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NFPA 502: A REPORT ON STANDARD UPDATES AND ACTIVITY

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ABSTRACT

The NFPA 502 Standard provides fire protection and fire life safety requirements for limited access highways, road tunnels, bridges, elevated higheays, depressed highways, and roadways that are located beneath air-right structures. The NFPA 502 three year cycle is closing and the next edition of the standard will be published in September, 2022.

The revisions to the Standard are nearly finalized, so this paper will impart an understanding of what the key changes are. The subjects addressed in the revision cycle include these:

1. Updates to the Critical Velocity Calculations Annex;
2. Changes to criteria from prevention of backlayer to control of backlayer;
3. Updates to the Autonomous Vehicles Annex;
4. Updates to the Alternative Fuels Annex;
5. Application of NFPA 72 (Fire Alarms);
6. Updates to the Tunnel Categories;
7. Structural fire protection.

Keywords: NFPA 502; Critical Velocity; Autonomous Vehicles; Alternative Fuels; Fire Protection.

1. INTRODUCTION

The 2023 Edition of NFPA 502 will be issued around September 2022. This issuance is the culmination of a lengthy process that all NFPA documents must traverse, see Figure 1. The NFPA 502 Standard received 57 Public Inputs for review and revision.

The process broadly follows four steps:

1. **Input stage:** There is a 9-month public input period for proposed revisions to a standard. This period begins almost immediately after the new NFPA Edition is published. Typically, this is from October to June. Comments must be entered via the NFPA website and anyone can participate. After closing, the First Draft meeting takes place where each comment is discussed in detail. After an official on-line balloting process, the results of the First Draft Process are posted on the NFPA website and are available for additional comments.
2. **Step 2:** This step begins with a time period to submit comments to the First Draft responses. Once comments are received, each comment is discussed in detail at the Second Draft meeting. After an official on-line balloting process, the results of the Second Draft Process are posted on the NFPA website. At this point, if a comment proponent still disagrees with the outcome of the process, a NITMAM (Notice of Intent to Make a Motion) may be submitted. Once certified, NITMAMs are dealt with in Step 3. If no public comments are received, there is not a second revision by the committee and the NITMAM process does not occur.
3. **Step 3:** NITMAM's are resolved at the annual NFPA Technical Meeting. This represents the last opportunity for changes to the Standard.

4. **Step 4:** The NFPA Council meets and the Standard is issued.

The four steps are a 3-year process that allows public input and comment with an appropriate review provided by the Standard Committee. The process is a consensus approach where changes are enacted upon a majority vote, in this case, on the NFPA 502 Committee.

For this cycle, the meetings occurred via conference call, due to the COVID-19 isolation measures taken by most countries. The meetings were held in October 2020 and October 2021. Preparation for these meetings was done by sub-committees which did a preliminary review of comments and recommended a path forward. These recommendations were then discussed at the technical meetings.

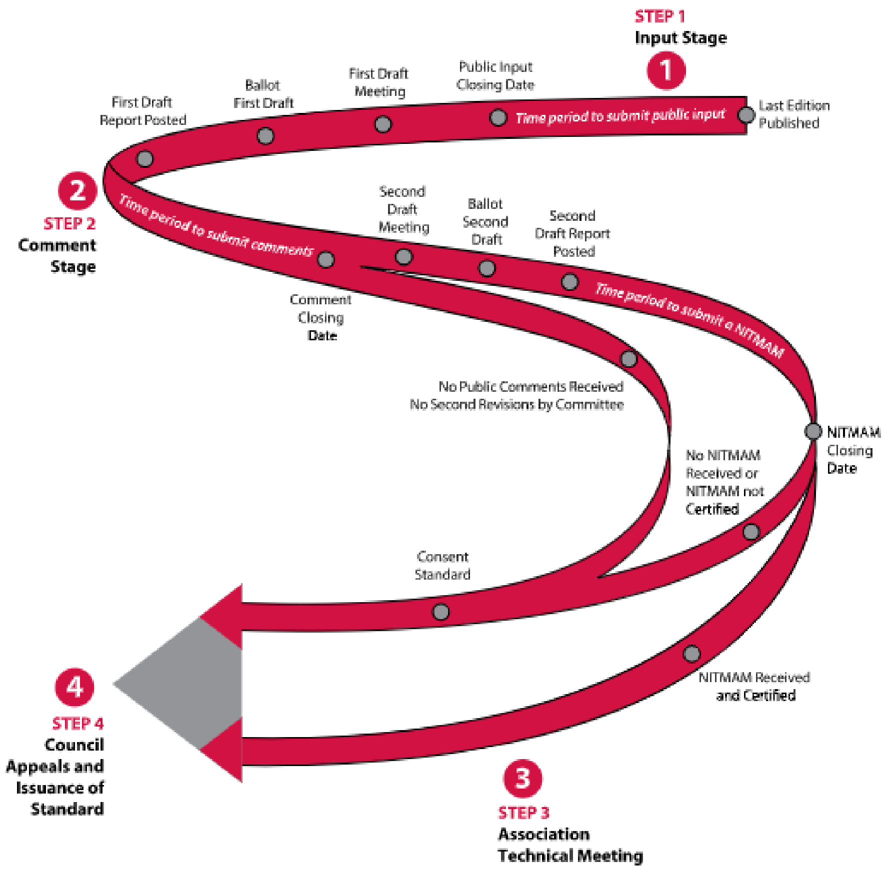

Figure 1: The NFPA standards development process [1]

The process is now coming to a close and the changes to NFPA 502 will be finalized in June at the Annual meeting. The key changes follow:

2. CHANGES TO NFPA 502

2.1. Annex D: Critical Velocity Calculations

The Critical Velocity Calculations Annex received a complete revision as the result of public comments and inputs. A Tentative Interim Amendment (TIA) was processed by the Technical Committee on Road Tunnel and Highway Fire Protection, and was issued by the Standards Council on August 26, 2021, with an effective date of September 15, 2021[2]. The TIA effectively removed the 2020 critical velocity equations from the Standard. To fill the void, new annex material was established by the committee via the extensive efforts of a sub-committee.

The new Annex D provided critical velocity calculation methods from the NFPA 502 2014 edition and the 2017 edition. The only difference between the two equations is the introduction of the variable critical Froude number factors in the 2017 edition which is dependent on the convective Fire Heat Release Rate (FHRR). The annex recognizes that both equations have their advantages and limitations. Both equations are compared with the Memorial Tunnel Fire Ventilation Test Program (MTFVTP) [3] data as shown in Figure 2. The intent is to allow the reader to make an informed decision about which equation to use.

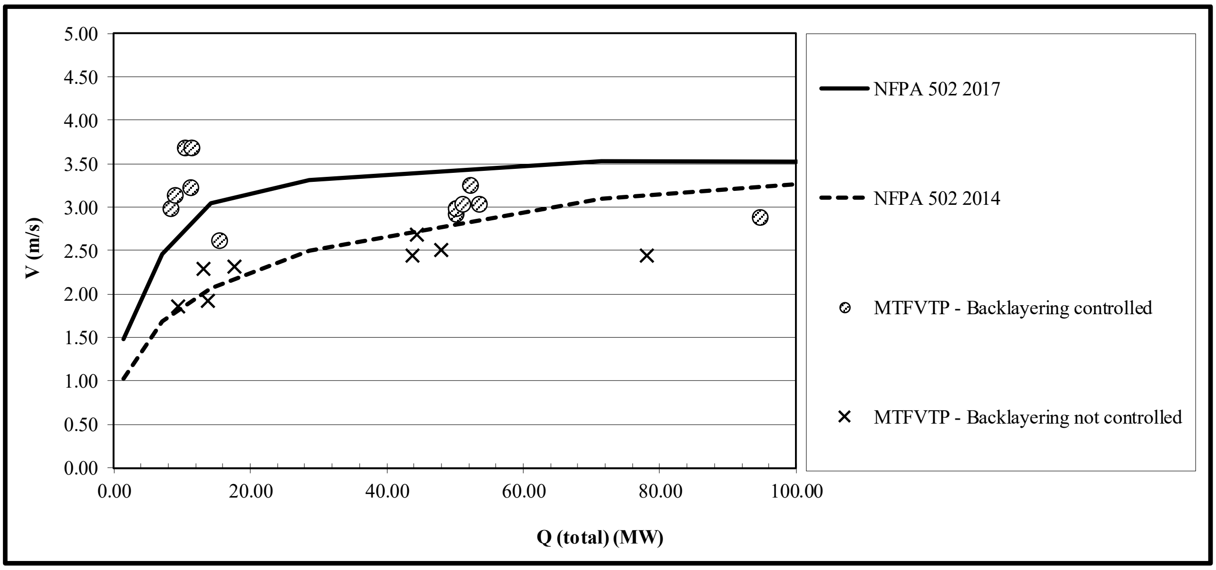

Figure 2: Critical velocity equation from NFPA 502 2014 and 2017 versus MTFVTP

Furthermore, the limitations of each equation are documented:

1. Both the 2014 and the 2017 equations are limited to the tunnel aspect ratio being similar to a two-lane tunnel (width to height on the order of 1 to 2 with a typical lane being 3.5 meters wide). For very wide road tunnels, the equations should be solved for velocity (not flow rate) as though the tunnel were two lanes wide [4].
2. The 2014 equations assume that the fire must be sufficiently wide and high such that no air can move past the fire without cooling it. (The fire plume and incoming airflow are well mixed, known as the complete mixing assumption). The equations use a constant critical Froude number factor equal to 0.606.
3. With the variable critical Froude number factors in the 2017 equations, different mixing conditions between the incoming airflow and the fire plume are better captured. However, the critical Froude number factors are based on small-scale tests and are still subject to uncertainty, and can only provide an indicative prediction of the critical velocity.

Recognizing that both equations are imperfect and that various parameters affect the critical velocity — including but not limited to tunnel geometry, design fire, tunnel blockage ratio, and tunnel wall and ceiling heat transfer — the annex acknowledges several other forms of smoke control equations exist that this is an area of active research and discussion in the industry.

The annex also introduced the term “confinement velocity” to recognize the possibility of achieving a tenable environment by controlling smoke backlayering especially during a fire incident with a relatively high FHRR. The confinement velocity is defined as the minimum steady-state velocity of the ventilation airflow moving toward the fire, within a tunnel or passageway, that is required to achieve steady-state smoke backlayer control. This is a significant change as critical velocity does not allow any backlayer by definition. To achieve the confinement velocity, it is recommended to follow Section B.3(2) on the zone of tenability. An equation to calculate the confinement velocity is not provided, instead the annex recognizes the performance-based tunnel fire safety design methods involving computational fluid dynamics (CFD). It also urges engineers to use industry best practices for CFD.

2.2. Confinement Velocity

The update to Annex D has shifted the previous view on smoke management from strictly preventing smoke backlayering to controlling smoke backlayering while concentrating on providing tenable environment. To execute the implementation, multiple updates are made within the Standard:

- The term confinement velocity is introduced in Section 3.3.14, meaning the steady-state velocity of the longitudinal ventilation airflow moving towards the fire, within a tunnel or passageway that controls the backlayering distance. It co-exists alongside the definition of critical velocity.
- Sections 11.2.1, 11.2.3, 11.2.4 and 11.3 add an emphasis on providing or maintaining a tenable environment as the key objective.
- Annex A.11.2.4, A.11.4.2 and C.3.3 update the word "prevent" to "control" when applied to smoke backlayering.
- The illustrations in annex A.3.3.5 are updated to reflect the inclusion of confinement velocity and to provide a visual comparison with the critical velocity as shown in Figure 3:

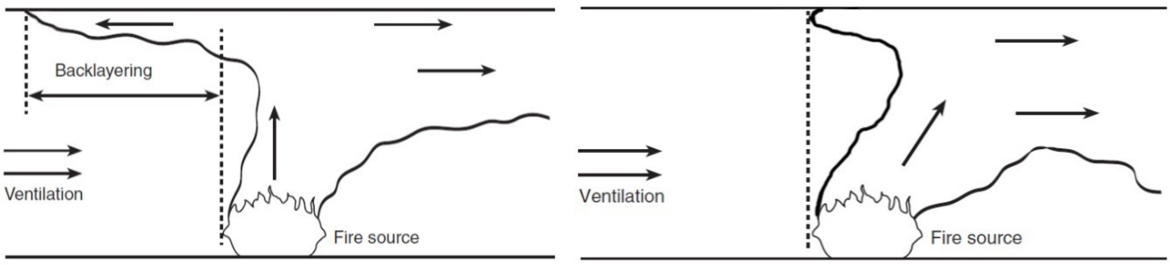

Figure 3 confinement velocity (left) vs. critical velocity (right)

2.3. Annex G: Alternative Fuels

Alternative fuels are advancing in the global automotive community. As a result, extensive editing was incorporated into the Alternative Fuels annex as the result of 9 of the 57 public inputs on this subject. The result was a significantly edited annex.

In summary the edits to the document are as follows (not inclusive):

In section G.2.1, additional information regarding compressed natural gas (CNG) storage was added. This information informs the reader about Standard FMVSS 304 "Compressed Natural Gas Fuel Container Integrity" and ANSI NGV2 "American National Standard for Natural Gas Vehicle Containers". A brief summary about full-scale testing of storage containers, pressure relief devices (PRDs), and other testing required by the Standard was provided.

In the section on hydrogen fuel, G.2.4, additional information was provided on the storage tanks and the hydrogen process in vehicles. It was noted that medium- and heavy-duty gaseous hydrogen vehicles are in their demonstration phase.

In section G.2.5, information was provided on battery electric vehicles (BEV). Many of the hazards were described which include thermal runaway and hazards deriving from lithium-ion smoke such as hazards from heavy metals and hydrogen flourides. The corrosive nature is also noted as the smoke can attack concrete and steel structures. Currently there is limited data on BEV fires.

Section G.2.5 on hybrid electric vehicles (HEV) was included to suggest that the risks from these vehicles is less than that of vehicles solely powered by batteries, as the battery bank is much smaller.

2.4. Application of NFPA 72 (Fire Alarms)

Typically, US codes and standards push for fire alarms and fire protection systems to be completely independent of the normal operation of supervisory control and data acquisition (SCADA) and building management systems. Underwriter Laboratories (UL) listing of these systems is based on an independent fire management system operating the tunnel fire protection systems. However, almost all tunnel systems are used for both normal and emergency operations which in many cases invalidates the UL listing for components. The changes in NFPA 502 are intended to address this issue which is US code related.

The Standard now allows the fire alarm control panel (FACP) to interface with the SCADA for the purpose of reporting alarms, but also requires a minimum safety integrity level (SIL) of SIL-2 for the SCADA system in accordance with IEC 61508 “Standard for Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems.”

2.5. Passive Fire Protection

Passive fire protection in road tunnels has for many years referenced the time-temperature curve developed by the Dutch Ministry of Transport (Rijkwaterstaat, RWS) and the Netherlands Organisation for Applied Scientific Research (TNO) from a series of tests done in the 1970s and later verified by the Runehamar tunnel tests done by the UPTUN project in Norway in 2003.

The RWS curve has been included for a number of editions in the Standard as a performance requirement in Clause 7.3.2, which also allows use of another time-temperature curve “acceptable to the AHJ.” Related informational material has also been included in Annex A.7.3.2.

Since publication of the current edition of the Standard, a new edition of a test standard has been published, ASTM E3134, Standard Specification for Transportation Tunnel Structural Components and Passive Fire Protection Systems **Fehler! Verweisquelle konnte nicht gefunden werden.**. This standard now incorporates a time-temperature curve similar to the RWS curve. It also contains an option of conducting a surface burning test on fire-resistive materials potentially used on tunnel surfaces and a fire-resistance rating test on any joint materials being considered.

Consequently, it was decided to add a reference to this newly revised standard in Annex A.7.3.2.

Section 9.4.4.2 now also permits a fixed water-based firefighting system to be an alternative to, or an augmentation of, passive fire protection.

2.6. Tunnel Categories

The classification of tunnel by length was revised. In the previous edition of the Standard, tunnels were classified by length into five Categories (X, A, B, C, D) in Clause 7.2, with Annex material in A.7.2, Table A.7.2, Figure A.7.2

The Category B tunnel was defined by length (240m / 800ft) qualified by distance to a “point of safety” (120m / 400ft). The stated maximum distance to a “point of safety” is not a prescribed requirement of the Standard, nor is it consistent with the requirement for maximum spacing between exits (300m / 1000ft) prescribed within the Standard.

Consequently, it was decided to revise the categorisation by deletion of the previous Category B, and to thus rename the two subsequent Categories i.e. C becomes B and D becomes C. There will now be four Categories (X, A, B, C). The differences are summarised in a comparison of the current Figure A.7.2 in the 2020 Edition (Figure 4) and a draft of Figure A.7.2 as it will appear in the 2023 Edition (Figure 5).

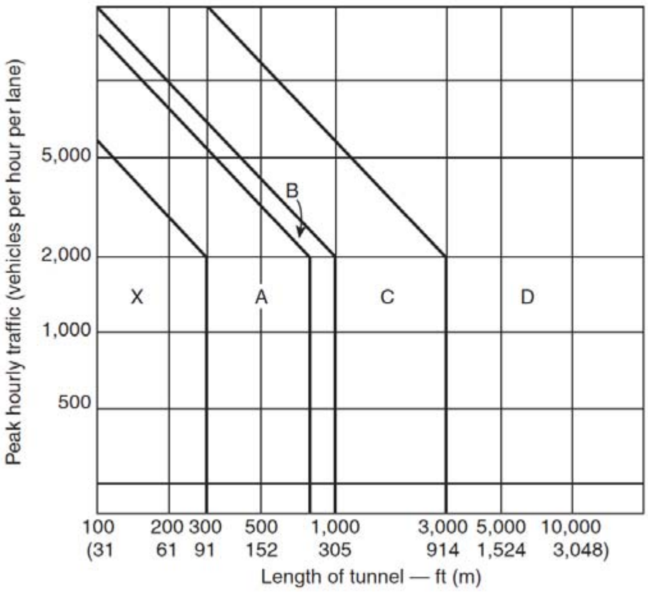

Figure 4. Figure A.7.2 NFPA 502, 2020 Edition

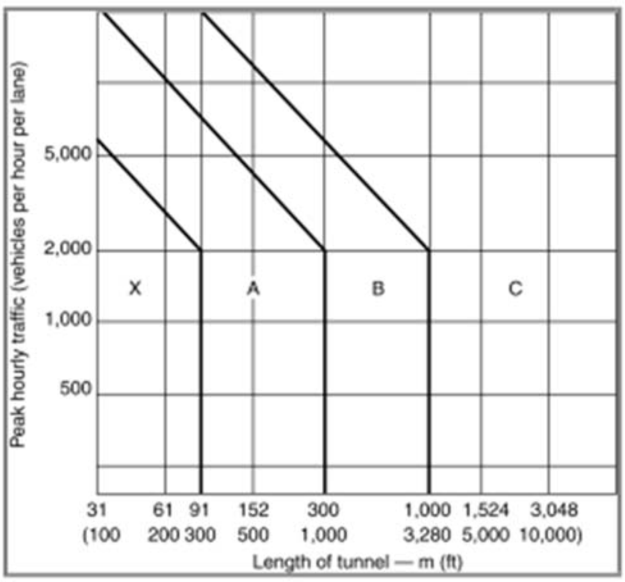

Figure 5. Draft Figure A.7.2 NFPA 502, 2023 Edition

The Reference Guide table (Table A.7.2) and Figure A.7.2 in the Annex were also reviewed and edited for consistency with the revised definitions, considering the increase of 60m (200ft) for tunnels that previously were classified as Category B.

With reference to Table A.7.2 of the Standard, noting that as Annex material this table is provided for information only, for items that were decreased in stringency from Mandatory Requirement (MR) to Conditionally Mandatory Requirement (CMR), it was decided that the minor length increase does not warrant maintaining these items as MR. One example is the increase in fires reported by cell phone, which could negate the need for mandatory installation of automatic fire detection.

For items that were retained in stringency at CMR, the length increase was not expected to have a material impact on risk for these items, however that could be confirmed via engineering analysis as required by Clause 4.3.1.

For items that were increased in stringency from "-" ("dash" i.e. no requirement) to CMR, it was decided that the length increase could have an impact on risks for these items, to be confirmed through the engineering analysis required by Clause 4.3.1.

2.7. Annex N: Autonomous Vehicles

In light of the increasing use of semi-autonomous vehicles on road networks globally and the presumption that autonomous vehicles may soon also become a reality, the current edition of the Standard introduced an Annex N providing background information on autonomous vehicles.

For the next edition, this Annex was revised to account for recent developments in the area.

Table N.2 was revised to update the SAE autonomous vehicles (AV) definitions to the latest used in SAE J3016, "Taxonomy and Definitions for Terms Related to Automated Driving Systems for On-Road Motor Vehicles" **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Terminology used in describing AV systems was updated. For example, since publication of the current edition of the Standard, the term V2X (vehicle-to-everything) has entered usage as a generic term to describe wireless communications between connected vehicles and other similar vehicles and infrastructure. V2X encompasses V2V (vehicle-to-vehicle), V2I (vehicle-to-infrastructure), and V2N (vehicle-to-network).

Other tests were revised to account for the current regulatory environment for AVs. For example, within the United States some local, state and federal agencies have authorized designated trial testing grounds for demonstration and development of AV technology for automobiles, buses and heavy goods vehicles (HGV).

The description of platooning in Section N.5 was updated to highlight new developments. Platooning is the synchronized movement of multiple AVs with minimal separation distances, such that the vehicles are separated by much smaller distances than is usual with driver-operated vehicles. Platooning of HGVs is attractive to the trucking and freight industry. However, its application within facilities addressed by NFPA 502 has potential implications for, among other things, the range of fire emergencies, design fire size, emergency response time and fire protection features. This places additional emphasis on the engineering analysis requirements in Section 4.3. Particular emphasis should be given to the type of facility, since platooning could have significant impacts previously not considered for bridges and limited-access highways.

3. SUMMARY AND CONCLUSION

The updates to the NFPA 502 Standard were extensive and many hours of time were spent considering and debating the resulting changes. The Standard is improved as a result.

There is always room for improvement. This is one of the reasons that the NFPA process updates the Standard every three years. End users are encouraged to submit recommended changes to the NFPA website during the open comment period. These comments should be concise, measurable, and enforceable.

At the time of publication, the information contained herein represents the views and opinions of the authors and is not the official opinion of NFPA. The official stance of NFPA will be published in the third quarter of this year.

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