

Application of NFPA 130 to low-floor vehicles

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INTRODUCTION

The Low-floor Vehicle Paradigm Shift

The advent of modern-era low-floor vehicles represented a paradigm shift in light rail vehicle design, providing a fundamentally new approach to passenger accessibility and ease of use. Debuting in Europe in 1984ⁱ, low-floor vehicles have since become the defacto standard for new light rail / streetcar / tramway systems throughout the world. The first US low-floor vehicles entered service in 1997ⁱⁱ. Since that time, the US has also experienced a resurgence of new surface-only streetcar systems, virtually all of which use low-floor vehicles. The use of low-floor vehicles in the U.S. is therefore expected to significantly increase in the coming decades.

Relevant to the discussion of fire life safety, low-floor vehicles are characterized by at least three significant differences from their high-floor predecessors:

1. Virtually all of the electrical power equipment is located on the vehicle roof instead of under the floor. Other than the running gear (primarily traction motors and gearboxes), couplers and a few ancillary devices, there is almost no electrical equipment under the vehicle floor (Figure 2). Further, the almost universal use of AC traction motors (which have no brushes or commutators to flash over) and roller bearings, has virtually eliminated any source of excessive heat or flame which might potentially lead to a fire under the vehicle.
2. Significantly improved passenger access; large number of wide doors with easy emergency egress, lower floor height in the majority of the passenger compartment - 14 inches (355 mm) or less, enabling passengers to exit vehicles quickly and directly to track level without additional assistance if necessary in an emergency situation (Figure 1).
3. In many cases, operation in tunnels or on elevated guideways is limited or non-existent. This is particularly true of streetcar systems.



Figure 1: Representative low-floor streetcar, illustrating relative ease of passenger egress.



Figure 2: Underbody view of a typical low-floor streetcar, illustrating the lack of underbody equipment other than running gear.

North American Standard

Rail transit vehicle procurements in the United States routinely specify compliance with NFPA 130 “Standard for Fixed Guideway Transit and Passenger Rail Systemsⁱⁱⁱ”. NFPA 130 is also cited in some Canadian transit car procurements. The first edition of NFPA 130 was published in 1983, while the North American Light Rail mode was still in its infancy. Developed in response to a need for standardizing fire life safety requirements (primarily for the subway operating environment which covered the largest number of rail vehicles then in use in the U.S.), NFPA 130 has been routinely updated every four years since the 1983 edition, with the latest edition published in August 2013 (NFPA 130, 2014 Edition).

The use of NFPA 130 offers a comprehensive approach to fire life safety for transit and rail passenger operations covering stations, trainways, tunnel ventilation, vehicles, emergency procedures and communications.

European standard

Railcar procurements in other parts of the world are subject to other fire life safety standards. Most notably, EN 45545:2013^{iv} is currently being implemented to provide a common fire life safety standard across Europe in place of a number of separate national standards. In a significant point of contrast, the vehicle requirements of NFPA 130 are broadly applicable to “all new passenger-carrying vehicles”, whereas EN 45545 and predecessor national standards use a system of operating categories that correlate to the risk associated with the operating environment. In the European standards, Streetcars (tramways) are in a separate category for vehicles that operate primarily on the surface and are readily evacuated. It is noted that both of these approaches have their proponents.

PROBLEM STATEMENT AND INDUSTRY SURVEY

The use of differing standards in North America and Europe is particularly significant in the discussion of low-floor light rail and streetcar vehicles due to the global nature of the vehicle supply industry. As a point of reference, as of 2012, more than 8,000 low-floor vehicles had been ordered in the almost three decades since the advent of modern-era low-floor technology. At that time, there were 1,045 low-floor vehicles in service or on order in the U.S., representing a modest 13 percent of world production of low-floor rail vehicles. In general, the

designs originate in Europe or Japan and are adapted for use in the North America.

In 2013, a working group comprised of members from several APTA rail transit subcommittees was formed to look into whether specifying NFPA-130 for low-floor vehicles (without additional guidance) might have unintended consequences such as increased vehicle weight, increased testing, capital and operating costs, or even other safety issues (e.g. impact on stopping distance). The group prepared a problem statement and performed a short survey of carbuilders in order to try and quantify the potential impacts of applying the standard to this type of vehicle. The carbuilders were asked the following questions:

1. What fire safety standards do your current low floor vehicle product lines meet?
2. What are the most significant differences between the requirements of NFPA-130 and other standards which you are required to meet in the global marketplace?
3. In cases of vehicles originally designed to fire safety standards other than NFPA-130, what changes were (or would be) required to comply with NFPA-130?
4. How have (or would) these changes impact vehicle weight and other systems?
5. How have (or would) these changes impact capital and life cycle costs?
6. Do you have suggestions for any guidance / exceptions that could be added to NFPA-130 that would provide relief without compromising safety? (e.g. allowing consideration of the operating environment in determining the time duration for the floor and roof burn-through tests)
7. How would receiving this relief translate into value for the purchaser of the vehicle?

Three issues mentioned by multiple carbuilders were fire barrier testing for floors and roof, and the lack of operating classifications in NFPA 130.

FIRE BARRIER TESTING

A number of the carbuilders commented that the floor and roof assemblies originally designed to meet European standards require modifications or a redesign to meet the current edition of NFPA 130, specifically the newer 30 minutes minimum for the ASTM E 119 burn-

through test for the floor and roof (see column 1 of Table 1). Compliant designs can also be heavier, resulting in potential ripple effects to other vehicle subsystems, as well as increased energy and maintenance costs for the life of the vehicle.

Explanation and History of Requirement

The current and past fire performance requirements from the 2014, 2010, 2007, and 2003 editions of NFPA 130 are shown in Table 1.

The current and previous editions of NFPA 130 (2014 and 2010) require an “absolute minimum” of 30-minutes for the roof and floor assembly fire performance tests in accordance with ASTM E 119. Absolute minimum is defined as the minimum period of time required for the test to be performed and passed. This requirement must be further increased if warranted by a longer evacuation times.

The 2007 Edition of NFPA 130 required a lower absolute minimum of 15 minutes^v. The current text in the 2014 edition is based on two proposed changes to the 2007 edition^{vi}. The first proposed change (130-130 Log#31) does not justify the increase in duration from 15 minutes to 30 minutes. Instead, “Committee Statement” states the change was to improve clarity. The only new requirement was for test sample support.

The second proposal (130-131 Log #75) to increase the duration from 15 minutes to 30 gives a substantiation that, "Rating floors for 30 minutes could reduce construction costs." The construction costs are referring to infrastructure. This is based on a correlation of the floor burn-through time and cross-passage spacing^{vii}. This requirement may be appropriate for high-floor rail vehicles in subway tunnels, but is not applicable to low-floor vehicles operating on surface-only systems.

The 2003 Edition and all previous editions of NFPA 130 also required 15 minutes, with additional language in the 2003 edition providing flexibility in applying this requirement to “equipment carrying portions of a vehicle’s roof and interior floors separating the lower level of a bi-level car”.

CORRELATION TO THE OPERATING ENVIRONMENT

Explanation of Correlation

Enclosure and evacuation are the two key operating environment factors affecting the level of fire life safety risk.

Enclosure

An enclosed system has more risk than an open system. An enclosed system, such as a subway tunnel, traps smoke and heat generated by a fire and creates an unsafe environment for passengers, operating crew and rescue personnel. In an open system located at the surface or elevated, smoke and heat can be released to the ambient environment and the fire therefore affects a smaller area.

Evacuation

A system with limited evacuation abilities is riskier. A ready evacuation capability enables passengers to quickly escape from an unsafe environment. In underground tunnels, egress is typically limited by the width of the safety walkway. For surface systems, passengers are more likely to be able to quickly escape an unsafe environment, generally without limitations.

The overall risk of an elevated system is generally somewhere in between an underground and surface system. Evacuation abilities in an elevated system may be the same as a tunnel. On the other hand, the lack of an enclosure is similar to a surface system. Therefore, the evacuation may be slower but the fire affects a smaller area.

Correlation of NFPA 130 Vehicle Requirements

Four of the six carbuilders surveyed noted the lack of operating categories for vehicles. Some components of the Vehicles chapter in NFPA-130 do relate to the system operating environment, but further correlation between operating environment and vehicle requirements could potentially make the application of the standard more universal.

The infrastructure requirements in NFPA 130 correlate to the operating environment. For instance, Chapter 5 - Stations requirements correlate to shelter stops (See first reference in 1.1.3 (6)), open stations, and enclosed stations. Chapter 6 – Trainways requirements correlate to underground, surface, and elevated sections. Chapter 7 – Ventilation requirements correlate to the length of tunnel.

In contrast, most vehicle requirements (in Chapter 8) do not explicitly correlate to the operating environment, although there are some exceptions. For example, combustible roofs need to meet requirements only if the vehicle operates in a tunnel (8.5.1.2.2). Other requirements correlate to evacuation time: Vehicle Sides and Ends (8.5.2) and Floor Assembly (8.5.1.3.2 (1)).

CONCLUSIONS

Possible Solutions

Use of NFPA-130 is well accepted among agencies procuring rail transit vehicles in North America. Other than the issue raised in this paper about the potential unintended consequences of using a 30-minute minimum duration for the floor and roof burn-through tests, the other content in Chapter 8 is well-established and did not receive major attention in the carbuilder survey responses.

In absence of explicit correlation, the vehicle requirements in Chapter 8 are appropriate for a high-risk operating environment, an enclosed system with limited egress abilities (such as a subway). The fire barrier requirements may not, however, be appropriate for surface-only streetcar systems, and may necessitate unwarranted changes to service-proven designs and increased vehicle weight, potentially increasing vehicle first cost as well as long-term operating and maintenance costs.

A number of possible strategies could be employed to better correlate NFPA-130 with the streetcar operating environment. In all cases, the time required to stop the car and evacuate the passengers would still be a fundamental basis.

1. **Introduce Operating Categories:** Chapter 8 could be changed to increase the correlation to operating environment using categorization, as in the European standards. The lowest risk categories could correlate to surface-only operations with unimpeded evacuation from most doors along the trainway (typical for streetcar). In this environment, passengers can quickly evacuate from a dangerous situation.

If categories were introduced, clarity would be required on the issue of vehicles that might potentially be used in multiple categories, either initially or during system expansion. EN 45545 addresses this by requiring that a vehicle operating in more than one operation category, or changing its service, “fulfill the requirements of all the relevant operation categories”

2. **Exception by vehicle type:** Change the text to require a 15-minute absolute minimum for low-floor vehicles operating on surface-only

alignments. The text currently allows an absolute minimum of 15 minutes for automated guideway vehicles, for example.

Explanatory language: Add text in Annex A that gives guidance on applying the fire performance tests to low-floor vehicles operating on surface-only alignments, defining a methodology for correlating operating environment to the absolute minimum test time. Guidance could also be provided on a standardized methodology for calculating vehicle evacuation time.

Next Steps / Further Research

At the time of this paper’s completion in June 2014, APTA is working with NFPA to determine the most appropriate method for conducting any further research that may be required, and the development of a proposal to change or supplement NFPA 130 to address the issue of floor and roof burn-through testing for low-floor vehicles. Topics to be addressed include:

- An accepted definition for a new low risk category (that correlates to a typical “streetcar” system), potentially based on existing definitions utilized in other US and international standards.
- Further research to fully understand the implications of the new EN 45545, which will now become the “new normal” for vehicles sold to the European market. As noted, this is particularly relevant to low-floor vehicle designs, the majority of which originate in the European market. The survey described in this paper asked the carbuilders to compare the requirements of NFPA 130 to their “existing designs”, but did not specifically address comparison of the requirements to those of EN 45545.
- Development of a standard methodology for calculating evacuation time for low-floor vehicles.
- Hazards associated with onboard energy storage, an increasing trend in streetcar / light rail / tramway vehicles.

Development of this material can take place as part of the ongoing industry dialogue on this topic and will provide a useful resource for agencies procuring electrically-propelled low-floor vehicles.

Table 1. Fire barrier requirements for NFPA 130

2014 and 2010 Editions	2007 Edition	2003 Edition
<p>8.5.1.1 Floor Assembly. All vehicle floor assemblies shall be tested as specified in 8.5.1.3.</p> <p>...</p> <p>8.5.1.2 Roof Assembly.</p> <p>8.5.1.2.1 Vehicles that contain propulsion equipment or equipment that operates at voltages higher than 600 V on the roof shall demonstrate roof assembly fire resistance testing as specified in 8.5.1.3.</p> <p>8.5.1.2.2 Vehicles that travel through tunnels and have a roof that is constructed of a combustible material shall require a fire hazard analysis to demonstrate that rapid fire spread to passenger and crew compartments or local roof collapse is not possible during the exposure period.</p> <p>...</p> <p>8.5.1.3.2 The minimum fire exposure duration shall be the greater of the following:</p> <p>(1)*Twice the maximum expected time period under normal circumstances for a vehicle to stop completely and safely from its maximum operating speed, plus the time necessary to evacuate a full load of passengers from the vehicle under approved conditions</p> <p>(2)*15 minutes for automated guideway transit (AGT) vehicles, 30 minutes for all other passenger-carrying vehicle.</p>	<p>8.5.1.2 The fire resistance test exposure duration shall be at least equal to the time required to evacuate passengers from a vehicle.</p> <p>8.5.1.2.1 The nominal test period shall be twice the maximum expected time period under normal circumstances for a vehicle to stop completely and safely from its maximum operating speed, plus the time necessary to evacuate all the vehicle’s occupants.</p> <p>8.5.1.2.1.1 The nominal test period shall be not less than 15 minutes.</p> <p>8.5.1.2.1.2 The fire resistance period required shall be consistent with the safe evacuation of a full load of passengers from the vehicle under conditions approved by the authority having jurisdiction.</p> <p>8.5.1.2.2 The fire exposure duration shall be at least 15 minutes.</p> <p>...</p> <p>8.5.2 Fire Assembly. All vehicle floor assemblies shall require fire resistance testing as described in 8.5.1</p> <p>...</p> <p>8.5.3 Roof Assembly.</p> <p>8.5.3.1 Vehicles that contain propulsion equipment or equipment that operates at voltages higher than 600 V on the roof shall demonstrate roof assembly fire resistance testing as specified in 8.5.1.3.</p> <p>8.5.1.3.2 Vehicles that travel through tunnels and contain a roof that is constructed of combustible material shall require a fire hazard analysis to demonstrate that rapid fire spread to passenger and crew compartments or local roof collapse is not possible during the exposure period.</p>	<p>8.4.1.5.18* A structural flooring assembly separating the interior of a vehicle from its undercarriage shall meet the performance criteria during a nominal test period as determined by the railroad. The nominal test period shall be twice the maximum expected time period under normal circumstances for a vehicle to stop completely and safely from its maximum operating speed, plus the time necessary to evacuate all the vehicle’s occupants to a safe area. The nominal test period shall not be less than 15 minutes. The fire resistance period required shall be consistent with the safe evacuation of a full load of passengers from the vehicle under worst-case conditions.</p> <p>8.4.1.5.19 Portions of the vehicle body (including equipment carrying portions of a vehicle’s roof and interior floors separating the lower level of a bilevel car, but not including a flooring assembly subject to 8.4.1.5.18) that separate major ignition sources, energy sources, or sources of fuel load from vehicle interiors shall have sufficient fire endurance as determined by a fire hazard analysis that addresses the location and quantity of the materials used, as well as vulnerability of the materials to ignition, flame spread, and smoke generation. In those cases, the use of the ASTM E 119 test procedure shall not be required.</p>

REFERENCES

ⁱ The first European low-floor tram vehicle of the modern era was a prototype delivered in 1984 to TPG Geneva, Switzerland.

ⁱⁱ Portland's Tri-Met ordered the first US low-floor vehicles in 1995. They were placed in service in 1997.

ⁱⁱⁱ "NFPA 130 Standard For Fixed Guideway Transit and Passenger Rail Systems", 2014 Edition, Published by the National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471.

^{iv} EN 45545-1: 2013. Railway applications– Fire protection on railway vehicles – Part 1: General

EN 45545-2: 2013. Railway applications– Fire protection on railway vehicles – Part 2: Requirements for fire behavior of materials and components

EN 45545-3: 2013. Railway applications– Fire protection on railway vehicles – Part 3: Fire resistance requirements for fire barriers

EN 45545-4: 2013. Railway applications– Fire protection on railway vehicles – Part 4: Fire safety requirements for rolling stock design

EN 45545-5: 2013. Railway applications– Fire protection on railway vehicles – Part 5: Fire safety requirements for electrical equipment including that of trolley buses, track guided buses and magnetic levitation vehicles

EN 45545-6: 2013. Railway applications– Fire protection on railway vehicles – Part 6: Fire control and management systems

EN 45545-7: 2013. Railway applications– Fire protection on railway vehicles – Part 7: Fire safety requirements for flammable liquid and flammable gas installations

^v The precise origins of the minimum 15-minute duration for the floor fire barrier are not known to the authors, although it is acknowledged as a commonly cited industry reference point. It appears in the first (1983) version of NFPA-130.

^{vi} Justin M. Edenbaum, Kang, Kennedy, and Rummel, "Subway Tunnel Cross Passage Spacing. A Performance-Based Approach", APTA 2006 Rail Conference.

^{vii} "2009 Annual Revision Cycle Report on Proposals", Published by the NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471