Comparison of the U.S. and European Approaches to Passenger Train Fire Safety

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ABSTRACT

The Federal Railroad Administration (FRA) approach to passenger rail equipment fire safety requires the use of primarily small-scale flammability and smoke emission tests and performance criteria for interior materials, such as seats and wall and ceiling panels; and fire endurance tests for structural components such as floors. The individual test methods measure one or more different fire performance characteristics: ignition resistance, flame spread, and smoke emission. In addition, FRA regulations include a requirement for conducting a fire safety analysis for new and existing equipment, and requirements for the inspection, testing, and maintenance of fire safety related equipment.

The European Committee for Standardization (CEN) has developed a Technical Specification, CEN *TS 45545*, based primarily on existing fire safety requirements for passenger railway rolling stock from the International Union of Railways (UIC) and individual European countries, as well as additional research sponsored by CEN.

This paper describes the results of a preliminary comparison of fire safety and related emergency systems requirements of CEN *TS 45545* with current FRA regulations.

KEYWORDS: Passenger Train Fire Safety; Federal Railroad Administration; 49 CFR, Part 238; CEN *TS 45545*

INTRODUCTION

Although the number of fires occurring on passenger rail vehicles has been historically low, the consequences, when a fire does occur, can be catastrophic, depending on the location of the train and the operating environment, particularly if the fire occurs at night or in a tunnel. Examples include fires that occurred: on Amtrak intercity trains in Gibson, CA (1983), Bourbonnais, IL (1999), and Miriam, NV (2011); on *Euroshuttle* trains in the Channel Tunnel (1996 and 2008); and on the Kaprun, Austria "ski-train" (2000).

Accordingly, fire safety is an area of particular importance for inter-city passenger and commuter railroad operations. A "systems" approach to fire safety addresses passenger rail equipment design and materials for fire prevention, fire detection and suppression, passenger evacuation, and the interrelationship between these elements. The Federal Railroad Administration (FRA) and other U.S. agencies and organizations, individual European countries, the International Union of Railways UIC, and most recently, the European Committee for Standardization (CEN), have all developed performance requirements for passenger rail vehicles, intended to provide such a "systems" approach for passenger safety that includes but extends beyond fire behavior test methods and related performance criteria.

For convenience, the term "requirements, as used in this paper," generically includes: regulations, standards, rules, specifications, guidelines, recommendations, and recommended practices. It should be noted that regulations and rules are the only requirements that can be and usually are legally enforceable unless other requirements are included in contracts or jurisdictional codes.

The various required fire test methods and criteria and other requirements described in this paper are presented only in summary form. Accordingly, the actual complete documents must be reviewed by the reader for complete understanding and to ensure compliance with all specific requirements.

FRA fire safety and related emergency systems-related requirements for passenger rail cars and locomotives are contained in the U.S. Code of Federal Regulations, Title 49 (49 CFR) in *Part 238, Passenger Equipment Safety Standards* [1] and *Part 239, Passenger Train Emergency Preparedness* [2].

CEN has developed a technical specification (*TS*) for the fire safety of rolling stock, CEN *TS 45545 Railway Applications - Fire Protection on Railway Vehicles* [3].

This paper describes the results of a preliminary study conducted by the John A. Volpe National Transportation Systems Center (Volpe Center) that compares the fire safety requirements of the new CEN *TS 45545* with current FRA regulations and other U.S. requirements.

FRA REQUIREMENTS

FRA's mission is to promulgate and enforce railroad safety regulations; administer railroad assistance programs; conduct research and development in support of improved railroad safety and assist in guiding national railroad transportation policy.

FRA has long recognized the importance of maintaining and improving the level of passenger train fire safety. In 1999, as part of the passenger rail equipment safety standards rulemaking process required by the U.S. Congress, FRA issued regulations in 49 CFR, *Part 238* [4] that include fire safety requirements for new and existing passenger cars and locomotives [5].

Section 238.103 and Appendix B of *Part 238* require that railroads comply with specific fire behavior tests and performance criteria for interior materials used in new passenger cars and locomotives. Based primarily on small-scale test methods that demonstrate fire characteristics, such as flammability, smoke emission, and fire endurance of individual materials, the FRA requirements for passenger rail equipment comprise a prescriptive set of design specifications that historically have been used to evaluate material fire performance. This approach provides a screening device to allow interested parties to identify particularly hazardous materials and to select preferred combinations of individual components that comply with the tests and performance criteria. Material suppliers can independently evaluate the fire safety performance of their own materials. (It is noted that the 1999 rule is based on recommended fire safety guidelines for passenger rail car material selection that FRA first published in 1984 [6] and updated

in 1989 [7]; which, in turn, were adapted from recommended fire safety practices for rail transit vehicle materials selection published in 1984 by the Federal Transit Administration (FTA) (formerly the Urban Mass Transportation Administration (UMTA)) [8]. In addition to the individual material tests, a floor assembly fire endurance test is required. A seat assembly test with heat release rate (HRR) criteria is permitted as an alternative to the small-scale testing and performance criteria for individual seat component materials; a fire hazard analysis is also required to account for the railroad operating environment, including acts of vandalism (such as arson).

In addition to the material fire performance tests, *Part 238* requires that railroads complete written fire safety analyses for new and existing passenger rail cars and locomotives. FRA's objective is to ensure that fire safety considerations and features in the design of the equipment reduce the risk of personal injury and equipment damage caused by fire to an acceptable level. Railroads are required to conduct written analyses for new equipment using a formal safety methodology, such as *MIL-STD 882* [9] for categorizing the risk of safety mishaps and hazards by their severity and probability. The following items must be included in those analyses:

- Identification, analysis, and prioritization of fire hazards inherent in equipment design
- Equipment design and material selection for fire resistance for time to detect fire and safely evacuate the passengers and crewmembers, if a fire cannot be prevented or extinguished. Factors to consider include:
  - Potential ignition sources,
  - Type, quantity, and location of materials, and
  - Availability of rapid and safe egress to the exterior of the equipment under conditions secure from fire, smoke, and other hazards.
- Ventilation system in the equipment does not contribute to the lethality of a fire.
- Train component overheat protection if necessary.
- Fire or smoke detection system in each normally unoccupied compartment that contains a fire hazard during operation of train, as necessary to ensure time for safe evacuation of passengers and crewmembers from that compartment (i.e., closet, baggage compartment, food pantry, etc.)
- Proper type and size of portable fire extinguisher, if necessary for occupied or unoccupied compartments (per *Part 239*); each passenger car must have at least one portable fire extinguisher.
- Proper size and type of fixed, automatic fire-suppression system in any unoccupied train compartment that contains a fire hazard, where practical and necessary to ensure sufficient time for safe evacuation of passengers and crewmembers from the train.
- Explanation of how safety issues are resolved in equipment design and selection of materials to reduce the risk of each fire hazard.
- Description of analysis and testing necessary to demonstrate that fire protection approach taken in the equipment design and material selection complies with *Part 238.*

Analysis for materials used in existing passenger equipment materials must include both consideration of different categories of rail service, and factors, such as potential ignition sources; type, quantity, and location of materials used in the equipment; and the availability of safe egress to the exterior of the equipment under conditions secure from fire, smoke, and other hazards.

Part 238 also requires that railroads develop and follow an inspection, testing, and maintenance plan for fire safety-related equipment.

An update to the FRA fire safety requirements was issued in 2002, which included clarification of certain fire performance requirements, as well as responses to comments to the 1999 final rule [10].

In addition to the *Part 238* fire safety requirements, *Part 239* requires that each passenger car and locomotive be equipped with a fire extinguisher [11]. To ensure passenger safety, *Part 239* also requires

that railroads consider, in developing their emergency preparedness plan(s), the special circumstances of evacuating passengers in tunnels more than 1000 ft (308 m) long, by providing emergency lighting, access to emergency exits, emergency effective communications, and other options for assistance from other trains [12]. In addition, *Part 238* and *Part 239* contain extensive requirements relating to emergency egress, including: the type, location, and size of emergency exits and the marking of such door and emergency window exits; as well as emergency lighting; and emergency communications systems [13][14].

In 2008, FRA issued enhancements to the emergency system requirements in *Part 238* [15] and in 2012, issued a new notice of proposed rulemaking to further enhance those requirements [16].

APTA RECOMMENDED PRACTICE FOR FIRE SAFETY ANALYSIS FOR EXISTING RAIL PASSENGER VEHICLES

Following FRA issuance of the 1999 final rule, an industry group, the American Public Transportation Association (APTA) developed a manual of standards and recommended practices for passenger rail equipment to supplement and provide guidance for complying with the FRA regulations. A task force representing system operators, the FRA, technical experts, and other interested parties developed a recommended practice to provide more specific guidance to railroads to identify, analyze, and resolve the risk of fire events for existing passenger equipment [17].

The APTA fire safety recommended practice also refers to APTA standards for passenger equipment emergency lighting systems, emergency egress and access signage, and low-location exit path marking systems developed during the same process described above, and which were updated in 2007.

NFPA 130 STANDARD FOR FIXED GUIDEWAY TRANSIT AND PASSENGER RAIL SYSTEMS

The National Fire Protection Association (NFPA) is an organization that develops and publishes life safety and fire protection codes and standards for a variety of U.S. buildings and other facilities. The NFPA codes and standards are developed by consensus and are revised periodically by committees that include system operators, regulators, fire departments, fire protection engineers, technical experts, and other interested parties. The NFPA standard (*NFPA 130*) for fixed guideway (e.g., rail) transit systems was first adopted in 1983 [18]. *NFPA 130* is a comprehensive approach because it includes fire safety and emergency evacuation-related requirements for vehicles, stations, and trainways. However, *NFPA 130* requirements are not enforceable unless adopted by the local authority having jurisdiction (e.g., State or city, or local fire department). In 1990, *NFPA 130* adopted the 1984 FTA table of recommended fire tests and performance criteria in its entirety [19]. The scope was expanded to include passenger rail vehicles in 2000 [20], while passenger rail stations and trainways were added in 2007 [21]. In 2007, the vehicle chapter was revised to update the table of tests and performance criteria to reflect, with few exceptions, the FRA requirements contained in the table in Appendix B of *Part 238*. The latest edition of was published in 2010 and included a reorganization of the vehicle structural fire testing requirements [22].

FRA AND *NFPA 130* FIRE PERMANCE TEST REQUIREMENTS

The individual fire behavior test methods cited by FRA and the Vehicle chapter of *NFPA 130* measure one or more of four different fire performance characteristics including the following:

- Ignition resistance,
- Flame spread,
- Smoke emission, and
- Fire endurance.

Table 1 shows the passenger rail equipment tests and performance criteria common to both FRA *Part 238,* Appendix B and *NFPA 130* requirements.

Table 1. U.S. passenger rail equipment fire behavior tests and performance criteria.

COMPONENT/FUNCTION	FIRE BEHAVIOR	TEST METHOD	PERFORMANCE CRITERIA [a]
Seat cushions & mattresses, armrests, seat pads	Flame Spread Smoke Emission	ASTM E 162 ASTM E 662	$I_s \leq 25$ D_s (1.5): ≤ 100 D_s (4.0) ≤ 175)
Fabrics (upholstery, curtains, etc.)	Flame Resistance Smoke Emission	14 CFR 25.853 (a) ASTM E 662	Flame Time $\leq$ 10 s Burn length $\leq$ 15.2 cm (6 in) D_s (4.0): $\leq$ 200 (for both coated and uncoated)
Composite seat/ mattress assembly	Heat Release Rate	ASTM E 1537 ASTM E 1590	Max HRR < 80 kW/m^2; THR < 25 MJ (10 min) ML< 3 lb (10 min); Max HRR < 100 kW/m^2; THR < 25 MJ
Panel, partition, wall, ceiling	Flame Spread Smoke Emission	ASTM E 162 ASTM E 662	$I_s \leq 35$ D_s (1.5.0) ≤ 100 D_s (4.0): ≤ 200
Other seat materials, thermal and acoustical insulation, HVAC ducting	Flame Spread Smoke Emission	ASTM E 162 ASTM E 662	$I_s \leq 35$ D_s (1.5): ≤ 100 D_s (4.0): ≤ 200
Light diffusers, windows, etc.	Flame Spread Smoke Emission	ASTM E 162 ASTM E 662	$I_s \leq 100$ D_s (1.5.0) ≤ 100 D_s (4.0): ≤ 200
Elastomers	Flame Spread Smoke Emission	ASTM C 1166 ASTM E 662	Pass (burn length $\leq$ than 10.2 cm (4 in) D_s (4.0) ≤ 200
Floor covering	Flame Spread Smoke Emission	ASTM E 648 ASTM E 662	CFR > 0.5 watts/cm^2 (5 kW/m^2) D_s (1.5): ≤ 100 D_s (4.0): ≤ 200
Small parts with surface area < 100 sq cm (16 sq in)	Heat Release Rate	ASTM E 1354	Avg HRR (q''_{180}) $\leq$ 100 kW/m^2 Avg specific extinction area (σ_f) $\leq$ 500 m^2/kg over same 180-second period
Floor structure	Fire Endurance	ASTM E 119	Pass: 15 min nom. (twice required evacuation time)

[a] The actual test requirements and performance criteria include several compliance notes.

The requirements are based primarily on two small-scale (*ASTM International,* formerly *American Society for Testing and Materials*) individual material test methods, as summarized in this section:

- *ASTM E 162, Standard Test Method for Surface Flammability of Materials Using a Radiant Energy Source* [23], (with a variant for cellular foams, *ASTM D 3675* [24]), and
- *ASTM E 662, Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials* [25].

Several other test requirements are specified for certain other individual material categories and functions, including:

- *ASTM E 648, Standard Test Method Critical Radiant Flux of Floor Covering Systems Using a Radiant Energy Source* [26],
- *ASTM C 1166, Standard Test Method for Flame Propagation for Dense and Cellular Elastomeric Gaskets and Accessories* [27], and
- *14 CFR, Part 25, Subsection 25.853 (a) Compartment Interiors* for fabrics [28].

All of the test methods are designed to study aspects of a material's fire behavior in a fixed configuration and exposure, with the exception of *ASTM E 119, Standard Test Methods for Fire Tests of Building Construction and Materials,* which is a real-scale fire endurance test [29].

FRA and *NFPA 130* both permit the use of alternative HRR-based tests of real-scale seat assemblies (*ASTM E 1537, Standard Test Method for Fire Testing of Upholstered Furniture*) [30] and mattresses (*ASTM E 1590, Standard Test Method for Fire Testing of Mattresses)* [31]. The respective required HRR performance criteria are specified in technical bulletins for public building occupancy issued by the State of California Bureau of Home Furnishings [32][33]. In addition, a small-scale HRR test (*ASTM E 1354, Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*) [34] is permitted for certain small parts.

NFPA 130 also includes an extensive section of vehicle electrical wire and cable flammability and smoke requirements. While FRA does include electrical system requirements in *Part 238* [35], no fire safety test requirements for electrical wire and cable installed in passenger cars are cited in Appendix B of *Part 238*.

HISTORICAL EUROPEAN PASSENGER ROLLING STOCK REQUIREMENTS

UIC 564-2 covers passenger rolling stock design for international service (including Europe) [35]. As a general guideline for vehicle design, *UIC Code 564-2* states that: "the coach design and interior fittings must above all prevent the spread of fire" and accordingly includes requirements for:

- Vehicle material flammability to reduce potential ignition and flame spread, and smoke emission,
- Compartmentation (to prevent spread of fire from one vehicle to another),
- Electrical systems, fire detection in engine compartments,
- Fire extinguishers, and
- Fire alarms.

The German *DIN 5510* [36], French *NF 101* and *102* [37][38], and British *BS 6853* [39] fire safety requirements for railway vehicles, all issued in the late 1980 and 1990s, contain similar provisions for small-scale flammability and smoke emission tests to evaluate individual component materials. A major commonality is the inclusion of more stringent fire performance requirements for interior materials installed in rolling stock operating in certain environments, such as in tunnels or in overnight service with sleeping cars; and less stringent requirements for exterior materials. The German *DIN* and French *NF* standards also reference the *UIC 564-2* newspaper "pillow" ignition source for the seat assembly test. Although the British *BS 6853* standard also includes a seat assembly test requirement, that test is considered to be more stringent because it uses a wooden "crib" as an ignition source. In addition, the German *DIN 5510*, French *NF 103* [40], and British *BS 6853* standards all include emergency evacuation-related requirements for railway rolling stock, including exit doors and/or emergency lighting.

CEN *TS 45545*

CEN *TS 45545* [3] is based primarily on previously existing fire safety requirements for railway vehicles developed by UIC and by several European countries, including Germany, France, and the United Kingdom; as well as an earlier extensive research program sponsored by the European Railway Research Institute (ERRI). That research program was initiated following the issuance of the 1991 *UIC 564-2* standard, and included a series of tasks and reports describing results for the analysis of small-, real-, and full-scale HRR fire performance tests. The final ERRI report [41] also referenced the activities of the CEN *Technical Committee (TC) 256*, responsible for developing a common European Union standard for passenger railway rolling stock.

CEN issued technical directives in 1996 and 2001 for the inter-operability of the Trans-European high-speed and conventional rail systems in terms of safety, reliability, etc. European standards (*EN*) must be translated into a national standard in all 30 member countries, which guarantees that a manufacturer has easier access to the markets of all these European countries. Member countries must also withdraw any conflicting national standard, because the *EN* prevails over any national standard. The *CEN 45545* Joint Working Group, composed of the *CEN TC 256* Working Group 1 and the *CENELEC TC 9X* Working

Group 3 (relating to electro-technical standardization), developed a basic framework for the contents of the proposed *EN 45545* standard, based primarily on hazards in the different passenger railway rolling stock operating environments.

The *FireStarr* research program was initiated in 1997 with funding from CEN and industry partners. A 2001 report [42] described the results of nine extensive fire research work areas, including risk and scenario selection; selection of 31 materials to be tested; selection of small- and large-scale ignitability; flame spread, heat release rate, and smoke and toxic gas tests; conduct of tests of representative railway vehicle structural, furniture, and electro-technical materials (excluding cable); and selection of performance criteria. A set of principles was developed for a reaction-to-fire-material test classification system related to the four selected operating categories that are described in the next section). The stated intent of the *FireStarr* research was to include proposals to be further developed by the CEN and CENELEC committees. Accordingly, the CEN/CENELEC Joint Working Group sponsored additional research and discussion activities over the following years for the proposed *EN 45545* standard.

In 2009, CEN approved the contents of the proposed *EN 45545* as a *TS* which is now available for provisional application at the national level. Although it is possible to keep a national standard in force in parallel to the *TS*, the *EN* designation will require implementation by each member country at the national level and withdrawal of any conflicting national standard**.** Accordingly, a special working group was formed to complete additional revisions to clarify certain proposals and to come to common agreement, particularly for some requirements in certain sections and parts, to enable *TS 45545* to become an *EN 45455* standard.

CEN *TS 45545* for rolling stock fire safety is comprised of seven parts that are summarized below.

Part 1, General includes definitions, operation and vehicle design categories, fire safety objectives and general requirements. The objectives are to: minimize the probability of a fire starting, to control the rate and extent of fire development, and to minimize impact on passengers and train staff. The scope includes different ignition models involving a variety of ignition sources, in order to reduce the risk of a fire spread resulting from accidental ignition by arson or a technical defect, through occupied areas; and endangering passengers and crew by obscuration of escape routes and presence of toxic fumes. The cited test methods are based on *FIRST* (flammability, ignition, rate of heat release, smoke, and toxicity).

The four categories of passenger railway rolling stock operation are summarized as follows:

1: Not designed to operate in or on underground sections, in tunnels, and/or on elevated sections, which can be stopped with minimum delay, after which immediate side evacuation to place of ultimate safety is possible.
2: Designed to operate in or on underground sections, tunnels and/or on elevated sections, where side evacuation to stations or emergency station (ultimate safety) is reachable within a short running time.
3: Designed to operate in or on underground sections, tunnels and/or on elevated sections, where side evacuation to stations or emergency stations (ultimate safety) is reachable within a long running time.
4: Designed to operate in or on underground sections, tunnels and/or on elevated sections, without side evacuation available to stations or emergency stations (place of ultimate safety) is reachable within a short running time.

Rolling stock vehicles are classified according to their design:

A: Part of automatic train having no emergency-trained staff onboard,
D: Double deck vehicles,
S: Sleeping and couchette vehicles, or
N: All other standard vehicles.

Part 2, Requirements for Fire Behavior of Materials and Components includes a classification system for different hazards, based on the operation category and the vehicle design category (see Table 2).

Table 2. Hazard Classification Levels (HL) (condensed and adapted from Table 3 in Part 2).

Operation Category	(Vehicle) Design Category			
	N	A	D	S
1	HL 1	HL 1	HL 1	HL 2
2	HL 2	HL 2	HL 2	HL 2
3	HL 2	HL 2	HL 2	HL 3
4	HL 3	HL 3	HL 3	HL 3

Depending on the hazard level, the interior materials (and to a lesser extent, the exterior structural materials), are required to comply with stringent test requirements, with the highest hazard level designated as HL3. However, as Table 2 shows, the hazard levels for N, A, and D vehicle categories, based on the four operation categories, are all identical. Although all vehicle design categories under Operation Category 4 are at the highest hazard level, only sleeping and couchette cars (S) have higher hazard levels for Operation Categories 1-3.

The remainder of *Part 2* includes general principles for testing requirements; including recognition that material reaction to fire depends on the location of the material or components, the shape and layout of materials, the direct surface exposed, and the relative mass and thickness of the materials. The materials are further classified according to their interior or exterior location, and their specific use: structural, furniture, electromechanical, or mechanical.

Part 2 contains an extensive comprehensive set of tables listing the required tests and performance criteria for the various categories of materials, based on the hazard level.

It is beyond the scope of this paper to provide a detailed description and comparison of all the extensive fire test requirements and performance criteria contained in *Part 2* (and other parts) of CEN *TS 45545*, with FRA *Part 238*, Appendix B, and *NFPA 130*. However, it is noted that flammability and smoke emission requirements for interior materials primarily rely on small-scale tests: For example, *ISO 5658-2* [43] (similar to *ASTM E 162*, except with different type of criteria); *ISO 5659-2* [44] (similar to *ASTM E 662*, except with different radiant heater used to heat sample and sample orientation, higher heat flux, as well as additional criteria); *ISO 5660-1* [45] (equivalent to *ASTM E 1354*, with a higher heat flux and different criteria); and *ISO 9239-1* [46] (similar to *ASTM E 648*) for floor covering (but with different criteria, depending on the hazard level).

In addition, a complete passenger seat assembly is required to be tested using a furniture calorimeter (similar to *ASTM E 1537*) according to *ISO/TR9705-2* [47]. However, the specified gas burner ignition source in one of the annexes to *Part 2* requires fewer tubing holes (27 versus 42) than *ASTM E 1357*, so the effect on the gas flow ignition source is unclear. In addition, another annex contains a detailed description of the required vandalism test for the seat assembly cushion that must be conducted prior to performing the fire test. The maximum average HRR permitted for the highest hazard level (HL3) for sleeping cars is much lower than the FRA/NFPA 130 criteria applicable for all passenger cars (20 versus 80 kw/m^2).

Lastly, *Part 2* requires that materials be tested according to a French *NS* toxicity test [48] with maximum limits for eight gases, including carbon monoxide (CO), hydrogen cyanide (HCN), and hydrogen fluoride (HFL). The limits are based on reference values for personal exposure to Immediately Dangerous to Life and Health (IDLH) limits developed by the U.S. National Institute for Occupational Safety and Health.

A summary of the other five parts includes*:*

- *Part 3, Fire Resistance Requirements for Fire Barriers:* to maintain fire and heat separation between two adjacent areas of the vehicle for minimum 15- or 30-minute time periods under specified conditions.
- *Part 4, Fire Safety Requirements for Rolling Stock Design:* to minimize the start of a fire, delay fire development, and aid evacuation.
- *Part 5, Fire Safety Requirements for Electrical Equipment:* to minimize a fire during operation as a result of technical defects of the electrical equipment and wiring.
- *Part 6, Fire Safety Requirements for Fire Control and Management System:* for fire detection, alarms, equipment shutdown, and fire extinguishers, emergency signs, and emergency lighting.
- Part 7, *Fire Safety Requirements for Flammable Liquid and Flammable Gas Installations:* to prevent a fire from occurring and spreading by leakage of flammable liquids or LPG used in traction or auxiliary power units, or heating or cooking gases.

The *TRANSFEU* (Transport Fire Safety Engineering in the European Union) project continues to further investigate toxicity for public transport guided systems including passenger railway rolling stock. A periodic newsletter describing the progress of the TRANSFEU work is available at www.transfeu.eu.

SUMMARY

The CEN *TS 45545* fire safety approach is similar to that of the FRA *Part 238* approach, in that only requirements for rolling stock (e.g., passenger equipment) are specified, although the objectives of both sets of requirements are to minimize the occurrence and impact of a fire and provide adequate time for evacuation. Although several of the fire safety test methods and performance criteria requirements cited in FRA *Part 238*, Appendix B and the vehicle chapter of *NFPA 130* are somewhat similar to *TS 45545*, clear differences exist, including the *TS 45545*-specified hazard levels for vehicles, based on operation environments, and rolling stock design. In addition, *TS 45545* requires HRR tests with performance criteria that apply to more vehicle components than the FRA/*NFPA 130*-required seat and mattress assemblies (and small parts); and also includes wire and cable fire performance tests and criteria. Finally, *TS 45545* includes toxicity requirements which FRA does not.

Part 238 and *Part 239* also contain requirements for equipment, such as fire extinguishers, and other fire safety related equipment and systems, based on the results of risk analysis. In addition, FRA has extensive emergency preparedness-related requirements, including emergency plans, as well as emergency evacuation-related equipment, such as emergency exits and emergency lighting. The *NFPA 130* approach considers the environment of the entire rail operating system because it includes requirements for stations and trainways, as well as vehicles; and also includes requirements for emergency preparedness plans. *TS 45545* also contains specific requirements for fire extinguishers, ventilation systems, fire detection and suppression systems; and emergency evacuation systems, including emergency exits and emergency lighting.

Further review and more extensive analysis are necessary to fully understand the similarities and differences in the respective U.S. and *TS 45545* approaches to ensure passenger rail equipment safety.

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