fully enclosed roadway.

Response Message: FR-14-NFPA 502-2023

Public Input No. 18-NFPA 502-2023 [Section No. 7.2.1]

First Revision No. 9-NFPA 502-2023 [Section No. 7.3.1]

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 firefighter ~~accessibility~~ operations

(2) Minimize economic impact

(3) Mitigate structural damage

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 08:25:51 EDT 2023

Committee Statement

Committee Statement: Accessibility is limited to "entering" the facility or structure. The terminology was modified to "operations" since it encompasses the entire emergency response. The intent of the change (from accessibility to operations) is to draw attention also to safe operations as well as departure of fire fighters after finishing their operations (in other words: the entire period of time the fire fighters are active in the facility or structure).

Response Message: FR-9-NFPA 502-2023

First Revision No. 23-NFPA 502-2023 [Section No. 7.17.3]

7.17.3

Acceptance tests for water-based firefighting 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.

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 14:14:49 EDT 2023

Committee Statement

Committee Statement: NFPA 16 was withdrawn and the requirements are covered within NFPA 11.

NFPA 18 and 18A are test standards for wetting agent and water additive performance. As such they do not belong in this paragraph or in the chapter. They have been referenced in new Annex A.9.1.2.

Response Message: FR-23-NFPA 502-2023

First Revision No. 16-NFPA 502-2023 [Section No. 9.1.2]

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.

A.9.1.2

Wetting agents and water additives in compliance with NFPA 18 and NFPA 18A can be considered for use in fixed systems with the approval of the authority having jurisdiction and by utilizing components that are specifically approved for these mediums.

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 11:27:43 EDT 2023

Committee Statement

Committee Statement: Chapter 9 addresses fixed fire suppression systems. The standards referenced in 9.1.2 are installation standards, except NFPA 18 and 18A. NFPA 18 and 18A are test standards for wetting agent and water additive performance. As such they do not belong in this paragraph or in the chapter. NFPA 16 was withdrawn and the requirements are covered within NFPA 11.

Response Message: FR-16-NFPA 502-2023

First Revision No. 24-NFPA 502-2023 [New Section after 10.1.6]

10.1.7*

Manual dry standpipe systems, where exposed to regular inspection, shall not be required to be supervised.

A.10.1.7

Portions of a standpipe system that cannot be exposed to visual inspection can be provided with an alternate means of inspection.

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 14:27:05 EDT 2023

Committee Statement

Committee Statement: NFPA 14 requires manual dry standpipe systems to be supervised via compressed air. Supervision of manual dry standpipes for tunnels and bridges is impractical.

Response Message: FR-24-NFPA 502-2023

First Revision No. 6-NFPA 502-2023 [Section No. 12.1]

12.1 General.

12.1.1*

The electrical systems shall support life safety operations, fire emergency operations, and normal operations.

12.1.2

Emergency circuits installed in a road tunnel and ancillary areas shall remain functional for a period of not less than 1 hour for the anticipated fire condition by one of the following methods:

(1)* Fire-resistive cables shall be approved or listed for no less than 2 hours ~~when tested to the time-temperature curve of ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials* ,~~ in accordance with <u>the standard time temperature curve specified in</u> UL 2196, *Fire Test for Circuit Integrity of Fire-Resistive Power, Instrumentation, Control, and Data Cables*, or other approved, recognized standards, as follows:

(a) Fire-resistive cables shall be tested as a complete system, in both vertical and horizontal orientations, on conductors, cables, and raceways as applicable.

(b) Fire-resistive cables intended for installation in a raceway shall be tested in the type of raceway in which they are intended to be installed.

(c) Each fire-resistive cable system shall have installation instructions that describe the tested assembly with only the components included in the tested assembly acceptable for installations.

(d) <u>Fire-resistive cables shall be installed in accordance with their listing and manufacturer's instructions.</u>

(2)* Circuits shall be protected by a 2-hour fire barrier system in accordance with UL 1724, *Outline of Investigation for Fire Tests for Electrical Circuit Protective Systems*. The cables or conductors shall maintain functionality at the operating temperature within the fire barrier system.

(3) ~~They shall remain functional by the routing of the cable system external to the roadway~~ <u>Circuits shall be protected by a 1-hour cable tested to IEEE 2412, *Standard Test Procedure for Determining Circuit Integrity Performance of Fire Resistive Cable Systems in Passenger Rail and Road Tunnels*</u> .

(4) They shall remain functional by using diversity in system routing as approved, such as separate redundant or multiple circuits separated by a 2-hour fire barrier, so that a single fire or emergency event will not lead to a failure of the system.

12.1.3

The requirement of 12.1.2 shall not apply to bidirectional antennas used for emergency communication circuits.

12.1.4

The electrical systems shall maintain ventilation, lighting, communications, drainage, a fixed water-based fire-extinguishing system, fire alarm and fire detection, exit signs, traffic control, and others for areas of refuge, exits, and exit routes, under all normal and emergency modes associated with the facility.

12.1.5*

The fire-life safety electrical systems shall be designed and installed to resist lateral forces induced by earthquakes (seismic forces) in the appropriate seismic zone and to continue to function after the event.

12.1.6

An electrical single-line diagram shall be posted within the main electrical room.

12.1.6.1

The diagram shall include utility short-circuit duty, all sources, uninterrupted power supplies (UPSs), or standby source and interlocking schemes, and other data per IEEE standards for single-line diagrams.

12.1.7

Labels, nameplates, or tags shall be affixed to switchboards, panelboards, motor controllers, switches, and breakers that correspond to the single line. The equipment or device operating instructions shall be available to operating personal.

Supplemental Information

File Name	Description	Approved
PI_24_WordFile.docx	Proposed text with Track Changes	

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 04:55:59 EDT 2023

Committee Statement

Committee Statement: The word "approved" was maintained in the requirements to allow flexibility for standards that may apply outside of the US or other unique situations. Part (d) was added as installation instructions are part of the requirements of UL 2196. Subsection (3) was revised to remove requirements for cables run outside the roadway and a new fire test was introduced (IEEE 2412) providing an alternate means of protecting a circuit within the roadway.

Response Message: FR-6-NFPA 502-2023

Public Input No. 24-NFPA 502-2023 [Section No. 12.1]

First Revision No. 4-NFPA 502-2023 [Section No. 12.2.1.3]

12.2.1.3

All cables and conductors used in road tunnels shall be resistant to the spread of fire and shall have reduced smoke emissions by one of the following methods:

(1) Wires and cables listed as having fire-resistant and low smoke-producing characteristics, by having a cable char height of not greater than 1.5 m (4.9 ft) when measured from the lower edge of the burner face, a total smoke release over the 20-minute test period no greater than 150 m^2, and a peak smoke release rate of no greater than 0.40 m^2/sec, when tested in accordance with either the IEEE 1202, *Standard for Flame-Propagation Testing of Wire and Cable*, the vertical tray flame test method (Method 2 – FT4) described in UL ~~1685,~~ ~~*Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables*~~ 2556, *Wire and Cable Test Methods* , or the CSA FT4 Vertical Flame Test per CSA C22.2 No. 0.3, *Test Methods for Electrical Wires and Cables*

(2) Wires and cables listed as having fire-resistant and low smoke-producing characteristics, by having a flame travel distance that does not exceed 1.5 m (4.9 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 the methods described in NFPA 262 or the CSA FT6 Horizontal Flame and Smoke Test per CSA C22.2 No. 0.3

(3) Wires and cables tested to equivalent internationally recognized standards approved by the authority having jurisdiction (AHJ)

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Wed Sep 27 16:47:11 EDT 2023

Committee Statement

Committee Statement: The revision replaces UL 1685 with UL 2556, Wire and Cable Test Methods as UL 1685 is being phased out. Communication raceways are not applicable for installation in tunnels since tunnels don't have plenums as defined in NFPA 90A.

Response Message: FR-4-NFPA 502-2023

Public Input No. 27-NFPA 502-2023 [Section No. 12.2.1.3]

First Revision No. 22-NFPA 502-2023 [Section No. A.12.7]

A.12.7

The security of the electrical supply substation to the facility should be in accordance with the recommendations in IEEE 1402, *IEEE Guide for* ~~*Electrical Substation Physical and Electric Power Security*~~ *Physical Security of Electric Power Substation* .

The following documents should be consulted for developing the security plan:

(1) NFPA 730

(2) NFPA 731

(3) ~~*NFPA 1600*~~ NFPA 1660

Submitter Information Verification

Committee: ROA-AAA

Submittal Date: Thu Sep 28 11:49:17 EDT 2023

Committee Statement

Committee Statement: NFPA's Emergency Response and Responder Safety Consolidation (ERRS) Project consolidated NFPA 1600 into NFPA 1660.

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First Revision No. 21-NFPA 502-2023 [Section No. A.13.7]

A.13.7

In addition to using NFPA 1561, consideration should be given to use ~~NFPA 1600~~ NFPA 1660 for planning for incidents.

Submitter Information Verification

Committee: ROA-AAA

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Committee Statement

Committee Statement: NFPA's Emergency Response and Responder Safety Consolidation (ERRS) Project consolidated NFPA 1600 into NFPA 1660. Reference was updated to new standard. NFPA 1561 is being consolidated to NFPA 1550, but currently NFPA 1550 is in draft and has not been published.

Response Message: FR-21-NFPA 502-2023

First Revision No. 26-NFPA 502-2023 [Chapter G]

Annex G Alternative Fuels and Energy Sources

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

G.1 General.

Most vehicles currently used in the United States are powered by either spark-ignited engines (gasoline, ethanol) or compression-ignited engines (diesel). Vehicles that use alternative fuels such as sources of energy such as battery electric vehicles (BEVs), fuel cell electric vehicles (FCEVs), compressed natural gas (CNG), compressed gas hydrogen (cGH_2), liquefied petroleum gas (LP-Gas), and liquefied natural gas (LNG) vehicles are entering the vehicle population, but the percentage of such vehicles is still not large enough to significantly influence the design of road tunnel ventilation with regard to vehicle emissions. With the introduction of fuel cell electric vehicles (FCEVs), compressed gas hydrogen (cGH_2) has entered the market as a source of power for fuel cells. However, it is possible that growing concerns regarding the safety of some alternative-fuel vehicles that operate within road tunnels will affect the fire-related life safety design aspects of highway tunnels. See Chapter 11 for requirements for road tunnel ventilation during fire emergencies.

As a result, in the short term, the decision will be in the hands of the AHJ as to the mitigation measures for dealing with alternative fuels in road tunnels.

Vehicles in the United States and most countries are required to comply with federal and state requirements for use on public roads. Some jurisdictions regulate the placarding of alternative fuel vehicles and their ability to utilize road tunnels. This regulation is not universal, which leaves alternative fuel vehicles unidentifiable in many jurisdictions. As a result, in the short term, the mitigation measures for dealing with alternative fuels in road tunnels will be in the hands of the AHJ.

Section G.2 provides some highlighted information about selected alternative fuels, Section G.3 provides some additional information about possible mitigation measures, and Section G.4 provides a brief discussion of applicable codes and standards, as well as recent research into the hazards of alternative fuels.

G.1.1 Properties of Alternative Fuels.

Table G.1.1 provides information on properties of alternative fuels and gasoline.

Table G.1.1 Properties of Alternative Fuels

Properties	Units	Hydrogen[a]	Methane[a]	Propane[a]	Methanol[a]	Ethanol[a]	Gasoline[b]
Chemical formula		H_2	CH_4	C_3H_8	CH_3OH	C_2H_5OH	C_xH_y (x = 4 − 12)
Molecular weight[c,d]		2.02	16.04	44.1	32.04	46.07	100 to 105
Density (NTP)[c,e,f]	kg/m^3	0.0838	0.668	1.87	791	789	751
	lb/ft^3	0.00523	0.0417	0.116	49.4	49.3	46.9
Viscosity (NTP)[c,d,e]	g/cm-sec	8.81×10^{-5}	1.10×10^{-4}	8.012×10^{-5}	9.18×10^{-3}	0.0119	0.0037 to 0.0044
	lb/ft-sec	5.92×10^{-6}	7.41×10^{-6}	5.384×10^{-6}	6.17×10^{-4}	7.99×10^{-4}	2.486×10^{-4} to 2.957×10^{-4}
Normal boiling point[c,d]	°C	−253	−162	−42.1	64.5	78.5	27 to 225
	°F	−423	−259	−43.8	148	173.3	80 to 437
Vapor specific gravity (NTP)[c,e,g]	air = 1	0.0696	0.555	1.55	N/A	N/A	3.66
Flash point[d,g]	°C	<−253	−188	−104	11	13	−43
	°F	<−423	−306	−155	52	55	−45
Flammability range in air[d,f,g]	vol%	4.0 to 75.0	5.0 to 15.0	2.1 to 10.1	6.7 to 36.0	4.3 to 19	1.4 to 7.6
Autoignition temperature in air[d,g]	°C	585	540	490	385	423	230 to 480
	°F	1085	1003	914	723	793	450 to 900

N/A: Not applicable.

[a]Properties of the pure substance.

[b]Properties of a range of commercial grades.

[c]Source: NIST Chemistry WebBook, https://webbook.nist.gov/chemistry/.

[d]Source: *Alternatives to Traditional Transportation Fuels: An Overview*, DOE/EIA-0585/US Energy Information Administration, US Department of Energy, Washington, DC, June 1994.

[e]NTP: Normal temperature and pressure [measured at 20°C (68°F) and 1 atmosphere].

[f]Source: *Perry's Chemical Engineers' Handbook*, 7th edition, McGraw-Hill, 1997.

[g]Source: *Hydrogen Fuel Cell Engines and Related Technologies*, Module 1: Hydrogen Properties, US Department of Energy, 2001.

G.2 Alternative Fuels.

It is evident that the use of vehicles powered by alternative fuels (i.e., fuels other than gasoline or diesel) will continue to increase. Of the potential alternative fuels, ethanol, compressed natural gas (CNG), LP-Gas, electric, and hybrid electric currently are the most widely used. LNG and cGH_2 are entering the market. Under the Energy Policy Act of 1992 and the Clean Air Act Amendment of 1990, the following are considered potential alternative fuels:

(1) Methanol

(2) Hydrogen

(3) Ethanol

(4) Coal-derived liquids

(5) Propane

(6) Biological materials

(7) Natural gas

(8) Reformulated gasoline

(9) Electricity (stored energy batteries)

(10) Clean diesel

G.2.1 Compressed Natural Gas (CNG).

CNG has some excellent physical and chemical properties that make it a ~~safer automotive fuel than gasoline or LP-Gas~~ good candidate , provided well-designed carrier systems and operational procedures are followed. Although CNG has a relatively high flammability limit, its flammability range is relatively narrow compared to the ranges for other fuels.

In air at ambient conditions, a CNG volume of at least 5 percent is necessary to support continuous flame propagation, compared to approximately 2 percent for LP-Gas and 1 percent for gasoline vapor. Therefore, considerable fuel leakage is necessary in order to render the mixture combustible. The risk of reaching this threshold might be higher in tunnels than in open air.

There are a number of standard requirements for these types of systems, and the requirements derive from existing requirements for storage and transport of CNG tanks. In the US, the primary standards used are FMVSS 304, *Compressed* ~~*Natural Gas Fuel Container Integrity*~~ *natural gas fuel container integrity* , and CSA/ ANSI NGV2, ~~*American National Standard for Natural Gas Vehicle Containers*~~ *Compressed Natural Gas Vehicle Fuel Containers* . Both of these standards were developed for the approval of compressed natural gas containers.

The tests in both of these standards include full-scale fire tests of the containers and their pressure relief devices (PRDs), as well as component reliability testing, such as pressure cycling, impact resistance, drop tests, and hydrostatic burst testing. In addition to the required tests, a quality-control system is required to be administered by an independent third party to ensure that the fuel system components are manufactured in the same manner as when they were approved through testing.

Furthermore, fires involving combustible mixtures of CNG are relatively easy to contain and extinguish. Since natural gas is lighter than air, it normally dissipates harmlessly into the atmosphere instead of pooling when a leak occurs. However, in a tunnel environment, such dissipation can lead to pockets of gas that collect in the overhead structure. ~~In addition, since natural gas can ignite only in the range of 5 percent to 15 percent volume of natural gas in air, leaks are not likely to ignite due to insufficient oxygen.~~

Another advantage of CNG is that its fueling system is one of the safest in existence. The rigorous storage requirements and greater strength of CNG cylinders compared to those of gasoline contribute to the superior safety record of CNG automobiles.

An incident with a CNG-propelled bus in the Netherlands [" Fire in a CNG bus" (" Brand in een aardgasbus," 2012)] highlighted the issue and associated risk of possible jet fires as a consequence of the pressure release valve operation.

G.2.2 Liquefied Petroleum Gas (LP-Gas).

~~There is a growing awareness of the economic advantages of using LP-Gas as a vehicular fuel. These advantages include longer engine life, increased travel time between oil and oil filter changes, longer and better performance from spark plugs, nonpolluting exhaust emissions, and, in most cases, mileage that is comparable to that of gasoline.~~ LP-Gas is normally delivered as a liquid and can be stored at up to 38°C (100.4°F) on vehicles under a design pressure of 1624 kPa to 2154 kPa (250 psi to 312.5 psi). LP-Gas is a natural gas and petroleum derivative. ~~One disadvantage is that it is costly to store because a pressure vessel is needed.~~ Also, where LP-Gas is engulfed in a fire, a rapid increase in pressure can occur, even if the outside temperature is not excessive relative to the gas–vapor pressure characteristics. Rapid pressure increase can be mitigated by venting the excessive buildup through relief valves. ~~In Australia a significant proportion of the vehicle fleet uses LP-Gas-powered vehicles. Alternative-powered vehicles are marked by colored labels on their registration plates. No restrictions on use of such vehicles exist in Australia. In Australia, the only impact on managing these vehicles is by alternative procedures for incident response by emergency services.~~

G.2.3 Methanol.

Currently, methanol is used primarily as a chemical feedstock for the production of chemical intermediates and solvents. Under EPA restrictions, it is being used as a substitute for lead-based octane enhancers in the form of methyl tertiary-butyl ether (MTBE) and as a viable method for vehicle emission control. MTBE is not available as a fuel substitute but is used as a gasoline additive.

The hazards of methanol production, distribution, and use are comparable to those of gasoline. Unlike gasoline, however, methanol vapors in a fuel tank are explosive at normal ambient temperature. Saturated vapors that are located above nondiluted methanol in an enclosed tank are explosive at 10°C to 43°C (50°F to 109.4°F). A methanol flame is invisible, so a colorant or gasoline needs to be added to enable detection.

G.2.4 Hydrogen.

Hydrogen is one of the most attractive alternative fuels due to its ability to power fuel cells in vehicles, its abundant availability, and its potential for higher efficiency in vehicles. Hydrogen can be used to power vehicles in the form of fuel cells or as replacement fuel in internal combustion engines. One kg (2.2 lb) of hydrogen gas has about the same energy as 3.8 L(1 gal) of gasoline. Commercially deployed hydrogen-powered vehicles employ fuel cells to convert hydrogen into electricity to power electric motors. For a driving range of 450 km (300 miles) or more, a light-duty fuel cell vehicle must carry approximately 5 kg (11 lb) of hydrogen. Commercially available storage technologies typically include high-pressure tanks for compressed hydrogen gas up to 70 MPa (10,000 psi/700 bar). Several automotive companies now sell or lease fuel cell electric vehicles (FCEVs), and networks of hydrogen fueling stations have been constructed on both US coasts with plans to provide fueling service to the entire country.

Medium and heavy-duty gaseous hydrogen vehicles are in their demonstration phase.

Currently, FCEV vehicles use tanks to store cGH_2. As of now, the onboard storage of liquid hydrogen (LH_2) is not used in any vehicles. The onboard hydrogen system usually contains a single or several cGH_2 storage tank(s), a refueling receptacle, and hydrogen fuel lines. Each tank is equipped with its own thermally activated pressure relief device (TPRD). In case of fire, TPRDs will either release hydrogen individually or route it to a single vent location. The direction of hydrogen release from a TPRD is vertically downwards or at a slight angle when a car is in normal position with four wheels on the ground. The hydrogen fuel lines contain hydrogen at much lower pressures [from ambient to about 0.7 MPa (102 psi)] than the tanks. The lines are made of stainless steel compatible with hydrogen. The entire fuel system is sealed and no to minimize the risk that any relevant amount of hydrogen is released during operation or parking.

The direction of a hydrogen release from a car is typically downwards at an angle of roughly 45 degrees. For usage in buses and heavy-duty vehicles, a vertical release upwards is recommended (PIARC Report WG4, 2023).

In addition, FCEVs contain high-voltage electricity, similar to electric and hybrid-electric vehicles, and therefore comply with FMVSS305.

In comparison to gasoline, hydrogen has a much wider flammability range (4 percent to 75 percent by volume) and explosive limit. The minimum ignition energy of hydrogen in air is about an order of magnitude (by a factor of 10) less than that of gasoline vapor. As the density is only about 7 percent of air, hydrogen release into the atmosphere usually results in rapid dispersion and mixing to a nonhazardous concentration. However, accumulation of hydrogen in stagnant space that cannot be ventilated is a fire and explosion hazard. A minimum separation distance from the ceiling or explosion proofing should be considered for electrical equipment (classified electrical systems). Proper ventilation is important to dilute released, unburned H_2 below critical values. For non-emergency ventilation requirements see ASHRAE 217, *Non-Emergency Ventilation in Enclosed Road, Rail, and Mass Transit Facilities*.

Emergency response to an incident involving a hydrogen fuel leak or fire requires certain training, such as recognizing a hydrogen tank, high-voltage battery, or capacitor pack that might be present in an incident vehicle. The NFPA website shown in G.2.4(2) provides specific emergency response information on commercially available FCEVs. The H_2 Tools website shown in G.2.4(1) provides training materials for emergency responders that can be used to prepare for incidents involving FCEVs. Use the following references for more information on emergency response and emergency response training for FCEVs:

(1) H_2 Tools: https://h2tools.org/training-materials

(2) NFPA: http://www.nfpa.org/training-and-events/by-topic/alternative-fuel-vehicle-safety-training https://www.nfpa.org/EV

(3) C. LaFleur, et al. *Hydrogen Fuel Cell Electric Tunnel Safety Study*. Sandia National Laboratories, SAND2017-11157, October 2017.

(4) C. LaFleur, et al. *Alternative Fuel Vehicles in Tunnels*. Sandia National Laboratories, SAND2020-5466, May 2020.

G.2.5 Battery Electric Vehicle (BEV).

~~Both battery EVs and gasoline-electric–type hybrid electric vehicles (HEVs)~~ Battery electric vehicles (BEVs) have been commercially available for a number of years. Their volumes are expected to grow rapidly in the next years. Due to the introduction of electric drive, energy storage, and conversion systems, one safety consideration involves the high-voltage system (e.g., 400 VDC) used for the powertrain, which might pose risks such as electric shock and short-circuit. ~~The other is heat generated during battery charging and discharging, which can generate toxic fumes.~~

The main ~~EV and HEV~~ BEV Li-ion battery pack failure mode is thermal runaway. Thermal runaways in batteries are typically the result of electrical failure, mechanical damage, or excessive exposure to heat. These events result in venting of flammable gases and could result in subsequent fires. Venting of these gases can occur before actually going into thermal runaway but ~~can~~ it might be difficult to ~~observe visually~~ detect this precursor event before thermal runaway has initiated . If vented gases are accumulated in a confined or semiconfined space, there is the potential to reach lethal concentrations or for combustion/explosion in the presence of an ignition source.

Typical cell vent gases consist of a mixture of carbon monoxide, carbon dioxide, hydrogen, methane, hydrogen fluoride, and a number of heavier hydrocarbons. Testing has confirmed that the exact composition of vent gases depends on the battery state-of-charge and battery chemistry [1].

Smoke originating from a lithium-ion battery fire is a severe potential health risk due to contamination with heavy metals and hazardous gases [2]. Smoke generated by battery fires ~~can severely~~ might damage concrete or steel structures due to the smoke's corrosive properties. Related health risks to first responders should be considered in the design of enclosed facilities for EV such as tunnels and parking garages. Further, the ~~potential~~ possible presence of high-voltage touch-potential areas is a risk to tunnel occupants and rescue services. One concern for first responders is also the hydrogen fluoride can enter the body through the skin, which increases the requirements and properties of the protective clothing and equipment used by first responders. NFPA provides information on most commercially available ~~EVs~~ BEVs detailing specific areas of risk [3] in a database on its public home page. NFPA also provides dedicated online training courses [4]. ~~Contaminated water treatment should also be considered during design.~~

Water is an effective suppression agent for ~~EV~~ BEV fires. However, the amount of water required for suppression in performance tests was much higher than for standard ~~IC~~ ICE vehicle fires and as high as 2600 gal (9850 L) [5]. Testing showed that the most effective way to attack EV and HEV fires is to concentrate the water flow onto the battery pack in order to reduce the temperature of the cells, avoiding thermal runaway and fire re-ignition. Contaminated water treatment should also be considered during design.

The risk of thermal runaway during charging and discharging of ~~EV~~ BEV batteries is higher than during periods of inactivity such as ~~normal~~ parking [6]. Therefore, enclosed spaces intended for EV charging should be equipped with a fire detection, ventilation, and fixed firefighting systems depending on the overall safety concept. Battery packs of ~~EVs~~ BEVs are typically located underneath the vehicle or below the trunk area and therefore difficult to be reached by water-based fixed firefighting systems. Hence, the main purpose of fixed firefighting systems in this case is to cool the ~~environment~~ area near the burning ~~EV~~ BEV and to reduce the ~~smoke's~~ presence of hazardous ~~content~~ smoke . This action will limit fire spread and provide better access for fire brigades. Again, the treatment of run-off water should be considered.

~~EVs~~ BEVs whose batteries have been mechanically damaged, exposed to mechanical impact, or involved in a fire have a risk for re-activation, even after seemingly stable conditions, and should be separated from other combustible material by at least 50 ft (15 m) [7]. In some European countries such as Germany, Austria, and Switzerland, fire brigades submerge ~~EV~~ BEV cars in water to prevent re-ignition during transport and disassembly. Submersion for larger ~~EVs~~ BEVs such as ~~busses~~ buses and trucks is not typically practical due to size limitations.

It should be noted that research on ~~EV~~ BEV fires so far has been ~~very~~ limited~~.~~ mainly to passenger vehicles [1] [2]. Most fire tests have been performed using a limited number of battery cells, single battery packs, or single ~~EV~~ BEV . There is limited information on larger battery installations. Furthermore, no methodical research is currently available for large size battery packs such as those used in ~~busses~~ buses or trucks or those transported in trucks. Neither have fire tests been carried out to examine fire scenarios involving multiple ~~EVs~~ BEVs or combinations of ~~EVs~~ BEVs and vehicles powered by other fuel sources such as diesel, petrol, gas, or hydrogen.

The following documents are referenced in this section:

[1] Sturm P. et al., Fire tests with lithium-ion battery electric vehicles in road tunnels; Fire Safety Journal 134 (2022) 103695.

[2] Willstrand O. et al., Toxic gases from fire in electric vehicles, RISE Report 2020:90, ISBN: 978-91-89167-75-9.

G.2.6 Hybrid (HEV/PHEV).

In contrast to battery electric vehicles, HEV and plug-in hybrid electric vehicles (PHEV) combine a conventional internal combustion engine (ICE) system with an electric propulsion system.

The battery systems used in hybrid vehicles are typically smaller in both size and energy capacity than full electric vehicles.

PHEVs offer the possibility to recharge the battery by connecting it to an external electric power source. HEVs are recharged by regenerative breaking. Therefore, HEVs do not imply additional risks. Whereas PHEVs, being charged during parking, should be assessed in a way similar to fully electric vehicles since the battery system is active.

In terms of energy release, PHEVs are not considered to be more dangerous than ICE vehicles as the vehicles themselves generate the major fire load. Nevertheless, research is not available that is focused on the burning characteristics of combined conventional and electric propulsion systems. Research conducted has revealed that risks and hazards of HEVs and PHEVs fires do not differ significantly from fires with EVs. Since the batteries of HEVs and PHEVs are substantially smaller than those of EVs, the amount of toxic fumes from battery fires is considerably less.

The following documents are referenced in this section:

[1] Colella et., *Electric Vehicle Fires*, International Symposium on Tunnel Safety and Security, 2016.

[2] Fire Protection Research Foundation Report: *Best Practices for Emergency Response to Incidents Involving Electric Vehicles Battery Hazards: A Report on Full-Scale Testing Results*.

G.3 Additional Considerations.

As the use of alternative fuels in road vehicles increases, each operating agency or AHJ must deal with the issue of whether to permit such vehicles to pass through the tunnels or lower levels of dual-level bridges for which it is responsible. Each alternative fuel type must be considered on its own merit.

It should be noted that Annex G mostly focuses on light-duty vehicles, such as passenger vehicles. However, alternative fuels are also being used to power medium and heavy-duty vehicles, such as buses, trucks, and industrial vehicles (e.g., refuse trucks). In these cases, special consideration is needed for the increased quantity of alternative fuel used and the fact that some of the storage tanks are mounted on the roofs of vehicles.

Identification of the alternative fuel type used within a vehicle is an important issue to address because it can inform responders on the most appropriate firefighting and emergency intervention strategies. Automobile manufacturers provide emergency response guides for all of their vehicles to address these issues and NFPA has an active database of these guides (~~https://www.nfpa.org/Training-and-Events/By-topic/Alternative-Fuel-Vehicle-Safety-Training/Emergency-Response-Guides~~ https://www.nfpa.org/EV).

This is still a difficult prospect for many agencies. It is not enough to realize that a fire incident involves an alternative fuel vehicle; the fuel must also be identified. Currently, there are no national requirements within the US for a standard placard system identifying the type of fuel in a vehicle. Typically, emergency responders undergo specialist training on how to identify specific alternative fuel vehicles and the most appropriate strategies for dealing with them in an emergency. Consequently, if a particular fuel is prohibited by regulation from entering a tunnel facility, vehicle identification is important for the enforcement of the facility's rules and procedures. Most emergency response guides for alternative vehicles offer methods on how to identify alternative fuel types. Specifically, SAE J2990 and SAE J2990/1 offer guidance on how to identify and respond to EV and hydrogen-powered vehicles.

Identification of alternative-fuel vehicles is critical, as the correct emergency response strongly depends on knowing the hazard posed by a fire incident. Specific emergency response procedures, precautions, and training requirements for each type of alternative-fuel must also be prepared and included as part of a facility's emergency response plan.

These should also be coordinated with the local fire department response plan. Examples of alternative fuel vehicle response plans are listed in Annex O. The hazards presented by various alternative fuel fires differ and are fuel dependent. For instance, hydrogen and methanol flames are not easily discernable with the naked eye. Specialized detection systems might be advisable, depending on an assessment of the risk. In addition, high-voltage touch potential in electric vehicles should be recognized. Therefore, emergency response personnel should be provided with training specific to each alternative-fuel vehicle. In addition, first responders should consider specialty response equipment such as, but not limited to, self-contained breathing apparatus (SCBA), high-voltage gloves, static dissipative equipment, and infrared cameras to visualize a vehicle fire.

Due to the gaseous nature of most alternative fuels and the common use of overpressure devices, there is a risk of having a continuous gas flow without direct ignition, creating a gas cloud that could potentially be ignited. The priority of emergency responders should be ~~extinguishing~~ suppressing the ~~fire~~ fires impinging on containers , cooling the fuel containment vessels, and not extinguishing any jet if present. The focus of the emergency response should be doing so in a safe and efficient way.

Fire sprinkler water density can be used to prevent a boiling liquid expanding vapor explosion (BLEVE) of containers that have been heated by flame if the density is below the suggested water flows recommended by the guidelines of the Pipeline and Hazardous Materials Safety Administration's *Emergency Response Guidebook* . Fire sprinkler water density (1) should not be expected to provide adequate cooling.

(1) DOT PHMSA p366 https://www.phmsa.dot.gov/training/hazmat/erg/emergency-response-guidebook-erg

Although unlikely, moving flammable gas through mechanical ventilation (e.g., jet fans) might provide an ignition source.

Designers and engineers might want to provide the AHJ with information on the hazards of alternate fuel vehicles in tunnels, as provided in this annex, as well as informational sources to research the state of the practice for prevention, mitigation, etc., beyond Annex G.

It is recognized that many alternative fuel vehicles have concealed pressure release devices that could be compromised if water freezes it open or closed.

Tunnel facilities must also review the potential of accumulation of a gaseous fuel. This could be at a low point, as in the case of dense gas clouds (e.g., propane, LNG), or at a high point, as in the case of CNG or hydrogen. If alternative fuel vehicles are using a tunnel, these areas should be identified and monitored to prevent unaware personnel from entering an environment with a latent hazard. Tunnel ventilation provides the tunnel facility with one means of mitigation. Tunnel ventilation can provide sufficient air to dilute escaped fuel to concentrations below the lower flammability limit (LFL). It is necessary to establish a minimum level of ventilation to provide such dilution under all circumstances.

AFVs are designed according to international regulation (e.g., GTR #13) to be as safe or safer than conventional vehicles. According to a risk assessment of hydrogen fuel cell electric vehicles in tunnels, the most likely (with 98.1 percent – 99.9 percent probability) consequence of a crash is no additional hazard from the hydrogen fuel [Ehrhart, B.D., D.M. Brooks, A.B. Muna and C.B. LaFleur, Risk Assessment of Hydrogen Fuel Cell Electric Vehicles in Tunnels. Fire Technology, 2020. 56(3): p. 891-912]. Current statistics indicate that BEVs cause less fires, i.e., they are safer [Willstrand, O., Bisschop, R., Blomqvist, P., Temple, A., & Anderson, J. (2020). Toxic Gases from Fire in Electric Vehicles (978-91-89167-75-9 (ISBN)). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:ri:diva-52000].

G.4 Informational References.

Published research exists to help assess the relative hazard of specific alternative fuels (and fuel systems) and to help develop consensus safety standards for regulators. Subsection O.2.1 references several codes and standards used for alternative fuels as well as a few website resources for new standards in development. Subsection O.2.2 contains a short list of published research in the area of alternative fuels.

This list of references represents a brief summary of some applicable documents, with some emphasis on hydrogen, as that seems to be the fastest growing technology. This list is not meant to be exhaustive. On the other hand, it is meant to be a starting point for document users to understand some of the hazards of alternative fuels, potential mitigation measures, as well as necessary future research.

Submitter Information Verification

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Committee Statement

Committee Statement: Due to rapid changing environment of alternative fuels input from technical members were solicited and used to update this Annex. The changes clarify risks associated with alternative fuels.

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First Revision No. 28-NFPA 502-2023 [Chapter O]

Annex O Informational References

O.1 Referenced Publications.

The documents or portions thereof listed in this annex are referenced within the informational sections of this standard and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.

O.1.1 NFPA Publications.

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

NFPA 3, *Standard for Commissioning of Fire Protection and Life Safety Systems*, ~~2021~~ 2024 edition.

NFPA 18, *Standard on Wetting Agents*, 2021 edition.

NFPA 18A, *Standard on Water Additives for Fire Control and Vapor Mitigation*, 2022 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, ~~2021~~ 2024 edition.

NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages*, ~~2021~~ 2024 edition.

NFPA 70B, ~~*Recommended Practice*~~ *Standard for Electrical Equipment Maintenance*, ~~2022~~ 2023 edition.

NFPA 72®, *National Fire Alarm and Signaling Code®*, ~~2022~~ 2025 edition.

NFPA *101®*, *Life Safety Code®*, ~~2021~~ 2024 edition.

NFPA 170, *Standard for Fire Safety and Emergency Symbols*, ~~2021~~ 2024 edition.

NFPA 262, *Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces*, ~~2019~~ 2023 edition.

NFPA 502, *Standard for Road Tunnels, Bridges, and Other Limited Access Highways*, 2014 edition.

NFPA 502, *Standard for Road Tunnels, Bridges, and Other Limited Access Highways*, 2017 edition.

NFPA 550, *Guide to the Fire Safety Concepts Tree*, 2022 edition.

NFPA 551, *Guide for the Evaluation of Fire Risk Assessments*, 2022 edition.

NFPA 730, *Guide for Premises Security*, ~~2020~~ 2023 edition.

NFPA 731, *Standard for the Installation of Premises Security Systems*, ~~2020~~ 2023 edition.

NFPA 1561, *Standard on Emergency Services Incident Management System and Command Safety*, 2020 edition.

~~*NFPA 1600®*, *Standard on Continuity, Emergency, and Crisis Management*, 2019 edition.~~

NFPA 1660, *Standard for Emergency, Continuity, and Crisis Management: Preparedness, Response, and Recovery*, 2024 edition.

O.1.2 Other Publications.

O.1.2.1 AISC Publications.

American Institute of Steel Construction, 130 East Randolph, Suite 2000, Chicago, IL 60601.

AISC 325, ~~*LRFD Manual of*~~ *Steel Construction Manual*, 16th edition, ~~2017~~ 2023.

O.1.2.2 ANSI Publications.

American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

CSA/ ANSI NGV2, *American National Standard for Compressed Natural Gas Vehicle Fuel Containers*, 2017 2023 .

O.1.2.3 ASCE Publications.

American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191-4400.

ASCE/SEI 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, 2016 2022 .

O.1.2.4 ASHRAE Publications.

ASHRAE, 180 Technology Parkway, Peachtree Corners, GA 30092.

ASHRAE 217, *Non-Emergency Ventilation in Enclosed Road, Rail, and Mass Transit Facilities*, 2020.

O.1.2.5 ASME Publications.

American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990.

Harris, K. J., “A Basis for Determining Fill Times for Dry Fire Lines in Highway Tunnels,” F. J. Mintz, ed., *Safety Engineering and Risk Analysis*, SERA Vol. 6, 1996.

O.1.2.6 ASTM Publications.

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

ASTM C666/C666M, *Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing*, 2015.

ASTM E136, *Standard Test Method for Assessing the Combustibility of Materials Using a Vertical Tube Furnace at 750°C*, 2019a 2022 .

ASTM E580/E580M, *Standard Practice for Installation of Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels in Areas Subject to Earthquake Ground Motions*, 2020 2022 .

ASTM E2652, *Standard Test Method for Assessing the Combustibility of Materials Using a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750°C*, 2018 2022 .

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Supplemental Information

File Name	Description	Approved
502_A2025_FDM_AnnexO.docx	Attached Word Document with Track Changes contains various updates to this Annex.	

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Committee Statement

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