NATIONAL FIRE PROTECTION ASSOCIATION
The leading information and knowledge resource on fire, electrical and related hazards

NFPA Technical Committee on Road Tunnel and Highway Fire Protection (ROA-AAA)
NFPA 502 SECOND DRAFT MEETING AGENDA

October 5, 6, 7, 14 & 19, 2021
1:00 pm – 5:00 pm (EST)
Web/Teleconference

October 5, 2021

1. Call to Order -1:00 pm
2. Attendance and Voting Members (See Page 2)
3. Review Agenda
4. NFPA Staff Liaison Presentation and Review of Key Dates
5. Chairman's Remarks
6. Approval of Previous Meeting Minutes (November 4, 2020) (Page 6)
7. Act on twenty-eight (28) Public Comments for NFPA 502 (Page 8)
8. Recess 3:00 pm
9. Call to Order – 3:15 pm
10. Recess 5:00 pm

October 6, 7, and 14, 2021

1. Call to Order -1:00 pm
2. Continue to act on eighteen (28) Public Comments for NFPA 502 (Page 8)
3. Recess 3:00 pm
4. Call to Order – 3:15 pm
5. Recess 5:00 pm

October 19, 2021

1. Call to Order -1:00 pm
2. Continue to act on Public Comments for NFPA 502
3. Recess 3:00 pm
4. Call to Order – 3:15 pm
5. New Business
6. Adjourn 5:00pm

1 Batterymarch Park, Quincy, MA 02169-7471 • p: 617-770-3000 • f: 617-770-0700 • nfpa.org

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Arthur G. Bendelius **O** 4/1/1993
Member Emeritus **ROA-AAA**
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Staff Liaison **ROA-AAA**
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NFPA Technical Committee on Road Tunnel and Highway Fire Protection (ROA-AAA)

NFPA 502 FIRST DRAFT MEETING MINUTES

Web/Teleconference Meeting
October , 6-8, 13,14,21 and November 2, 2020

Tuesday, October 6, 2020

1. Committee Chair Norris Harvey called the meeting to order -1:00 pm (EST)
2. Meeting attendance and introductions were conducted
3. First draft meeting agenda was reviewed and approved
4. Minutes from the previous Second Draft Meeting (October 9-11, 2018) was reviewed and approved
5. NFPA Staff Liaison presented the Standards development process and reviewed key dates in current cycle.
6. Chairman made remarks regarding NFPA 502.
7. Technical Committee began acting on fifty six (56) Public Inputs for NFPA 502
8. Meeting recessed at 2:50 pm
9. Meeting was called back to Order -3:10 pm
10. Technical Committee continued to Act on Public Inputs for NFPA 502
11. Meeting recessed at 5:00 pm (EST)

October 7,8,13,14,21, 2020

1. Committee Chair Norris Harvey called the meeting to order -1:00 pm (EST)
2. Technical Committee continued to act on Public Inputs for NFPA 502
3. Meeting recessed at 2:50 pm
4. Meeting was called back to Order -3:10 pm
5. Technical Committee continued to Act on Public Inputs for NFPA 502
6. Meeting recessed at 5:00 pm (EST)

Friday, November 2, 2020

1. Committee Chair Norris Harvey called the meeting to order -1:00 pm (EST)
2. NFPA 72 Applicability, updates on Tunnel Categories, updates on Autonomous Vehicles Annex was discussed.
3. Meeting recessed at 2:50 pm
4. Meeting was called back to Order -3:10 pm
5. Tomas Rakovec gave a presentation on updates to the Efectis 2008 report
6. Committee decided to form task groups to address Public Comments and Committee Inputs
7. Meeting adjourned at 5:00pm (EST)

Attendance:
Norris Harvey (Chair)
Jarrod Alston
Cornelis Both
William Connell
James Conrad
John Dalton
Alexandre Debs
Arnold Dix
Michael Fitzpatrick
Haukur Ingason
Ahmed Kashef
Dimitry Kogan
Joseph Kroboth
James Lake
Max Lakkonen
Igor Maevski
Zachary Magnone
Maurice Pilette
David Plotkin
Tomas Rakovec
Ana Ruiz
Paul Sparrow
Dirk Sprakel
Peter Sturm
William Ventura
Hadi Wijaya
Iain Bowman
Eric Cheong
Robert Cordell
Larry Degraff
Daniel Dirgins
Gary English
Armin Feltmann
Anders Lonnermark
Robert Schmidt
Nader Shahcheraghi
Baran Ozden (NFPA Staff Liaison)
Chad Duffy (NFPA Staff)
Stephan Ganoe (NFPA Staff)
Nicole Cassels (NFPA Staff)

Guest:
Matt Bilson (WSP)
Spencer Quong (Toyota)
Steven Bartha (FHWA)
David Hahm (Jacobs)
Bernd Hagenah (HNTB)
Conrad Stacy (Stacy Agnew)
Daniel Fruhwirt (IVT T.U. Graz)
Michael Beyer (Stacy Agnew)
Scott Shi (Mott MacDonald Ltd.)

Public Comment No. 11-NFPA 502-2021 [Section No. 2.3]

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*, 2020.

ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, 2019.

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

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

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, Non-combustibility test for materials*, 1970, corrigendum, 2014.

2.3.3 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.

2.3.4 Efectis Publications.

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

Efectis-R0695:2020, *Fire Testing Procedure for Concrete Tunnel Linings and Other Tunnel Components*, 2020.

2.3.5 FHWA Publications.

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

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

2.3.~~5~~ 6 IEEE Publications.

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

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

2.3.~~6~~ 7 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*, 2020.

2.3.~~7~~ 8 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~~ 9 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~~ 10 UL Publications.

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

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

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.

2.3.~~10~~ 11 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.

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

Additional Proposed Changes

File Name	Description	Approved
502-2020_Chapter_2_Updates.1606319402936.docx		

Statement of Problem and Substantiation for Public Comment

We voted for the proposals and I think there is an unintentional mistake in section 2.3: the reference to the Efectis procedure has been completely removed.
But, I do not think it should be removed; it should be only updated, as discussed during the previous committee meeting and as given in the document 502-2020_Chapter_2_Updates.docx attached in Terra (and also to this public comment), prepared by Baran Ozden.

Related Item

- FR-59

Submitter Information Verification

Submitter Full Name: Tomas Rakovec
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State:
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Submittal Date: Wed Apr 07 02:47:41 EDT 2021
Committee: ROA-AAA

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,* 2021 edition.

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

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

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

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

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

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

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

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

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

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

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

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

NFPA 750, *Standard on Water Mist Fire Protection Systems,* 2022 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*, 2020.

ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, 2019.

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

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

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.

Efectis-R0695:2020, "Fire Testing Procedure for Concrete Tunnel Linings and Other Tunnel Components" 2020.

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*, 2020.

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.

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

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.

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.
IEC 61508 Standard for Functional Safety of Electrical/Electronic/Programable Electronic Safety-Related Systems, 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.

Public Comment No. 15-NFPA 502-2021 [Section No. 2.3.1]

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*, ~~2020~~ 2021 .

ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, ~~2019~~ 2020 .

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

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

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

Statement of Problem and Substantiation for Public Comment

updates

Also, ASTM E3134 is being added, in conjunction with an associated PC (PC18).

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 18-NFPA 502-2021 [Section No. 7.3.2]	

Related Item

- FR59

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Committee: ROA-AAA

Public Comment No. 23-NFPA 502-2021 [Section No. 2.3.10]

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.

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

ASHRAE Standard 217-2020 "Non-Emergency Ventilation in Enclosed Road, Rail, and Mass Transit Facilities". ASHRAE, 1791 Tullie Circle, NE, Atlanta GA 30329-2305.

Statement of Problem and Substantiation for Public Comment

Standard Annex Material references requirements for non-emergency ventilation in Road Tunnels. ASHRAE recently published Standard 217 which addresses requirements for non-emergency road tunnel ventilation.

Related Item

- FR-37; FR-59

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Submittal Date: Sat May 08 11:14:25 EDT 2021
Committee: ROA-AAA

Public Comment No. 12-NFPA 502-2021 [Section No. 3.3.44]

3.3.44 Noncombustible Material.

~~A material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors, when subjected to fire or heat.~~ (See 4.8).

Statement of Problem and Substantiation for Public Comment

There are three reasons for making this change:
1. It is technically incorrect. Materials that meet the criteria of ASTM E136 can ignite, since materials pass ASTM E136 if they flame for less than 30 seconds. Similarly, the criteria of EN 13501.1 also allows some flaming to occur/ Therefore, this proposed definition will not be valid for some materials that NFPA 502 will consider noncombustible.
2. NFPA definitions should not contain requirements and this one does.
3. The language recommended in the first revision is not consistent with the language in other NFPA documents (as pointed out by Jarrod Alston), such as NFPA 1, 101, 5000, or 130.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 13-NFPA 502-2021 [Section No. 4.8]	
Public Comment No. 14-NFPA 502-2021 [Section No. A.4.8]	

Related Item

- FR58

Submitter Information Verification

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Committee:	ROA-AAA

Public Comment No. 13-NFPA 502-2021 [Section No. 4.8]

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

Statement of Problem and Substantiation for Public Comment

The FR deleted one of the criteria and placed it, incorrectly, in the definition section. If a material does not ignite, that is one criterion for noncombustibility, but it is not the only one.
EN 13501-1 does not contain any information about BS 476-4 and, therefore, referencing it in relation to the EN standard is incorrect.
Also, EN 13501-1 contains two sets of criteria based on ISO 1182, with the criteria for Class A1 being the more severe of the two and the one that should be referenced.
Since the intent of referencing EN 13501-1 is for it to be used in Europe, the correct information is essential.
As was pointed out by Jarrod Alston, deleting the first criterion and placing it in a definition (which is also incorrect) makes it inconsistent with other NFPA documents.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 12-NFPA 502-2021 [Section No. 3.3.44]	
Public Comment No. 14-NFPA 502-2021 [Section No. A.4.8]	

Related Item

• FR60

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Committee:	ROA-AAA

Public Comment No. 24-NFPA 502-2021 [Section No. 7.2 [Excluding any Sub-Sections]]

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 the tunnel length equals or exceeds ~~240 m~~ 300 m (~~800 ft~~ 1000 ft), all provisions of this standard shall apply unless noted otherwise in this document.

(4) Category C — Where the tunnel length equals or exceeds 1000 m (3280 ft), all provisions of this standard shall apply.

Statement of Problem and Substantiation for Public Comment

Section 7.16.6.2 states that spacing between exits for protection of tunnel occupants shall not exceed 300 m (1000 ft). The proposed revision matches with the egress spacing maximum requirement of 7.16.6.2

Related Item

• FR-42; FR-46

Submitter Information Verification

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Submittal Date: Sat May 08 11:30:04 EDT 2021
Committee: ROA-AAA

Public Comment No. 18-NFPA 502-2021 [Section No. 7.3.2]

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~~ comply with the transmission of heat and spalling requirements from applying the time-temperature curve in ASTM E3134, unless an engineering analysis, as required in Chapter 4, that is acceptable to the ahj, demonstrates that an alternate time-temperature curve is suitable .

Statement of Problem and Substantiation for Public Comment

The time-temperature curve in the RWS Efectis report was developed specifically for fire safety of tunnels. It is not just any curve but one that is severe enough that it is suitable for tunnels and it has been the required curve for many editions of NFPA 502. Recently, ASTM committee E05 developed ASTM E3134, which is a consensus standard that incorporates the RWS time-temperature curve. The standard is entitled "Standard Specification for Transportation Tunnel Structural Components and Passive Fire Protection Systems" and it contains the same time-temperature curve as the RWS test and acceptance criteria, the critical one being the transmission of heat and spalling requirements. By referencing ASTM E3134 NFPA 502 references a consensus standard rather than a proprietary test method. Associated with this there will be a need to add ASTM E3134 (dated 2020) into section 2 on referenced ASTM standards.

This PC also deletes any reference to a potential alternate test because it has been shown that the RWS curve (or the alternate curve in ASTM E3134) is the most severe fire resistance test curve around and it should not be acceptable to offer a less suitable alternative.

Note that the first draft has deleted the (now unnecessary) RWS curve and the Efectis report from section 2 but has retained it in this section. It needs to be deleted from this section. The annex note to 7.3.2 should be amended by adding an explanation that the RWS curve is the one contained in ASTM E3134 and a PC to that effect will be submitted.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 19-NFPA 502-2021 [Section No. A.7.3.2]	
Public Comment No. 15-NFPA 502-2021 [Section No. 2.3.1]	
Public Comment No. 19-NFPA 502-2021 [Section No. A.7.3.2]	

Related Item

- PI8

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Committee:	ROA-AAA

Public Comment No. 17-NFPA 502-2021 [Section No. 7.3.3]

7.3.3

During a ~~120-minute period of~~ fire exposure ~~or other time that is~~ period acceptable to the AHJ, but of no less than 120 min, 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.

Statement of Problem and Substantiation for Public Comment

In view of the severe potential for a massive fire in case of failure, an exposure period of less than 120 min (i.e. 2 hours) would not be safe. This section has always required an exposure of not less than 2 hours and such a period should remain.

Related Item

- PI12

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Committee: ROA-AAA

Public Comment No. 2-NFPA 502-2021 [Section No. 7.4.7.2]

7.4.7.2*

For facilities that utilize a nonlisted supervisory control and data acquisition (SCADA) system to monitor and control facility subsystems that are a part of an integrated emergency response system, the FACP ~~shall~~ may be ~~allowed~~ permitted to interface with the SCADA system for the purpose of reporting alarm signals from the automatic fire detection system directly to the SCADA system.

Statement of Problem and Substantiation for Public Comment

Removes unintentional approval of FACP interface with SCADA. Change of words provides a mechanism to check if the particular interface is appropriate.

Related Item

- First draft report

Submitter Information Verification

Submitter Full Name: Arnold Dix
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Submittal Date: Mon Mar 15 19:11:41 EDT 2021
Committee: ROA-AAA

Public Comment No. 3-NFPA 502-2021 [Section No. 7.4.7.4]

7.4.7.4

For facilities ~~that do not utilize a nonlisted~~ that utilize a listed SCADA system to monitor and control facility subsystems, the activation of subsystems in response to a fire emergency shall be directly initiated from the FACP.

Statement of Problem and Substantiation for Public Comment

Removes a double negative to make section clearer.

Related Item

- First Draft Report

Submitter Information Verification

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Submittal Date: Mon Mar 15 19:16:57 EDT 2021
Committee: ROA-AAA

Public Comment No. 4-NFPA 502-2021 [Section No. 9.4.4.2]

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~~ elements by a fixed water-based firefighting system the performance of the proposed fixed water-based firefighting system ~~is~~ must be demonstrated and approved by the AHJ.

Statement of Problem and Substantiation for Public Comment

The current wording refers to section 7.3 which is not onerous or appropriate for structural fire protection. Section 7.3 is primarily focused on fire and life safety issues from a human safety perspective and not a structural perspective. The proposed changes seek to focus attention on the unique issues of structural fire protection with active systems.

Related Item

- First Draft Report

Submitter Information Verification

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Submittal Date: Mon Mar 15 19:21:51 EDT 2021
Committee: ROA-AAA

Public Comment No. 20-NFPA 502-2021 [Section No. 11.2.4]

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

(2)* Prevent backlayering by producing a longitudinal air velocity in the direction of traffic flow.

~~Avoid~~

(a) Minimize disruption of the smoke layer initially when feasible by not operating jet fans that are located near the fire site; operate fans that are farthest away from the site first.

(3) Transverse or reversible semitransverse systems

(4) 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.

(5) Create a longitudinal airflow in the direction of traffic flow by operating the upstream ventilation zone(s) in maximum supply and the downstream ventilation zone(s) in maximum exhaust.

Statement of Problem and Substantiation for Public Comment

*** TerraView is showing more edit than provided. ***
11.2.4(1)b guidance on jet fan starting sequence is a goal and not a mandatory requirement. Implementing that goal is sometimes not viable, and when viable can greatly increase system complexity and potentially reduce reliability. As such, softened wording from mandatory to goal.

Related Item

- CI-52, CI-51

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Committee: ROA-AAA

Public Comment No. 5-NFPA 502-2021 [Section No. 11.2.4]

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

(2)*

~~Prevent backlayering by producing~~

(a)Have authority over backlayering by controlling 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.

(3) Transverse or reversible semitransverse systems

(4) 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.

(5) Create a longitudinal airflow in the direction of traffic flow by operating the upstream ventilation zone(s) in maximum supply and the downstream ventilation zone(s) in maximum exhaust.

Statement of Problem and Substantiation for Public Comment

The concept of zero backlayering is problematic in terms of its calculation and its application. The proposed amendment seeks to introduce the concept of appropriate authority over the air flow and not to preclude in absolute terms backlayering.

Related Item

• First Draft Report

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Submittal Date: Mon Mar 15 19:29:18 EDT 2021
Committee: ROA-AAA

Public Comment No. 6-NFPA 502-2021 [Section No. 11.3]

11.3 Design Objectives.

The design objectives of the emergency ventilation system shall be to control, to extract, or to control and extract smoke and heated gases as follows:

(1) A stream of noncontaminated air is provided to motorists in path(s) of egress in accordance with the anticipated emergency response plan *(see Annex C).*

(2) Longitudinal airflow rates are produced to ~~prevent backlayering~~ control backlayering of smoke in a path of egress away from a fire *(see Annex D).*

Statement of Problem and Substantiation for Public Comment

Absolute backlayering control is an illusion. In practical terms controlling the backlayering to facilitate emergency egress is the objective.

Related Item

• First Draft Report

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Submittal Date: Mon Mar 15 19:33:04 EDT 2021

Committee: ROA-AAA

Public Comment No. 10-NFPA 502-2021 [Section No. 12.8.1.1]

12.8.1.1– _*

Wayfinding lighting systems shall be installed and maintained in accordance with *NFPA 70*, NFPA 110, and NFPA 111._

A.12.8.1.1 Minimum marker illumination levels should be designed in accordance with NCHRP 20-47(59) Proposed Guidelines for Emergency Exit Signs and Marker Systems for Highway Tunnels.

Statement of Problem and Substantiation for Public Comment

A design reference specific to tunnels is necessary for performance criteria. The existing NFPA 502 section 12.8 and 7.16 has no wayfinding performance criteria.

Related Item

• Public input 1 resolved in 1st revision, relates to this comment.

Submitter Information Verification

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Submittal Date: Mon Mar 22 17:32:17 EDT 2021
Committee: ROA-AAA

Public Comment No. 7-NFPA 502-2021 [Section No. 13.2]

13.2* Emergency Incidents.

The following ~~typical~~ incidents shall be considered during the development of facility emergency response plans:

(1) Fire or a smoke condition in one or more vehicles or in the facility

(2) Fire or a smoke condition adjoining or adjacent to the facility

(3) Collision involving one or more vehicles

(4) Loss of electric power that results in loss of illumination, ventilation, or other life safety systems

(5) Rescue and evacuation of motorists under adverse conditions

(6) Disabled vehicles

(7) Flooding of a travel way or an evacuation route

(8) Seepage and spillage of flammable, toxic, or irritating vapors and gases

(9) Multiple casualty incidents

(10) Damage to structures from impact and heat exposure

(11) Serious vandalism or other criminal acts, such as bomb threats and terrorism

(12) First aid or medical attention for motorists

(13) Extreme weather conditions, such as heavy snow, rain, high winds, high heat, low temperatures, or sleet and ice, that cause disruption of operation

(14) Earthquake

(15) Hazardous materials accidentally or intentionally being released into the tunnel

(16)* Fires exceeding design basis

Statement of Problem and Substantiation for Public Comment

The addition of fires exceeding design basis to a list of scenarios that 'shall be' considered means that these emergency incidents are not typical - they are being included to assist emergency responders prepare (not design). There should be no confusion that the design is appropriate, even where these mandated emergency incidents do not form part of the design process.

Related Item

• First Draft Report

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Public Comment No. 8-NFPA 502-2021 [Section No. A.3.3.5]

A.3.3.5 Backlayering.

See Figure A.3.3.5(a) through Figure A.3.3.5(c).

Figure A.3.3.5(a) Tunnel Fire Without Ventilation and Zero Percent Grade.

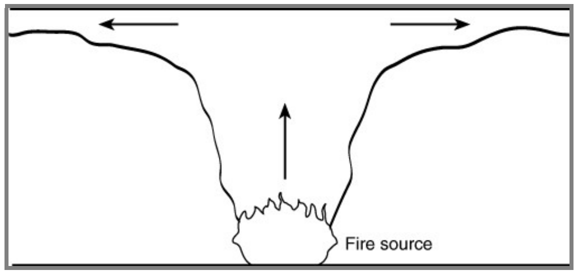


Figure A.3.3.5(b) ~~Insufficiently~~ Ventilated Tunnel Fire Resulting in Backlayering.

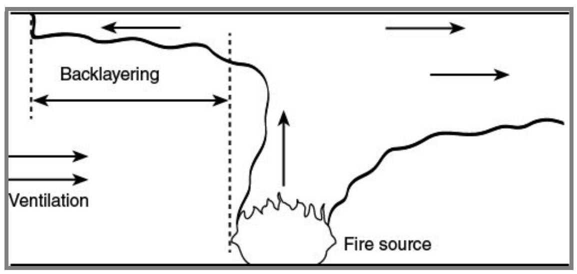
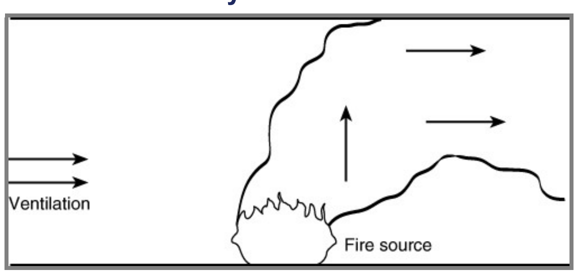


Figure A.3.3.5(c) Tunnel Fire Sufficiently Ventilated to Prevent Backlayering.



Statement of Problem and Substantiation for Public Comment

Under the revised ventilation control regime proposed in 2021 a tunnel may be sufficiently ventilated, even though there is backlayering so long as the degree of backlayering is acceptable and as a result of authority over the smoke. Therefore the word 'insufficiently' should be removed.

Related Item

- First Draft Report

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Public Comment No. 14-NFPA 502-2021 [Section No. A.4.8]

A.4.8

The provisions of Section 4.8 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 4.8, 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 ~~recently~~ since 1970 . ~~ISO 1182 and~~ ASTM E2652 ~~use~~ uses the same test equipment ~~, but neither standard contains acceptance~~ 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 (EN 13501-1) uses ISO 1182 for determining whether a material is noncombustible and includes its own acceptance criteria. EN 13501-1 contains two sets of acceptance criteria based on ISO 1182, they are ones associated with Class A1 or with Class A2 materials, with Class A1 being the more severe. ASTM E136 allows the use of the ASTM E2652 test apparatus but requires the same set of acceptance criteria irrespective of the test apparatus used.

Statement of Problem and Substantiation for Public Comment

Update the information.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 12-NFPA 502-2021 [Section No. 3.3.44]	
Public Comment No. 13-NFPA 502-2021 [Section No. 4.8]	

Related Item

- FR60

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Submittal Date: Wed Apr 21 18:42:04 EDT 2021
Committee: ROA-AAA

Public Comment No. 25-NFPA 502-2021 [Section No. A.7.2]

A.7.2

The categorizing of road tunnels is also influenced by their level of traffic congestion as evidenced by the tunnel's peak hourly traffic count, as shown in Figure A.7.2. These minimum requirements, which are fully described within this standard, are summarized in Table A.7.2, as a reference guide to assist in the search for requirements listed elsewhere in this standard.

Figure A.7.2 Urban and Rural Tunnel Categories.

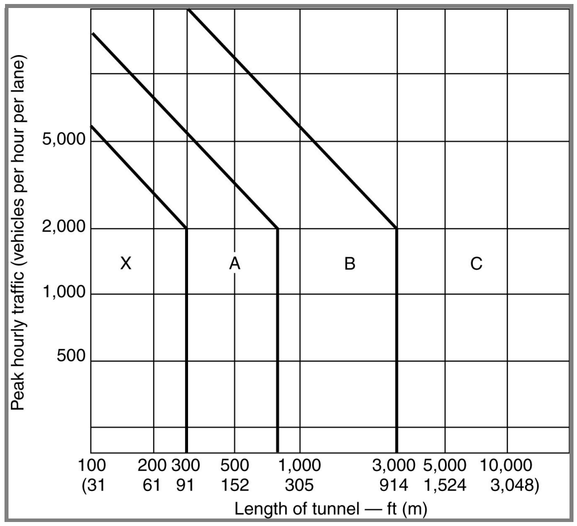

Table A.7.2 Minimum Road Tunnel Fire Protection Reference Guide

		-		Road Tunnel Categories		
		X	A	B		C
Fire Protection Systems	NFPA 502 Sections	[See 7.2(1).]	[See 7.2(2).]	[See 7.2(3).]	-	[See 7.2(4).]
Engineering Analysis -		-	-	-	- -	
Engineering analysis	4.3.1	MR	MR	MR	-	MR
Fire Protection of Structural Elements[a]	-	-	-	-	- -	
Fire protection of structural elements	7.3	MR	MR	MR	-	MR
Fire Detection		-	-	-	- -	
Detection, identification, and location of fire in tunnel	7.4	—	—	MR	-	MR
CCTV systems[b]	7.4.3	—	—	CMR	-	CMR
Automatic fire detection systems[b]	7.4.6.7	—	—	CMR	-	CMR
Fire alarm control panel	7.4.7	—	—	MR	-	MR
Emergency Communications Systems[c]		-	-	-	- -	
Emergency communications systems	4.5/7.5	CMR	CMR	CMR	-	CMR
Traffic Control		-	-	-	- -	
Stop traffic approaching tunnel portal	7.6.1	MR	MR	MR	-	MR

				Road Tunnel Categories		
		X	A	B		C
Fire Protection Systems	NFPA 502 Sections	[See 7.2(1).]	[See 7.2(2).]	[See 7.2(3).]	-	[See 7.2(4).]
Stop traffic from entering tunnel's direct approaches	7.6.2	—	—	MR	-	MR
Fire Protection		-	-	-	- -	
Fire apparatus[d]	7.7	—	—	—	——	
Fire standpipe	7.8/10.1	—	MR	MR	-	MR
Water supply	7.8/10.2	—	MR	MR	-	MR
Fire department connections	10.3	—	MR	MR	-	MR
Hose connections	10.4	—	MR	MR	-	MR
Fire pumps[e]	10.5	—	CMR	CMR	-	CMR
Portable fire extinguishers	7.9	—	—	MR	-	MR
Fixed water-based fire-fighting systems[f]	7.10/Chapter 9	—	—	CMR	-	CMR
Emergency ventilation system[g]	7.11/Chapter 11	—	—	CMR	-	MR
Tunnel drainage system[h]	7.12	—	CMR	MR	-	MR
Hydrocarbon detection[h]	7.12.7	—	CMR	MR	-	MR
Flammable and combustible environmental hazards[i]	7.15	—	—	CMR	-	CMR
Means of Egress		-	-	-	- -	
Emergency egress	7.16.1.1	—	—	MR	-	MR
Exit identification	7.16.1.2	—	—	MR	-	MR
Tenable environment	7.16.2	—	—	MR	-	MR
Walking surface	7.16.4	—	—	MR	-	MR
Emergency exit doors	7.16.5	—	—	MR	-	MR
Emergency exits (includes cross-passageways)[j]	7.16.6	—	—	MR	-	MR
Electrical Systems[k]		-	-	-	- -	
General	12.1	—	CMR	MR	-	MR
Emergency power	12.4	—	CMR	MR	-	MR
Emergency lighting	12.6	—	CMR	MR	-	MR
Exit signs	12.6.8	—	CMR	MR	-	MR
Security plan	12.7	—	CMR	MR	-	MR
Emergency Response Plan		-	-	-	- -	
Emergency response plan	13.3	MR	MR	MR	-	MR

MR: Mandatory requirement (3.3.42). CMR: Conditionally mandatory requirement (3.3.42.1).

Note: The purpose of Table A.7.2 is to provide guidance in locating minimum road tunnel fire protection requirements contained within this standard. If there is any conflict between the requirements defined in the standard text and this table, the standard text must always govern.

[a]Determination of requirements in accordance with Section 7.3.

[b]Determination of requirements in accordance with Section 7.4.

[c]Determination of requirements in accordance with Sections 4.5 and 7.5.

[d]Not mandatory to be at tunnel; however, they must be near to minimize response time.

[e]If required, must follow Section 10.5.

[f]If installed, must follow Section 7.10 and Chapter 9.

[g]Section 11.1 allows engineering analysis to determine requirements.

[h]If required, must follow Section 7.12.

[i]Determination of requirements in accordance with 7.16.2.

[j]Emergency exit spacing must be supported by an egress analysis in accordance with 7.16.6.

[k]If required, must follow Chapter 12.

Statement of Problem and Substantiation for Public Comment

Revise Figure A.7.2 to change Zone A from 800 ft to 1,000 ft in accordance with the Public Comment #24

Related Item

- FR-42; FR-46

Submitter Information Verification

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Submittal Date: Sat May 08 11:36:13 EDT 2021
Committee: ROA-AAA

Public Comment No. 19-NFPA 502-2021 [Section No. A.7.3.2]

A.7.3.2

Any passive fire protection material should satisfy the following performance criteria:

(1) Be resistant to freezing and thawing and follow STUVA Guidelines; BS EN 12467, *Fibre-cement flat sheets. Product specification and test methods*; or ASTM C666, *Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing*

(2) Withstand dynamic suction and pressure loads; 3 kPa (12 in. w.g.) to 5 kPa (20 in. w.g.) depending on traffic type, cross section, and speed limits; amount of cycles to be determined based on traffic volume

(3) Withstand both hot and cold thermal shock from fire exposure and hose streams

(4) Meet all applicable health and safety standards

(5) Not itself become a hazard during a fire

(6) Be resistant to water ingress; follow BS EN 492, *Fibre-cement slates and fittings. Product specification and test methods*

The time-temperature development for the RWS curve is shown in Table A.7.3.2(a) and in Figure A.7.3.2(a). Other internationally recognized standardized time-temperature curves are shown in Figure A.7.3.2(c).

Table A.7.3.2(a) Furnace Temperatures

Time	Temperature	
(min)	ºC	ºF
0	20	68
3	890	1634
5	1140	2084
10	1200	2192
30	1300	2372
60	1350	2462
90	1300	2372
120	1200	2192

An engineering analysis for the purposes of determining the appropriate time-temperature curve should consider the following:

(1) Tunnel geometry

(2) Types of vehicles anticipated

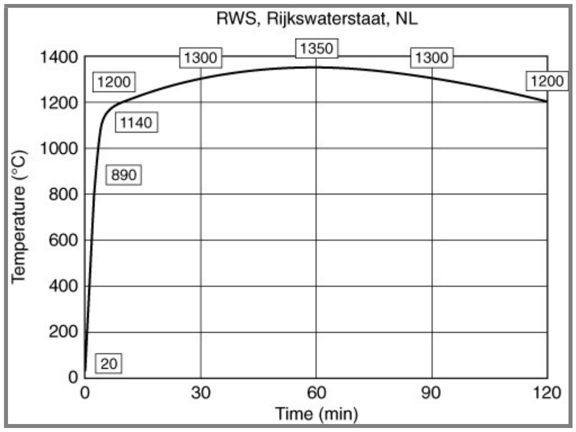
(3) Types of cargoes

(4) Expected traffic conditions

(5) Fire mitigation measure(s)

(6) Reliability and availability of fire mitigation measure(s)

Figure A.7.3.2(a) RWS Time-Temperature Curve.



The RWS fire curve represents one of the standardized time-temperature curves, which was initially developed during extensive testing conducted by the Dutch Ministry of Transport (Rijkswaterstaat, RWS) in cooperation with the Netherlands Organization for Applied Scientific Research (TNO) in the late 1970s, and later proven in full-scale fire tests in the Runehamar tunnel tests in Norway in September 2003, conducted as part of the European Union (EU)–funded research project, Cost-Effective Sustainable and Innovative Upgrading Methods for Fire Safety in Existing Tunnels (UPTUN), in association with SP Technical Research Institute of Sweden and the Norwegian Fire Research Laboratory (SINTEF/NBL).

As shown in Table A.7.3.2(b), four tests were carried out on fire loads of nonhazardous materials using timber or plastic, furniture, mattresses, and cardboard cartons containing plastic cups in a tunnel protected with fire insulation board.

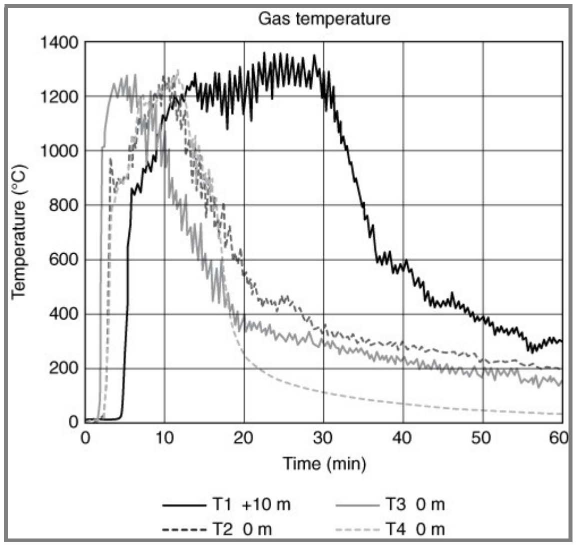
Table A.7.3.2(b) Fire Test Data

Test	Time from Ignition to Peak HRR (min)	Linear Fire Growth Rate (MW/min) (R-Linear Regression Coefficient)	Peak HRR (MW)	Estimated HRR from Laboratory Tests (No Target / Inclusive Target) (MW)
1	18.5	20.1 (0.996)	201.9	186/217
2	14.3	26.3 (0.992)	156.6	167/195
3	10.4	16.4 (0.998)	118.6	—
4	7.4	16.9* (0.996)	66.4	79/95

* 5-66.4 MW

All tests produced time-temperature developments in line with the RWS curve as shown in Figure A.7.3.2(b).

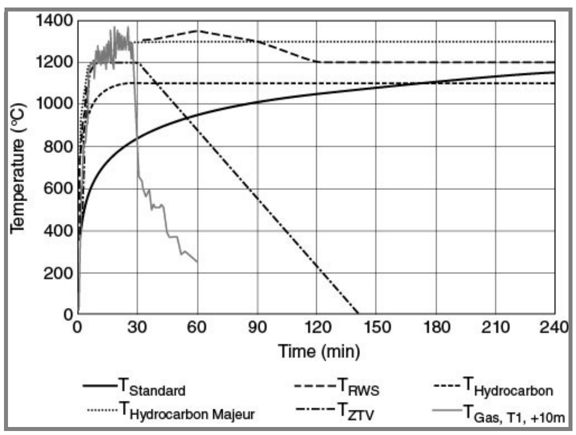
Figure A.7.3.2(b) Test Fire Curves.



All fires produced heat release rates of between 70 MW for cardboard cartons containing plastic cups and 203 MW for timber/plastic pallets.

Figure A.7.3.2(c) depicts the T1 fire test time-temperature development in comparison to various standardized time-temperature curves.

Figure A.7.3.2(c) Various Standardized Time-Temperature Curves and Fire Test Time-Temperature Development.



The RWS requirements are adopted internationally.

The level of fire resistance of structures and the emergency time/temperature certification of equipment should be proven by testing or reference to previous testing.

Fire test reports are based on the following requirements:

(1) Concrete slabs used for the application of passive fire protection materials for fire testing purposes have dimensions of at least 1400 mm × 1400 mm (55 in. × 55 in.) and a nominal thickness of 150 mm (6 in.).

(2) The exposed surface is approximately 1200 mm × 1200 mm (47 in. × 47 in.).

(3) The passive fire protection material is fixed to the concrete slab using the same fixation material (anchors, wire mesh, etc.) as will be used during the actual installation in the tunnel.

(4) In the case of board protection, a minimum of one joint in between two panels should be created, to judge if any thermal leaks would occur in a real fire in the tunnel.

(5) In the case of spray materials, the number of applications (number of layers) should be registered when preparing the test specimen. This number of layers should be considered when the spray material is applied in a real tunnel.

(6) Temperatures are recorded by K-type thermocouples in the following locations:

(7) At the interface between the concrete and the passive fire protection material

(8) At the bottom of the reinforcement

(9) On the nonexposed face of the concrete slab

For an example test procedure to assess the spalling and the thermal protection of a concrete structure, see Efectis-R0695, "Fire Testing Procedure for Concrete Tunnel Linings and Other Tunnel Components."

The installation of passive fire protection materials should be done with anchors having the following properties:

(1) The diameter should be limited to a maximum of 6 mm (¼ in.) to reduce the heat sink effect through the steel anchor into the concrete. Larger diameter anchors can create a spalling effect on the concrete.

(2) The use of high-grade stainless steel anchors is recommended.

(3) If necessary, a washer should be used to avoid a pull-through effect when the system is exposed to dynamic loads.

(4) The anchors should be suitable for use in the tension zone of concrete (cracked concrete).

(5) The anchors should be suitable for use under dynamic loads.

Note that ASTM E3134 has been developed with the same time-temperature curve as in the RWS report. Thus, any previous reference to the RWS curve and report can be replaced by a reference to ASTM E3134. The acceptance criteria that correspond to those in the RWS report are those involving heat transmission and no evidence of spalling. ASTM E3134 also contains the option of conducting a flame spread test on fire resistive materials potentially used on tunnel surfaces and the option of a fire resistance rating test for any joint materials being considered.

Statement of Problem and Substantiation for Public Comment

This PC adds four sentences at the end of the annex note, indicating that ASTM E3134 contains the same time-temperature curve as the RWS test and what other properties can be measured. Any other changes are due to Terra.
Note that the acceptance pf this change will require adding ASTM E3134 (Standard Specification for Transportation Tunnel Structural Components and Passive Fire Protection Systems, 2020) into the section on informative ASTM references.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 18-NFPA 502-2021 [Section No. 7.3.2]	
Public Comment No. 16-NFPA 502-2021 [Section No. O.1.2.5]	
Public Comment No. 18-NFPA 502-2021 [Section No. 7.3.2]	

Related Item

• PI8

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Committee: ROA-AAA

Public Comment No. 1-NFPA 502-2021 [Section No. D.1]

~~**D.1** – General.~~

The critical velocity can be calculated according to Equation D.1:

$$\frac{u}{\sqrt{gH}}=\begin{cases}0.81\left(\frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}}\right)^{1/3}\left(\frac{H}{W}\right)^{1/12} e^{\left(-\frac{L_b}{18.5H}\right)}, & \frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}}\leq 0.15\left(\frac{H}{W}\right)^{-1/4}\\ 0.43e^{\left(-\frac{L_b}{18.5H}\right)}, & \frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}}> 0.15\left(\frac{H}{W}\right)^{-1/4}\end{cases} \quad \text{[D.1]}$$

where:

ρ_a = ambient density (kg/m^3)

C_p = heat capacity (kJ/kg K)

g = gravitational acceleration (m/sec^2)

H = tunnel height (m)

L_b = backlayering length (m), where L_b = 0 defines critical velocity (no backlayering of smoke), and $L_b \neq 0$ defines confinement velocity (velocity corresponding to the controlled backlayering length)

T_a = ambient gas temperature (K)

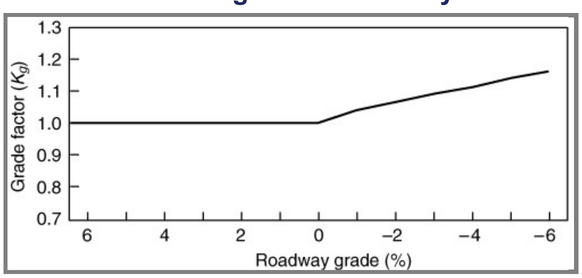
u = longitudinal velocity (m/sec)

$\dot{Q}$ = total heat release rate (HRR) (kW)

W = tunnel width (m)

The effect of the tunnel grading is obtained by multiplying the calculated critical velocity, u_c, by the grade factor, K_g, given in Figure D.1.

Figure D.1 Grade Factor for Determining Critical Velocity.



Example:

Assume a road tunnel that is 5 m in height (H) with a width (W) of 12 m. Calculate the critical velocity (L_b = 0 m) for a 30 MW heat release rate, as well as the velocity required to obtain L_b = 30 m [*see B.3(2)*]. Ambient values include: ρ_a = 1.2 kg/m^3; C_p = 1 kJ/kg K; g = 9.81 m/sec^2; T_a = 293 K; and roadway grade is 4 percent.

Solution:

First, establish which critical velocity relationship to apply by solving:

$$\frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}}\leq 0.15\left(\frac{H}{W}\right)^{-1/4} \text{ or } \frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}}> 0.15\left(\frac{H}{W}\right)^{-1/4}$$

Since $\frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}}=0.487$ is greater than $0.15\left(\frac{H}{W}\right)^{-1/4}=0.187$, the lower equation in Equation D.1 should be used.

$$\frac{u}{\sqrt{gH}} = 0.43e^{\left(-\frac{L_b}{18.5H}\right)}$$

~~Therefore, u is solved in~~ ~~with the result that u = 3.01 m/sec (592.5 fpm) where L_b = 0 m. For L_b = 30 m, the corresponding velocity is u = 2.18 m/sec (429.1 fpm).~~

~~The grade factor (K_g) according to Figure D.1 is 1.1, which means that the calculated critical velocity is 3.3 m/sec (649.6 fpm) and the corresponding velocity is 2.4 m/sec (472.4 fpm).~~

~~See further information in the following:~~

(1) ~~Li, Y. Z. and Ingason, H., "Effect of cross section on critical velocity in longitudinally ventilated tunnel fire," *Fire Safety Journal* , 91: 303–311, 2017.~~

(2) ~~Li, Y. Z., Lei, B., and Ingason, H., "Study of critical velocity and backlayering length in longitudinally ventilated tunnel fires," *Fire Safety Journal* , 45: 6–8, 361–370, 2010.~~

See committee input for updated section.

Statement of Problem and Substantiation for Public Comment

The current equations do no properly resolve critical velocity. The equations are currently being reviewed in the sub-committee.

Related Item

• Public Input #48 Confinement Velocity • Public Input #31 • Public Input #45 • Public Input #5

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Submittal Date: Sat Mar 13 08:57:56 EST 2021
Committee: ROA-AAA

Public Comment No. 21-NFPA 502-2021 [Section No. D.1]

D.1 – General.

The critical velocity can be calculated according to Equation D.1:

$$\frac{u}{\sqrt{gH}} = \begin{cases} 0.81\left(\frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}}\right)^{1/3}\left(\frac{H}{W}\right)^{1/12} e^{\left(-\frac{L_b}{18.5H}\right)}, & \frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}} \le 0.15\left(\frac{H}{W}\right)^{-1/4} \\ 0.43 e^{\left(-\frac{L_b}{18.5H}\right)}, & \frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}} > 0.15\left(\frac{H}{W}\right)^{-1/4} \end{cases} \quad \textbf{[D.1]}$$

where:

ρ_a = ambient density (kg/m ^{3})

C_p = heat capacity (kJ/kg K)

g = gravitational acceleration (m/sec ^{2})

H = tunnel height (m)

L_b = backlayering length (m), where $L_b = 0$ defines critical velocity (no backlayering of smoke), and $L_b \neq 0$ defines confinement velocity (velocity corresponding to the controlled backlayering length)

T_a = ambient gas temperature (K)

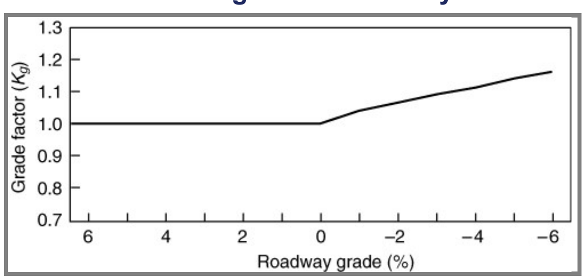
u = longitudinal velocity (m/sec)

$\dot{Q}$ = total heat release rate (HRR) (kW)

W = tunnel width (m)

The effect of the tunnel grading is obtained by multiplying the calculated critical velocity, u_c , by the grade factor, K_g , given in Figure D.1 .

Figure D.1 Grade Factor for Determining Critical Velocity.



Example:

Assume a road tunnel that is 5 m in height (H) with a width (W) of 12 m. Calculate the critical velocity (L_b = 0 m) for a 30 MW heat release rate, as well as the velocity required to obtain L_b = 30 m [*see B.3(2)*]. Ambient values include: ρ_a = 1.2 kg/m ^{3} ; C_p = 1 kJ/kg K; g = 9.81 m/sec ^{2} ; T_a = 293 K; and roadway grade is 4 percent.

Solution:

First, establish which critical velocity relationship to apply by solving:

$$\frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}} \le 0.15\left(\frac{H}{W}\right)^{-1/4} \text{ or } \frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}} > 0.15\left(\frac{H}{W}\right)^{-1/4}$$

Since $\frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}} = 0.487$ is greater than $0.15\left(\frac{H}{W}\right)^{-1/4} = 0.187$, the lower equation in Equation D.1 should be used.

~~Therefore, u is solved in~~ $$\frac{u}{\sqrt{gH}} = 0.43e^{\left(-\frac{L_b}{18.5H}\right)}$$ ~~with the result that u = 3.01 m/sec (592.5 fpm) where L_b = 0 m. For L_b = 30 m, the corresponding velocity is u = 2.18 m/sec (429.1 fpm).~~

~~The grade factor (K_g) according to Figure D.1 is 1.1, which means that the calculated critical velocity is 3.3 m/sec (649.6 fpm) and the corresponding velocity is 2.4 m/sec (472.4 fpm).~~

~~See further information in the following:Li, Y. Z. and Ingason, H., "Effect~~

Figure 1 below plots observed critical velocities from full-size fire tests and the same data adjusted to zero backlayering, and a best fit curve. It is seen from Figure 1 that 3.0 m/s is a reasonable value for critical velocity of large fires in down-grade tunnels up to 3.2% slope, but may be over-estimating critical velocity for very small fires, and lower velocities are appropriate if a tunnel has very restricted fire loads (such as a tunnel only for passenger cars).

The plot and the underlying data also do not provide for the wide range of gradients in real road tunnels. We are not aware of a reliable data set that fills in that missing information, which is the reason why the plotted data in Figure 1 are not grade-corrected. The recommended approach for tunnels with high gradients (especially >3.2%) and other aberrant tunnel characteristics right now (in the absence of a useful model) is to carry out CFD of the subject tunnel, having previously calibrated the CFD technique (including software, inputs and the analyst) against a relevant known real case. CFD methodology recommendations for analysing smoke propagation in tunnel are given in (PIARC (C5), 1999), (Karki, Patankar, Rosenbluth, & Levy, 2000) and (Kashef, Benichou, & Lougheed, 2003).

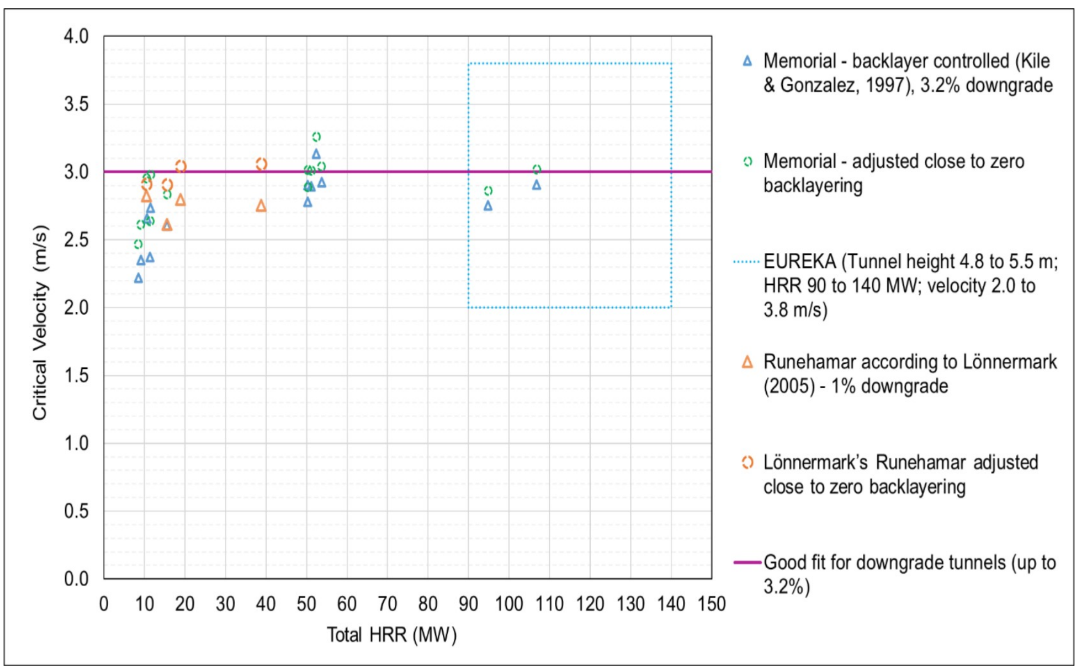


Figure 1 . Critical velocity values from full scale fire tests with an applied best fit curve. Memorial Tunnel test data are taken from (Kile & Gonzalez, 1997), Runehamar test data from (Lönnermark, 2005) and EUREKA test results are from (EUREKA 499 Report, 1995), (Ingason, 1994), (Sorlie & Mathisen, 1994) and (Steinert, 1994). Note: Unlike the Memorial Tunnel Tests, the velocity in the Runehamar tests was not varied to pinpoint the conditions where the upstream backlayering of smoke was balanced or just prevented. As also stated in (Lönnermark, 2005), the HRR in the Runehamar test were transient and no real steady state conditions were reached. Caution should also be taken in interpreting the 'adjusted' Memorial and Runehamar data as the minor backlayering correction was also done by the method of

(Li, Lei, & Ingason, 2010) *, problems with which resulted in the Annex D equations being urgently withdrawn from NFPA 502 2020. However, the corrections are minor, so in this case, the errors will be second order.*

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~~fire,"~~

fires. *Fire Safety Journal*

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~~: 303–311~~

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303-311 .

Li, Y.

~~Z.~~

, Lei, B.,

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& Ingason, H.

~~, "Study~~

(2010). Study of critical velocity and backlayering length in longitudinally ventilated tunnel fires

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Additional Proposed Changes

File Name	Description	Approved
Annex_D_public_input_20210507.pdf	Public comment following CI-48, giving background and suggested text for Annex D.1	

Statement of Problem and Substantiation for Public Comment

The Committee Input “agreed” on in the October NFPA 502 meetings was flawed in its science and in the governance that gave rise to it. In our view, it was flawed scientifically in that it attempted to use a supposed blockage effect in the Memorial Tunnel test data. The CI had the effect of maintaining the formula of Li, Lei & Ingason, by applying an inferred blockage. Our Graz conference presentation (Stacey & Beyer, 2020b) made it quite clear that the inferred blockage supporting the CI was inconsistent with clear information in the Memorial Tunnel test report (CD-ROM, http://www.tunnelfire.com/order.htm). The issues and concerns with the small-scale tests and the applied scaling method as noted in (Stacey & Beyer, 2020a), (Stacey & Beyer, 2020b), (PIARC (C5), 1999) and (Grant, Jagger, & Lea, 1998) were not addressed. No evidence has been given that simple Froude scaling is valid, or that important physical phenomena for analysing critical velocity are appropriately represented in a small (1:20 scale) tunnel.

Ingason confirmed that: (i) he believed the (Li, Lei, & Ingason, 2010) formula, and (ii) the Memorial Tunnel data in (Li, Lei, & Ingason, 2010) were “shifted” to where they expected them to be. That is, there is no dispute that the Memorial Tunnel data did not align with their formula, but were well removed from it.

Having confirmed that the agreement between Memorial Tunnel tests and the scaling formula was the result of shifting of data, Ingason was invited by the Committee to work on the Committee Input. It is extraordinary in a governance sense that an author whose work was supported by shifted data, and which by doing so made the 2020 Annex D irrelevant and embarrassing, be invited to participate in a ‘consensus process’ of drafting a new Annex D version. The Committee must recognise that such

involvement was inappropriate from the time that they had the data shifting confirmed to them. As shown (Stacey & Beyer, 2020b), the CI was only a different, unjustified shifting of the Memorial Tunnel data, and not a solution to the technical issues. A different approach is required to recover credibility for the Committee, and importantly to recover credibility for the NFPA 502 process and document.
With that background, the CI as 'agreed' in October 2020 is rejected completely. The scientific record is clear. Our original objections to the form of the equation stand (Stacey & Beyer, 2020a), (Stacey & Beyer, 2020b) and the issues have also since been explained in two articles available on the Australian Tunnelling Society website (ATS-Article Part 1: https://www.ats.org.au/2021/03/11/critical-velocity-a-cautionary-note-to-practitioners/, ATS-Article Part 2: https://www.ats.org.au/2021/05/03/critical-velocity-and-tunnel-smoke-control-part-two/). The use of a blockage ratio 'correction' as proposed in the new CI is both contradicted by the data and unrealistic to apply in any design sense (what is the cross section of that truck behind the fire?).
We proposed (Stacey & Beyer, 2020b), a value for critical velocity of 2.7 m/s (with grade correction according to (NFPA 502, 2020) and (Kennedy, 1997)) and in (Beyer, Stacey & Dix, 2021b) 3.0 m/s (for tunnel downgrade slopes up to 3.2%) as fitting most of the reliable data quite well, across a range of tunnel sizes relevant to road tunnels.
The original data must be respected. Theories and simplified trends as to why the critical velocity data are the way they are, have been used in place of real data on many occasions. Such trends may be interesting, but, there is not yet solid, accepted physics that allows a trend to be imposed onto data to deal with 'noise' in the data. To the extent that they seek to represent data within a modelling framework that is uncertain, or even unlikely, trends are less reliable than looking at the original data, with an understanding of experimental variability.

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Related Item

- CI-48

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Committee:	ROA-AAA

NFPA 502 Annex D

Public Comment

Conrad Stacey, Michael Beyer

BACKGROUND

The Committee Input "agreed" on in the October NFPA 502 meetings was flawed in its science and in the governance that gave rise to it. In our view, it was flawed scientifically in that it attempted to use a supposed blockage effect in the Memorial Tunnel test data. The CI had the effect of maintaining the formula of Li, Lei & Ingason, by applying an inferred blockage. Our Graz conference presentation (Stacey & Beyer, 2020b) made it quite clear that the inferred blockage supporting the CI was inconsistent with clear information in the Memorial Tunnel test report (CD-ROM, http://www.tunnelfire.com/order.htm). The issues and concerns with the small-scale tests and the applied scaling method as noted in (Stacey & Beyer, 2020a), (Stacey & Beyer, 2020b), (PIARC (C5), 1999) and (Grant, Jagger, & Lea, 1998) were not addressed. No evidence has been given that simple Froude scaling is valid, or that important physical phenomena for analysing critical velocity are appropriately represented in a small (1:20 scale) tunnel.

Ingason confirmed that: (i) he believed the (Li, Lei, & Ingason, 2010) formula, and (ii) the Memorial Tunnel data in (Li, Lei, & Ingason, 2010) were "shifted" to where they expected them to be. That is, there is no dispute that the Memorial Tunnel data did not align with their formula, but were well removed from it.

Having confirmed that the agreement between Memorial Tunnel tests and the scaling formula was the result of shifting of data, Ingason was invited by the Committee to work on the Committee Input. It is extraordinary in a governance sense that an author whose work was supported by shifted data, and which by doing so made the 2020 Annex D irrelevant and embarrassing, be invited to participate in a 'consensus process' of drafting a new Annex D version. The Committee must recognise that such involvement was inappropriate from the time that they had the data shifting confirmed to them. As shown (Stacey & Beyer, 2020b), the CI was only a different, unjustified shifting of the Memorial Tunnel data, and not a solution to the technical issues. A different approach is required to recover credibility for the Committee, and importantly to recover credibility for the NFPA 502 process and document.

With that background, the CI as 'agreed' in October 2020 is rejected completely. The scientific record is clear. Our original objections to the form of the equation stand (Stacey & Beyer, 2020a), (Stacey & Beyer, 2020b) and the issues have also since been explained in two articles available on the Australian Tunnelling Society website (ATS-Article Part 1: https://www.ats.org.au/2021/03/11/critical-velocity-a-cautionary-note-to-practitioners/, ATS-Article Part 2: https://www.ats.org.au/2021/05/03/critical-velocity-and-tunnel-smoke-control-part-two/). The use of a blockage ratio 'correction' as proposed in the new CI is both contradicted by the data and unrealistic to apply in any design sense (what is the cross section of that truck behind the fire?).

We proposed (Stacey & Beyer, 2020b), a value for critical velocity of 2.7 m/s (with grade correction according to (NFPA 502, 2020) and (Kennedy, 1997)) and in (Beyer, Stacey &

Dix, 2021b) 3.0 m/s (for tunnel downgrade slopes up to 3.2%) as fitting most of the reliable data quite well, across a range of tunnel sizes relevant to road tunnels.

The original data must be respected. Theories and simplified trends as to why the critical velocity data are the way they are, have been used in place of real data on many occasions. Such trends may be interesting, but, there is not yet solid, accepted physics that allows a trend to be imposed onto data to deal with ‘noise’ in the data. To the extent that they seek to represent data within a modelling framework that is uncertain, or even unlikely, trends are less reliable than looking at the original data, with an understanding of experimental variability.

The remainder of this public comment offers appropriate text for Annex D, in place of the CI.

TEXT FOR ANNEX D

Figure 1 below plots observed critical velocities from full-size fire tests and the same data adjusted to zero backlayering, and a best fit curve. It is seen from Figure 1 that 3.0 m/s is a reasonable value for critical velocity of large fires in down-grade tunnels up to 3.2% slope, but may be over-estimating critical velocity for very small fires, and lower velocities are appropriate if a tunnel has very restricted fire loads (such as a tunnel only for passenger cars).

The plot and the underlying data also do not provide for the wide range of gradients in real road tunnels. We are not aware of a reliable data set that fills in that missing information, which is the reason why the plotted data in Figure 1 are not grade-corrected. The recommended approach for tunnels with high gradients (especially >3.2%) and other aberrant tunnel characteristics right now (in the absence of a useful model) is to carry out CFD of the subject tunnel, having previously calibrated the CFD technique (including software, inputs and the analyst) against a relevant known real case. CFD methodology recommendations for analysing smoke propagation in tunnel are given in (PIARC (C5), 1999), (Karki, Patankar, Rosenbluth, & Levy, 2000) and (Kashef, Benichou, & Lougheed, 2003).

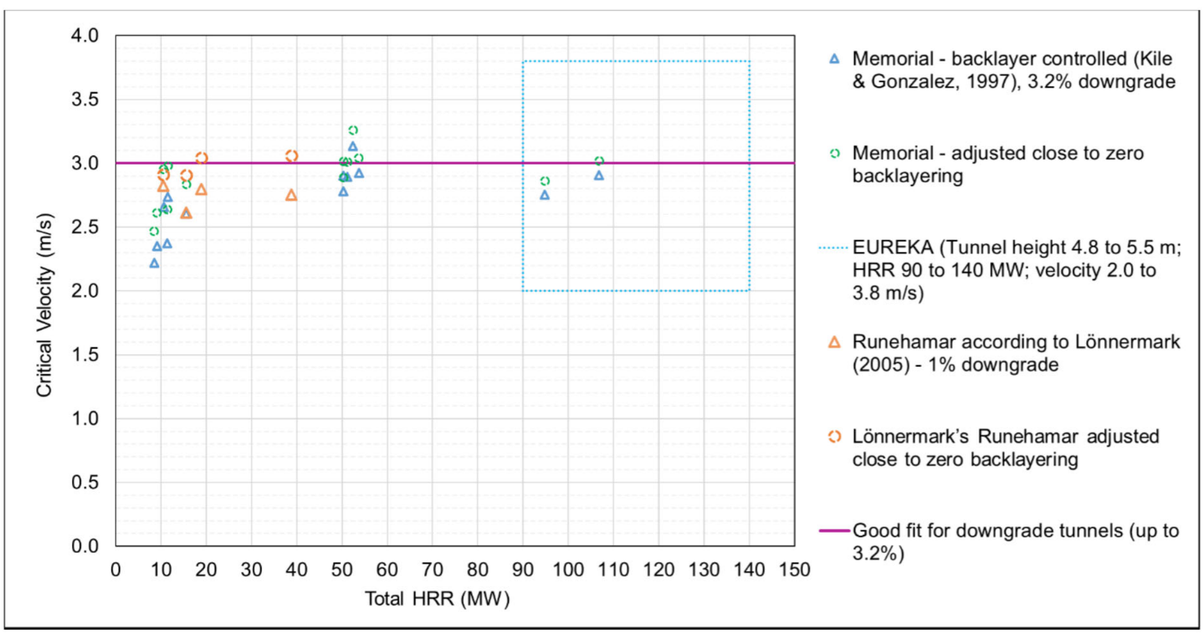

Figure 1. Critical velocity values from full scale fire tests with an applied best fit curve. Memorial Tunnel test data are taken from (Kile & Gonzalez, 1997), Runehamar test data from (Lönnermark, 2005) and EUREKA test results are from (EUREKA 499 Report, 1995), (Ingason, 1994), (Sorlie & Mathisen, 1994) and (Steinert, 1994). Note: Unlike the Memorial Tunnel Tests, the velocity in the Runehamar tests was not varied to pinpoint the conditions where the upstream backlayering of smoke was balanced or just prevented. As also stated in (Lönnermark, 2005), the HRR in the Runehamar test were transient and no real steady state conditions were reached. Caution should also be taken in interpreting the 'adjusted' Memorial and Runehamar data as the minor backlayering correction was also done by the method of (Li, Lei, & Ingason, 2010)*, problems with which resulted in the Annex D equations being urgently withdrawn from NFPA 502 2020. However, the corrections are minor, so in this case, the errors will be second order.*

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Public Comment No. 9-NFPA 502-2021 [Section No. D.1]

D.1 General.

The critical velocity can be calculated according to Equation D.1:

$$\frac{u}{\sqrt{gH}}=\begin{cases}0.81\left(\frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}}\right)^{1/3}\left(\frac{H}{W}\right)^{1/12} e^{\left(-\frac{L_b}{18.5H}\right)}, & \frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}} \le 0.15\left(\frac{H}{W}\right)^{-1/4} \\ 0.43 e^{\left(-\frac{L_b}{18.5H}\right)}, & \frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}} > 0.15\left(\frac{H}{W}\right)^{-1/4}\end{cases} \quad \text{[D.1]}$$

where:

ρ_a = ambient density (kg/m^3)

C_p = heat capacity (kJ/kg K)

g = gravitational acceleration (m/sec^2)

H = tunnel height (m)

L_b = backlayering length (m), where $L_b = 0$ defines critical velocity (no backlayering of smoke), and $L_b \neq 0$ defines confinement velocity (velocity corresponding to the controlled backlayering length)

T_a = ambient gas temperature (K)

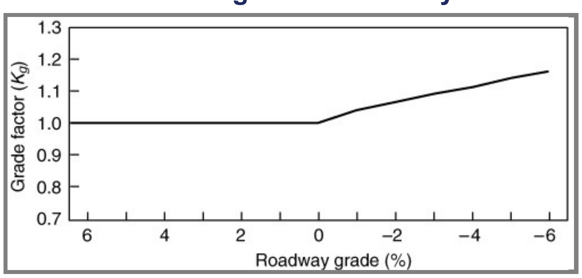
u = longitudinal velocity (m/sec)

$\dot{Q}$ = total heat release rate (HRR) (kW)

W = tunnel width (m)

The effect of the tunnel grading is obtained by multiplying the calculated critical velocity, u_c, by the grade factor, K_g, given in Figure D.1.

Figure D.1 Grade Factor for Determining Critical Velocity.



Example:

Assume a road tunnel that is 5 m in height (H) with a width (W) of 12 m. Calculate the critical velocity (L_b = 0 m) for a 30 MW heat release rate, as well as the velocity required to obtain L_b = 30 m [*see B.3(2)*]. Ambient values include: ρ_a = 1.2 kg/m^3; C_p = 1 kJ/kg K; g = 9.81 m/sec^2; T_a = 293 K; and roadway grade is 4 percent.

Solution:

First, establish which critical velocity relationship to apply by solving:

$$\frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}} \le 0.15\left(\frac{H}{W}\right)^{-1/4} \text{ or } \frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}} > 0.15\left(\frac{H}{W}\right)^{-1/4}$$

Since $\frac{\dot{Q}}{\rho_a C_p T_a g^{1/2} H^{5/2}} = 0.487$ is greater than $0.15\left(\frac{H}{W}\right)^{-1/4} = 0.187$, the lower equation in Equation D.1 should be used.

$$\frac{u}{\sqrt{gH}} = 0.43e^{\left(-\frac{L_b}{18.5H}\right)}$$

~~Therefore, *u* is solved in~~ ~~with the result that *u* = 3.01 m/sec (592.5 fpm) where L_b = 0 m. For L_b = 30 m, the corresponding velocity is *u* = 2.18 m/sec (429.1 fpm).~~

~~The grade factor (K_g) according to Figure D.1 is 1.1, which means that the calculated critical velocity is 3.3 m/sec (649.6 fpm) and the corresponding velocity is 2.4 m/sec (472.4 fpm).~~

~~See further information in the following:~~

- ~~Li, Y. Z. and Ingason, H., "Effect of cross section on critical velocity in longitudinally ventilated tunnel fire," *Fire Safety Journal* , 91: 303–311, 2017.~~

~~Li, Y. Z., Lei, B., and Ingason, H., "Study of critical velocity and backlayering length in longitudinally ventilated tunnel fires," *Fire Safety Journal* , 45: 6–8, 361–370, 2010~~

No equation is exact enough to predict the critical velocity or backlayering length perfectly in every single scenario. A number of assumptions need to be made and justified:

- Blockage ratio
- Radiative heat fraction
- Value of H (base of fire to tunnel ceiling)
- Tunnel aspect ratio

The equations show a range of behaviors, but generally (backed up by Memorial Tunnel data):

- The 2014 equation under predicts the velocity at FHRR 50 MW and less
- The 2017 equation does a reasonable job of predicting critical velocity at FHRR 50 MW and less
- The 2014 and 2017 equations predict the same critical velocity at large FHRRs (on the order 100 MW)
- The 2020 equation, when used with no blockage considerations or backlayer length allowance, will over predict critical velocity at large FHRRs

Demonstration of authority over smoke during design fire events is an alternative method for demonstration of meeting ventilation design criteria.

In lieu of any detailed analysis, critical velocity shall be defined per the NFPA 502 2017 equations, provided the following conditions are met:

- Tunnel aspect ratio is similar to a two lane tunnel
- Radiative heat fraction is 30% or less
- Tunnel height parameter, H is measured from the base of the tunnel to the highest point at the ceiling
- Blockage ratio is fully justified; and, where there is any doubt then a blockage ratio of 0 shall be used

Where the above conditions cannot be met, then a CFD model should be considered. The model shall be fully validated and the designer shall at least achieve a reasonable result (within 10%) of the critical velocity predicted using equations for a scenario where conditions for equation validity can be met.

All three prior NFPA502 critical velocity equations may be used as part of a sensitivity analysis of various inputs, and to help make a case of why the inputs used are appropriate.

Each tunnel must be assessed carefully in accordance with its unique properties and operational design objectives .

Statement of Problem and Substantiation for Public Comment

The current Annex D is problematic because it grossly overestimates ventilation requirements. The proposed text explains the value of each of the previous NFPA502 equations for assisting the designer develop and appropriate ventilation system and makes practical suggestions about how to perform a sensitivity analysis for ventilation requirements given the unique physical and operational objectives for each tunnel. The text preserves the value of previous NFPA equations as tools in the design process subject to their known limitations.

Related Item

• First Draft Report •

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Public Comment No. 26-NFPA 502-2021 [Section No. G.1]

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 compressed natural gas (CNG), compressed gas hydrogen (cGH_2), liquefied petroleum gas (LP-Gas), and liquefied natural gas (LNG) 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.

~~It should be feasible for regulators to only allow vehicles that carry an approved listing and label to travel through a road tunnel~~ Vehicles in the United States are required to meet federal standards and those that do not are not allowed to drive on roads nor within tunnels . In the short term, this is unrealistic, since the standards process is under development and there is some level of controversy as to the minimum acceptable design parameters. 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.

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, http://webbook.nist.gov/chemistry/.

[d]Source: *Alternatives to Traditional Transportation Fuels: An Overview*, DOE/EIA-0585/U.S. Energy Information Administration, U.S. 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.

Statement of Problem and Substantiation for Public Comment

The concept of “approved listed and labeled” is specific to products and is not used for vehicles. Vehicles are required to meet Federal Motor Vehicle Safety Standard, but there is no certifying agency to “approve” or “list and label” them. This statement should be deleted and replaced with the correct statement.

Related Item

- FR-36

Submitter Information Verification

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Public Comment No. 22-NFPA 502-2021 [Section No. G.2.4]

G.2.4 Hydrogen.

Hydrogen is one of the most attractive alternative fuels due to its ability to power fuel cells in vehicles, the abundant availability, and the potential 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. 2.2 lb (1 kg) of hydrogen gas has about the same energy as 1 gal (3.8 L) of gasoline. Commercially deployed hydrogen-powered vehicles employ fuel cells to convert hydrogen into electricity to power an electric motor. For a driving range of 300 miles (450 km) or more, a light-duty fuel cell vehicle must carry approximately 11 lb(5 kg) 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. Currently, the on-board storage of liquid hydrogen (LH_2) is not used in any vehicles. The on-board 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 release hydrogen either individually or they can be routed to a single vent location. The direction of hydrogen release from 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) than in the tanks. The lines are made of stainless steel compatible with hydrogen. The entire fuel system is sealed, and no relevant amount of hydrogen is released during operation or parking.

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

In comparison with 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 in 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 ~~equipmen~~ equipment (classified electrical systems). Proper ventilation is important to dilute released, unburned H_2 below critical values. For ventilation requirements see ASHRAE Standard 217-2020 "Non-Emergency Ventilation in Enclosed Road, Rail, and Mass Transit Facilities".

Emergency response to an incident involving hydrogen fuel leak or fire requires necessary training, such as recognizing the hydrogen tank, high-voltage battery, or capacitor pack that might be present on the 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. See the following sites for information on emergency response and emergency response training for FCEVs:

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

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

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

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

Statement of Problem and Substantiation for Public Comment

New ANSI/ASHRAE Standard 217-2020 "Non-Emergency Ventilation in Enclosed Road, Rail, and

Mass Transit Facilities" provides requirements for road tunnel ventilation under non-emergency conditions and should be referenced for proper guidelines. The revised text supplements Public Input #25 providing proper reference.

Related Item

- FR-37; FR-59

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Public Comment No. 27-NFPA 502-2021 [Section No. G.2.4]

G.2.4 Hydrogen.

Hydrogen is one of the most attractive alternative fuels due to its ability to power fuel cells in vehicles, the abundant availability, and the potential 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. 2.2 lb (1 kg) of hydrogen gas has about the same energy as 1 gal (3.8 L) of gasoline. Commercially deployed hydrogen-powered vehicles employ fuel cells to convert hydrogen into electricity to power an electric motor. For a driving range of 300 miles (450 km) or more, a light-duty fuel cell vehicle must carry approximately 11 lb(5 kg) 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.

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

In comparison with 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 in 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 ~~equipmen~~ equipment (classified electrical systems). Proper ventilation is important to dilute released, unburned H_2 below critical values.

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

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

Statement of Problem and Substantiation for Public Comment

Editorial correction.

Related Item

- FR-37

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Committee:	ROA-AAA

Public Comment No. 28-NFPA 502-2021 [Section No. G.3]

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 tunnel or lower level of a dual-level bridge 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 roof 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 which address these issues, and NFPA has an active database of these guides. (https://nfpa.org/Training-and-Events/By-topic/Alternative-Fuel-Vehicle-Safety-Training/Emergency-Response-Guides). This is 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. Typically emergency responders undergo specialist training on how to identify specific alternative fuel vehicles and the most appropriate strategies to deal with them in an emergency. As a consequence, if a particular fuel is prevented 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 type. 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 upon 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 the facility 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. High voltage potential in electric vehicles should be recognized. Therefore, emergency response personnel should be provided with training specific to each alternative-fuel vehicle. In addition, the first responder 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 a direct ignition, creating a gas cloud that potentially could later be ignited. The priority of emergency responders should be extinguishing the fire, cooling the fuel containment vessels, and not extinguishing any jet if present. The focus of the emergency response should be to do so in a safe and efficient way.

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

Typically, the pressure release valves are protected against exposure to water during normal operations and thereby create an opportunity for appropriate emergency intervention by emergency responders trained in responding to vehicles involved in incidents that use pressure relief valves.

The facility 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 the 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 the 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.

Statement of Problem and Substantiation for Public Comment

The additional sentence and link provides valuable information on where information for each type of alternative vehicle can be found. Emergency Response Guides are known by the first responder community, as the most reliable up-to-date form of information on how to react to any vehicle, including those which use alternative fuels, in an accident.

Related Item

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O.1.2.5 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.

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*, ~~2017~~ 2020 .

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.

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

Statement of Problem and Substantiation for Public Comment

update
Also, ASTM E3134 is being added, because of an associated PC.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 19-NFPA 502-2021 [Section No. A.7.3.2]	

Related Item

- fr2

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