FIRE TESTING OF ELECTRICAL CABLES IN TRANSPORTATION ENVIRONMENTS: TRAINS, SHIPS AND AIRCRAFT

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ABSTRACT

Cabling in public transportation is a large, and growing, part of the fuel load, but the fire performance of electric cables has traditionally been based on semi-mandatory guidelines, of relatively low severity. Recently, the Federal Railroad Administration, the International Maritime Organization, the US Coast Guard and the Federal Aviation Administration have all investigated the requirements for electric cable fire performance. Thus, this is an area with extensive activity.

INTRODUCTION

NFPA statistics indicate that in the United States there have been approximately 1,975,500 fires in 1996, with 397,000 occurring in vehicles. Fires in public transportation vehicle environments are rare: most fires occur in buildings, and those in vehicles (20%) often occur in private road vehicles (road vehicles account for almost 75% of all vehicle fires). However when such fires occur, the results can be very severe, because of the multitude of passengers using public transportation: buses, trains, ships or airplanes. Furthermore, there is a growing realization that the increase in communications and electronics has resulted in a vast increase in the amount of electrical wires and cables that are present in such environments, and particularly in the fuel load that these products represent. Table 1 shows the proportion of electrical wire or cable insulation as the item first ignited in vehicle fires. As a further example, Table 2 shows some recent statistics of fires in rail transportation environments (0.2% of vehicle fires), where traditional guidelines have focused most on upholstery contents. In recent years, the fraction of rail transportation vehicle fires starting in electrical wiring has been over 10% of all fires, a much greater proportion than the fraction of fires starting in upholstery, and the greatest single material source of fires other than the inevitable fuel used to power the rail cars.
Table 1. Vehicle Fires in the United States, 1992-1996, and percentage of fires where the material first ignited was electrical wire or cable insulation, by vehicle type [Ref: 1]

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>% of Vehicle Fires</th>
<th>% Electrical First</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Road Vehicle</td>
<td>72.9</td>
<td>25.6</td>
</tr>
<tr>
<td>Freight Road Transport Vehicle</td>
<td>9.3</td>
<td>22.0</td>
</tr>
<tr>
<td>Heavy Equipment Vehicle</td>
<td>1.4</td>
<td>20.3</td>
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<tr>
<td>Special Vehicle</td>
<td>0.5</td>
<td>13.9</td>
</tr>
<tr>
<td>Water Transport Vehicle</td>
<td>0.4</td>
<td>13.3</td>
</tr>
<tr>
<td>Rail Transport Vehicle</td>
<td>0.2</td>
<td>11.4</td>
</tr>
<tr>
<td>Air Transport Vehicle</td>
<td>0.1</td>
<td>11.8</td>
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<tr>
<td>Unclassified Vehicle</td>
<td>15.3</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Material First Ignited in: All Rail Transportation Fires in 1991-95 and in 1992-96 and in Rail Passenger and Diner Car Fires in 1988-1997 [Ref: 1-3]

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Fuel</td>
<td>17 %</td>
<td>17 %</td>
<td>16 %</td>
</tr>
<tr>
<td>Electrical Wire</td>
<td>11 %</td>
<td>11 %</td>
<td>18 %</td>
</tr>
<tr>
<td>Trash</td>
<td>8 %</td>
<td>9 %</td>
<td>1 %</td>
</tr>
<tr>
<td>Upholstery</td>
<td>3 %</td>
<td>2 %</td>
<td>11 %</td>
</tr>
<tr>
<td>Unclassified</td>
<td>16 %</td>
<td>15 %</td>
<td>7 %</td>
</tr>
<tr>
<td>Other</td>
<td>45 %</td>
<td>46 %</td>
<td>47 %</td>
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<tr>
<td>Total # Fires</td>
<td>3,150</td>
<td>3,500</td>
<td>710</td>
</tr>
</tbody>
</table>

Fire safety in mass transportation has been an issue in the United States for years. The 1973 Urban Mass Transportation Administration (UMTA) project on fire safety of transit vehicles resulted in the Transportation Systems Center "Guidelines for Flammability and Smoke Emission Specifications" for materials used in transportation vehicles [4]. These guidelines have developed to some extent over the years, and they are now quoted, in various guises, by a number of organizations, including the Federal Railroad Administration (FRA) [5], the Federal Transit Administration (FTA, successor to UMTA) [6] and the National Fire Protection Association (NFPA), for passenger rail systems [7]. Table 3 contains a summary of the details of all the specifications, based on a 1994 review by NIST [8], and Table 4 has the corresponding annotations. The list of references gives titles and locations for the standards mentioned [9-16].

The earliest concern about the introduction of combustible materials into trains was expressed following full-scale testing of the burning behavior of a real-scale mockup of a rail passenger coach compartment [17], and that started the strong emphasis on upholstery, which is evident in Table 3, and which continued to be the trend until the 1990's. Early studies
highlighted the fact that rail transit car assembly and transit bus interior assembly mock-ups could be built with standard (i.e. with minimal if any fire retardance) polyurethane foam seats which met the requirements of MVSS 302 [18], but caused room flashover in 6-7 min [19]. The same concerns were immediately expressed for buses, which were soon intended to meet the same guidelines as trains (Table 3). Separate fire test requirements were developed for public transportation on water and air, some of which included tests for electrical cables.

**EARLY REQUIREMENTS FOR RAIL**

Fire testing requirements for wire and cable are found in Amtrak specifications [20] and NFPA 130 (even editions addressing only fixed guideway transit systems). Amtrak "high performance wire and cable" insulated conductors must meet the flame test in ICEA S-19 [21], the VW-1 test [22] and ASTM E662 [14] limits. In NFPA 130 vehicles, wires for control and other low voltage (i.e. less than 100 V ac and 150 V dc) functions must meet the requirements of ICEA S-19, (with Amendment FR-1); or of UL 44 [23], for thermosetting insulation and UL 83 [24], for thermoplastic insulation. In NFPA 130 vehicles, also, power cables must meet the requirements of IEEE 383 [25], with the additional requirement that circuit integrity continue for 5 minutes after the start of the test (even though circuit integrity is not defined in the IEEE 383 test). All cables must meet National Electrical Code [26] requirements.

**RECENT REQUIREMENTS FOR PUBLIC TRANSPORTATION**

**Buses and Other Passenger Road Vehicles**

There are almost no mandatory fire safety requirements for such vehicles. The National Highway Safety Transit Administration (NHTSA) has as its only mandatory fire safety test one that applies a small burner to interior materials (MVSS 302, [18]). This test is very mild and has been replaced in most public transport applications by the FTA guidelines [6], which do not, however, contain information about electrical cables. Manufacturers of road vehicles do have specifications of their own, which help obtain a certain degree of fire safety.

**Aircraft**

In aircraft, the regulatory authority is the Federal Aviation Administration (FAA), via Title 14 in the Code of Federal Regulations. All of their fire test requirements are published in a Fire Test Handbook [15]; new versions are made available (in draft form) to all aircraft parts suppliers. A new edition is likely to be published in 2000. Wire and cable needs to meet a relatively mild exposure to a Bunsen burner, at a 60 degree angle, for 30 seconds, although the majority of the wire and cable actually used exhibits a fire performance that significantly exceeds the test requirements. The FAA has announced that it intends to search for a new test for materials concealed outside of the passenger cabin, and wire and cable is prominent in that location. They have a test under development for that purpose, probably based on the flooring radiant panel (ASTM E648) [13]. This is unlikely to happen before 2002. There is also a test for wire and cable in a "designated fire zone" (based on MIL SPEC W 25038E or on ISO 2685) and one for smoke emission from wire and cable, using the NBS smoke chamber (ASTM E662). The FAA prefers to develop test methods that are of specific use to the industry, and to work
with the interested parties in the industry to complete the final test modifications and improvements.

**Ships**

All ships that engage in international trade and fly the flag of a country that has signed the International Convention for Safety of Life at Sea (SOLAS) [27], which includes the USA, must comply with the regulations of the International Maritime Organization (IMO). The IMO regulations are detailed in the SOLAS book, periodically amended by "Resolutions" of the IMO committees, and ratification by the signatory states. Details of the fire issues are given in the IMO Fire Test Procedures Code [28], also reissued regularly. Some special vessels are regulated separately: high speed craft that is never too far from shore is regulated by the IMO High Speed Craft Code [29]. All ships that sail in US waters must comply with the requirements specified by the US Coast Guard, laid out in US Federal Government - Coast Guard: Title 46, Shipping, Code of Federal Regulations, Parts 1–199 [30], and in NVIC (US Coast Guard Guide to Structural Fire Protection) [31]. The Coast Guard is also the authority having jurisdiction over ships engaging in international trade and sailing into US waters or US ports; such ships must comply with IMO regulations and need not also comply with separate Coast Guard requirements. With the instructions from the US federal government that standards should, whenever possible, be delegated to private organizations, the Coast Guard and NFPA agreed to develop NFPA 301 [32], to add to the existing NFPA 302 [33]. NFPA 301 applies to passenger vessels carrying more than 12 passengers, cargo and tank vessels and towing vessels 12 m or more in length and greater than 500 hp; it does not apply to military ships (although military ships must comply with Coast Guard requirements). NFPA 302 applies to boats of less than 300 gross tons used for pleasure or commercial purposes that meet one of the following conditions: (a) motor craft, (b) boats that use cooking, heating, or auxiliary appliances, or (c) boats that have permanently installed ignition source(s); it does not apply to personal watercraft. In fact, passenger vessels carrying up to 12 passengers are covered by NFPA 302. In order for NFPA 301 or NFPA 302 to be a requirement, someone must choose to meet them, and that would typically be a shipbuilder in conjunction with ABS (American Bureau of Shipping, who certify ships in the USA). The market of ships that are not built to comply with IMO requirements is actually extremely large, because it encompasses all the ships sailing through rivers (e.g. Mississippi River), lakes (e.g. Great Lakes) and (most importantly) the ships sailing in amusement parks (e.g. Disney parks, as the Disney fleet is one of the largest fleets in the world). Typically, wire and cable for ships in the USA was regulated by military specifications included in CFR 46 (Subchapter J) and by the recommendations of IEEE 45 [34].

The first edition of NFPA 301 contains fire test requirements for cables by reference to 46 CFR Subchapter J (Electrical Engineering, Parts 110-113) [30] and to IEEE 45 (1983 edition [34]) and not by direct requirements in the code. IEEE 45 (1983 edition) requires all shipboard cables to meet a test with a flame insult equivalent to the vertical tray test in IEEE 383 or in UL 1581-1160 [25, 35], and its jacket to be flame retardant (unspecified). This means that large diameter cables have to meet the actual IEEE 383 test (a 2.4 m vertical cable tray test, with a 20 kW horizontal gas flame applied for 20 min, at a specified cable loading) and thin cables have to meet a watered down version of that vertical cable tray test. The 1998 edition of IEEE 45 (the one that follows from the 1983 one) has not been adopted by any regulatory body, and will be
followed by a 2001 edition. Both editions will require all cables to meet IEEE 1202 [36]. IEEE 1202 is also a vertical cable tray test, with an application of a flame of the same intensity as IEEE 383 or UL 1581-1160, but it is virtually identical to CSA FT4 or UL 1581-1164 [37-38]. The Canadian FT4 standard differs from UL 1581-1160 in a few main aspects, as follows (see added details in reference [39]):

- The burner is at an angle of 20° from the horizontal, rather than vertical, and it is sited 30 cm (1 ft) from the floor rather than 45 cm (18 in) from the floor;
- The burner is sited in front of cable tray rather than at the back;
- Cable loadings are different, the CSA FT4 test having significantly more cable, particularly for smaller diameters;
- Tray length is 3 m (10 ft) and not 8 ft (2.4 m); minimum cable length is 2.3 m (but it still is 2.4 m in IEEE 1202);
- Failure criterion is a char length of 1.5 m, rather than 8 ft (2.4 m);
- In summary, the CSA FT4 test is substantially more severe than UL 1581-1160.

Thus, cables in ships would normally be required to pass some vertical cable tray test (the mildest one being the one in IEEE 45, for thin cables), but can actually, in some cases, "get away" with meeting the UL 1581 VW-1 test (Bunsen burner test) for most applications. No requirements at all exist for UL 1666 (riser [40]) or NFPA 262 (plenum [41]), nor for smoke obscuration of the cables themselves, all of which are required in the National Electrical Code (except that some requirements for smoke obscuration via ASTM E662 are found both in IEEE 45 and in the referenced MIL C24643A [42]. This lack of cable fire tests for riser cables and plenum cables are doubly inconsistent, in that modern ships are: (a) multi-storied constructions, with many shafts communicating the various storeys and concealed spaces and (b) have a multitude of communications cables critical for ship performance. There is also little internal consistency between the various test method requirements, since there are no requirements directly in the NFPA 301 standard. Proposals for revision of NFPA 301 added a new chapter for fire performance of cables that should clarify the situation, and contain requirements for a fire performance hierarchy of cables. Neither 46 CFR, IEEE 45 (1983) nor NFPA 301 offer direct references to communications cables, which is the growing application for cables, and where the most severe fire requirements are needed. Again, this may be remedied in the next editions of IEEE 45 and NFPA 301, to a significant extent by reference to the NEC. The National Electrical Code contains requirements for fire tests for a broad range of cables: all cables (including power) associated with information technology supply circuits, remote control, signaling and power limited circuit cables, fire alarm cables, optical fiber cables and raceways, communications wires and cables and raceways, community antenna television and radio cables, coaxial cables and network-powered broadband communications equipment and cables. However, the NEC requires all cables to be grounded, and that requirement should not apply to cables in ships.

Listing and certification of naval cables can also be accomplished via a joint UL/CSA standard (UL 1309 and CSA 245, [43]) and, internationally, via IEC 92-350 or IEC 92-353 ([44-45]), which are required by SOLAS. UL 1309 requires cables to meet a vertical cable tray test, either the one contained in UL 1581-1160 or the one in UL 1581-1164/IEEE 1202/CSA FT4. The international standards bodies have a set of three fire tests for electrical cables: IEC 60332-1, IEC 60332-2 and IEC 60332-3 [46-48], where the first 2 apply to a single insulated wire or
cable and IEC 60332-3 is a vertical cable tray test, somewhat less severe than both UL 1581-1160 and CSA FT4 [39]. The US Coast Guard is recommending that electric installations listed to UL 1309, IEC 92-350 or IEC 92-353 be accepted as equivalent to those presently permitted.

New editions of IEEE 45 are likely to contain references to smoke obscuration of materials (via ASTM E662) and of cables (via UL 1685, limited smoke [49], which has also been adopted by CSA and by ASTM, and NFPA 262, low smoke). In particular, they may require some cables to be "low smoke", by meeting one of those requirements. Details of all of these tests can be found in reference [39].

In NFPA 302, electrical systems are described, but no specific fire test requirements are mentioned (other than the UL designations for various cables). Systems connected to electrical ac current in the marina must meet the National Electrical Code requirements for the application.

**Rail**

NFPA 130 has expanded its scope in the 2000 edition to address not just Fixed Guideway Transit Systems (i.e. underground city trains) but all passenger rail systems. There have been, however, no recent changes to the requirements for electrical cables or electrical installations. The new edition of NFPA 130 also discusses the need to consider heat release rate as a critical component of fire hazard assessment, and that the mandatory rules are simply one way of solving the fire safety problem. In 1999 two other major developments occurred: the Federal Railroad Administration published a new mandatory Rule [50], to be applied to all new rail passenger systems, and the ASTM committee on Fire Standards issued a new guide for the fire hazard assessment of rail transportation vehicles [51]. Both contain significant new concepts for fire testing of electrical cables.

The new FRA Rule is a set of Mandatory Requirements, as opposed to the Guidelines and Voluntary Requirements of earlier vintages. The new Table of mandatory requirements contains only a few subtle changes for most materials (such as upholstery or interior finish), when compared to Table 3, but it includes a section on electrical cables, absent before (see Table 5), with new notes for those. The new tests for wire and cable are almost identical to those included in NFPA 130, but were then not applied system wide. Another major change presented by the new FRA rule is the explicit assertion that alternative test methods can be used to replace existing test methods (The notes include some examples of these statements). Finally, the most important change is the fact that the FRA Rulemaking publication explicitly states that it is desirable to use overall systems approaches to fire hazard, including mentioning specifically the ASTM E2061 guide, which was, at the time of publication of the FRA rule, under development at the fire and transportation subcommittee ASTM E05.17.

According to the new ASTM Standard Guide for Fire Hazard Assessment of Rail Transportation Vehicles, the procedure for conducting a fire hazard assessment on a product in a rail transportation vehicle is based on a series of explicit fire safety objectives, requiring the application of specific design considerations, in particular scenarios, where explicit assumptions are presented. The Guide provides lists of test methods from which the test methods to be used
should be chosen, as well as appropriate calculation methods. It does not state which test method, model or procedure is to be used. Documentation and validity checks are essential at every step. The final step in a fire hazard assessment procedure should be the development of a detailed procedure to ensure consistent quality control over time. Thus, if it is decided not to follow the series of prescriptive small-scale tests, from the Federal Railroad Administration, that dictate the minimum fire-test response characteristics required for each material or product, alternative means should be described so that the fire safety of the rail transportation vehicle can be ensured without having to conduct full rail transportation vehicle burn tests. Examples of the use of this guide for assessing electrical cables were developed, and are contained in the guide; significant data on fire performance of relevant electrical cables is also included.

The recommendations by FRA constitute a significant step forward in the way to develop fire safety assessments for an overall system. There are, however, some issues that need to be corrected in the FRA rules. Marcelo Hirschler made an official submission [52] indicating some errors, four of which affect wire and cable.

1. Material testing with the cone calorimeter, at a 50 kW/m² heat flux is an excellent idea. Unfortunately, Note 11 states that a material must exhibit a value of the ratio of time to ignition and maximum rate of heat release which is not larger than 1.5, when what is actually meant is that the ratio should be not smaller than that value, as the property indicated by that ratio becomes poorer as the ratio decreases.

2. Wire and cable/Power cable: The concept of using a test such as IEEE Standard 383 is correct, in principle, as IEEE 383 is a medium-to-large scale test, assessing flame spread. However, there are 3 disadvantages of IEEE 383: (a) it is an old version (issued in 1974 and not amended) of the same test now addressed better in ASTM D5424 [53] (for flame spread and smoke release) and ASTM D5537 [54] (for flame spread and heat release), or by UL 1685 [49], and IEEE 383 can be conducted by using an "oily rag" as the ignition source (instead of a well-characterized gas burner); (b) it measures only flame spread (and neither release of heat nor smoke) and (c) it cannot fully differentiate between cables with good and mediocre fire performance. On the other hand, the ASTM pair of tests (which can both be conducted together in a single burn) can do a much better job of differentiating products and identifying the truly excellent performers, by assessing heat and smoke release. UL 1685 contains two protocols for flame spread, heat release and smoke release, with pass/fail criteria for flame spread and smoke, and the ASTM D5424/D5537 standards have the same tests, more fully described, albeit without pass-fail criteria. In the proposed FRA requirements, smoke is measured in a small-scale test (ASTM E662) instead of in the medium-large scale vertical cable tray test. Thus, the IEEE 383/ASTM E662 combination should be replaced by ASTM D5424/ASTM D5537, with the addition of pass-fail criteria (char length of 2.4 m, total smoke released of 95 m² and peak rate of smoke release 0.25 m²/s [UL protocol] and char length of 1.5 m, total smoke released of 150 m² and peak rate of smoke release 0.40 m²/s [CSA protocol]) or by UL 1685, which already contains the pass-fail criteria but is less well defined and has not been developed through the consensus process.
3. Wire and cable/Low voltage wire and cable: The criteria in ICEA S-19 paragraph 6.19.6 are restricted to a fire test on a single wire, while there are many criteria and requirements in UL 44 and UL 83 (including the fire test). The way the FRA requirements are written it is unclear whether all the requirements of UL 44 or UL 83 are to be met or just the fire test. That should be clarified. Also, the test required is similar to the UL VW-1 test. This test is much less severe than the IEEE 383 (or the ASTM D5424/ASTM D5537, or the UL 1685) test for cables, except that it is sometimes unsuitable for very thin wires (which are very desirable, as they have lower weight and occupy less space). In recognition of this, the National Electrical Code accepts the idea of substitutions for cables meeting more severe fire tests. This issue did not present a problem in NFPA 130, because the scope permitted substitutions. However, as the new FRA rule is intended to be mandatory, the following leeway should be allowed, accepting the substitutions, so that a cable required to meet a small-scale vertical test, such as the ICEA S-19 paragraph 6.19.6, or the UL VW-1 test, can be replaced by a cable meeting the requirements from any of the more severe tests: (a) IEEE 383 or UL 1685 or ASTM D5424/ASTM D5537; (b) UL 1666 (riser cable test) or (c) NFPA 262 (plenum cable test). This would ensure that fire safety is not dependent on simply cable thickness but on actual fire performance.

4. Wire and cable (Note 18): section 2.5 of IEEE 383 neither describes a circuit integrity test, nor describes how to test for circuit integrity, leaving room for misinterpretation and misapplication of the rule. NFPA 130 permits exceptions based on scope section 1-1.3; furthermore transit authority specifications have not included circuit integrity requirements within the flame test. Therefore, cables presently used in rail transit applications often do not meet the circuit integrity requirements. Thus, this vague reference to a circuit integrity test, should be replaced by a test requiring that one cable conductor not cease transmitting electricity during the first 5 min of test, as verified by a flashlight bulb remaining lit for the entire period. Alternatively, cables listed to a circuit integrity test, such as IEC 60331 [55] or ULC/ORD C854-1996, containing all the requirements, or the draft tests in UL 2196 or ULC S139, should be acceptable.

NFPA 130 - Scope Section 1-1.3: Nothing in this standard is intended to prevent or discourage the use of new methods, materials, or devices, provided that sufficient technical data are submitted to the authority having jurisdiction to demonstrate that the new method, material, or device is equivalent to or superior to the requirements of this standard with respect to fire resistance and safety.

The first of these comments is particularly important, but is basically an editorial correction: the ratio of time to ignition to rate of heat release has been inverted in the Rulemaking. The third comment is much more subtle, and requires explanation. The National Electrical Code details the fire test requirements for cables. It contains 4 types of test requirements: UL 1581 VW-1, UL 1581-1160 or UL 1581-1164, UL 1666 and NFPA 262, in degree of increasing severity. Of these tests, the UL VW-1 test can usually be met by any cable that has a thick enough insulation, irrespective of the fire performance of the insulating material used. The NEC understands, too, that, as a cable meets more severe fire test requirements, it can replace one that meets less severe requirements. Thus, the NEC permits cables meeting the UL
1581 cable tray test, the UL 1666 riser test or the NFPA 262 plenum cable test to be used in any application where the VW-1 test is required. This is particularly important in environments where space and weight are at a premium, such as a transportation environment (train or ship), where the “modern” trend is to develop cables with thinner walls.

CONCLUSIONS

Fires in public transportation are rare, but can affect multiple people if they occur. Furthermore, statistics indicate that electrical cables are a critical area in such environments. In recent years, this has led to more emphasis being placed on fire safety requirements for electric cables in various public transportation sectors: ships, trains and aircraft. In particular, the emphasis is moving towards the use of heat release and fire hazard assessment, so that tests can be chosen in order to obtain validated fire safety engineering test results, which can then be used as input into fire models. A fire hazard assessment developed as a result of these procedures should be able to assess a new product being considered for use in a vehicle, and conclude whether the new product considered is, or not, safer, in terms of predicted fire performance, than the one in established use. The result of such assessments will be the ability to design, with a high degree of confidence, public transportation vehicles which offer excellent fire protection to passengers, while incorporating as much comfort as is consistent with the fire safety required.

REFERENCES


[16] FED STD 191A Textile Test Method 5830, General Services Administration, Specifications Activity, Printed Materials Supply Division, Building 197, Naval Weapons Plant, Washington, DC, 20407. [The American Association of Textile Chemists and Colorists (AATCC, Research Triangle Park, NC) has issued the Standard Laboratory Practice for Home Laundering Fabrics prior to Flammability Testing, to Differentiate Between Durable and Non-durable Finishes (May 1, 1991). Although no AATCC formal equivalent standard exists, the practice mentioned can be useful as a replacement to the Federal Test Method, since the Federal Standards are in the process of being withdrawn.]


[21] ICEA S-19/NEMA WC3, Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy, Insulated Cable Engineers Association, South Yarmouth, MA.

[22] VW-1, in UL 1581, Reference Standard for Electrical Wires, Cables, and Flexible Cords, 1080. VW-1 (Vertical Wire) Flame Test (UL 1581 VW1), Underwriters Laboratories, Northbrook, IL.


[26] NFPA 70 (NEC), National Electrical Code, National Fire Protection Association, Quincy, MA.


[35] UL 1581, Reference Standard for Electrical Wires, Cables, and Flexible Cords, 1160. UL Vertical-Tray Flame Test, Underwriters Laboratories, Northbrook, IL.


[38] UL 1581, Reference Standard for Electrical Wires, Cables, and Flexible Cords, Section 1164. CSA Vertical-Tray Flame Test. Underwriters Laboratories, Northbrook, IL.


[40] UL 1666, Test for Flame Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts, Underwriters Laboratories, Northbrook, IL.

[41] NFPA 262, Standard Method of Test for Fire and Smoke Characteristics of Wires and Cables, National Fire Protection Assn., NFPA, Quincy, MA.


[49] UL 1685, Standard Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables. Underwriters Laboratories, Northbrook, IL.


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<thead>
<tr>
<th>Category</th>
<th>Function of Material</th>
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<th>Performance Criteria</th>
<th>Test Procedure</th>
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<td>I&lt;sub&gt;s&lt;/sub&gt; #25</td>
<td>ASTM E 662</td>
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<td>ASTM E 162</td>
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<td></td>
<td>Window, light diffuser</td>
<td>ASTM E 162</td>
<td>I&lt;sub&gt;s&lt;/sub&gt; #100</td>
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<td></td>
<td>Covering</td>
<td>ASTM E 648</td>
<td>C.R.F. $5 kW/m&lt;sup&gt;2&lt;/sup&gt;</td>
<td>ASTM E 662</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>ASTM E 162&lt;sup&gt;d&lt;/sup&gt;</td>
<td>I&lt;sub&gt;s&lt;/sub&gt; #25</td>
<td>ASTM E 662</td>
<td></td>
</tr>
<tr>
<td>Insulation</td>
<td>Thermal, acoustic</td>
<td>ASTM E 162</td>
<td>I&lt;sub&gt;s&lt;/sub&gt; #25&lt;sup&gt;e&lt;/sup&gt;</td>
<td>ASTM E 662</td>
<td>D&lt;sub&gt;s&lt;/sub&gt; (4.0) #100</td>
</tr>
<tr>
<td>Elastomers</td>
<td>Window gaskets, door nosing, diaphragms, roof mat</td>
<td>ASTM C 542</td>
<td>Pass</td>
<td>ASTM E 662</td>
<td>D&lt;sub&gt;s&lt;/sub&gt; (1.5) #100; D&lt;sub&gt;s&lt;/sub&gt; (4.0) #200</td>
</tr>
<tr>
<td>Exterior Plastic Components</td>
<td>End cap roof housings</td>
<td>ASTM E 162</td>
<td>I&lt;sub&gt;s&lt;/sub&gt; #35</td>
<td>ASTM E 662</td>
<td>D&lt;sub&gt;s&lt;/sub&gt; (1.5) #100; D&lt;sub&gt;s&lt;/sub&gt; (4.0) #200</td>
</tr>
<tr>
<td>Component Box Covers</td>
<td>Interior, exterior boxes</td>
<td>ASTM E 162</td>
<td>I&lt;sub&gt;s&lt;/sub&gt; #35</td>
<td>ASTM E 662</td>
<td>D&lt;sub&gt;s&lt;/sub&gt; (1.5) #100; D&lt;sub&gt;s&lt;/sub&gt; (4.0) #200</td>
</tr>
</tbody>
</table>

<sup>a</sup> NFPA 130 and FTA requirement is D<sub>s</sub> (1.5) #100; D<sub>s</sub> (4.0) #200
<sup>b</sup> "May use test criteria for floors or criteria appropriate to the physical locations and magnitude of the major ignition, energy, or fuel loading sources." 
<sup>c</sup> Amtrak requirement is C.R.F. $6 kW/m<sup>2</sup>
<sup>d</sup> NFPA 130 only
<sup>e</sup> Amtrak requirement is I<sub>s</sub> #35
Table 4. Federal Railroad Administration Notes to Table 3 [5]

C ASTM D 3675 & E 162: Materials tested for surface flammability should not exhibit any flaming running or flaming dripping; window and light diffuser panels need not meet the running or dripping requirement.

C Cushions, mattresses, seat upholstery, mattress ticking, and covers, curtains: The surface flammability and smoke emission characteristics of a material should be demonstrated to be permanent by washing, if appropriate, according to FED STD 191-A Textile Test Method 5830.

C Seat upholstery, mattress ticking, and covers, curtains: The surface flammability and smoke emission characteristics of a material should be demonstrated to be permanent by dry-cleaning, if appropriate, according to ASTM D 2724. Materials that cannot be washed or dry-cleaning should be so labeled and should meet the applicable performance criteria after being cleaned as recommended by the manufacturer.

C Window panels: For double window glazing, only the interior glazing should meet the material recommendations specified herein; the exterior need not meet those recommendations.

C ASTM E 662: ASTM E 662 maximum test limits for smoke emission (specific optical density) should be measured in either the flaming mode or the non-flaming mode, depending on which mode generates the most smoke.

C ASTM E 119: Structural flooring assemblies should meet the performance criteria during a nominal test period determined by the transit property. The nominal test period should be twice the maximum expected period of time, under normal circumstances, for a vehicle to come to a complete, safe stop from maximum speed, plus the time necessary to evacuate all passengers from a vehicle to a safe area. The nominal time period should not be less than 15 min. Only one specimen need be tested. A proportional reduction may be made in dimensions of the specimen provided that it represents a true test of its ability to perform as a barrier against undercar fires. Penetrations (ducts, etc.) should be designed against acting as passageways for fire and smoke.

C Floor coverings: Floor covering should be tested in accordance with Test Method E 648 with its padding, if the padding is used in actual installation.

C Seat or mattress frames: Arm rests, if foamed plastic, are tested as cushions, and, if hard material, are tested as a seat back shroud.

C Cushions and mattresses: Testing is performed without upholstery.

C Wall and ceiling panels, floor coverings: Carpeting on walls and ceilings are to be considered wall and ceiling panel materials, respectively.

C Elastomers: The fire test method in specification C 542 is Test Method C 1166.
TABLE 5. NEW FRA REQUIREMENTS FOR COMMUTER AND INTERCITY RAIL 

VEHICLE MATERIALS [50]

<table>
<thead>
<tr>
<th>Category</th>
<th>Function of Material</th>
<th>Test Procedure</th>
<th>Performance Criteria</th>
<th>Test Procedure</th>
<th>Performance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire and cable</td>
<td>Low voltage wire and cable</td>
<td>ICEA S-19 or UL 44 and UL 83 (Note # 17)</td>
<td>Pass</td>
<td>ASTM E 662</td>
<td>D_1 (4.0) #200 (flaming) D_1 (4.0) #75 (non flaming)</td>
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<td></td>
<td></td>
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<tr>
<td>Power cable</td>
<td>IEEE 383 (Note # 18)</td>
<td>Pass</td>
<td>ASTM E 662</td>
<td>D_1 (4.0) #200 (flaming) D_1 (4.0) #75 (non flaming)</td>
<td></td>
</tr>
</tbody>
</table>

See also notes # 10, 11 and 12

Notes to Table 5 [50]

10. Materials used to fabricate miscellaneous, discontinuous small parts, such as knobs, rollers, fasteners, clips, grommets, and small electrical parts) that will not contribute materially to fire growth in end use configuration may be exempted from fire and smoke emission performance requirements, provided that the surface area of any individual small part is not $400 square inches (100 cm²) in end use configuration and an appropriate fire hazard analysis is conducted which addresses the location and quantity of the materials used, and the vulnerability of the materials to ignition and contribution of flame spread.

11. If the surface area of any individual small part is less than 16 square inches (100 cm²) in end use configuration, materials used to fabricate such small part shall be tested in accordance with ASTM E 1354, unless such small part has been shown not to contribute materially to fire growth following an appropriate fire hazard analysis as specified in Note 10. Materials tested in accordance with ASTM E 1354 shall meet the performance criteria of t /q" max #1.5. Testing shall be at 50 kW/m² applied heat flux. (Note the error in the criterion)

12. Assessment of smoke generation by small miscellaneous, discontinuous parts may be made by utilizing the results from the ASTM E 1354 test procedure conducted in accordance with Note 11, rather than the ASTM E 662 test procedure, if an appropriate fire hazard analysis is provided which addresses the location and quantity of the materials used, and the vulnerability of the materials to ignition and contribution of smoke spread.

17. Testing shall be conducted in accordance with ICEA S-19/NEMA WC3, paragraph 6.19.6; or UL 44 for thermosetting wire insulation and UL 83 for thermoplastic wire insulation.

18. Testing shall be conducted in accordance with IEEE Standard 383, Section 2.5, with the additional requirement that circuit integrity shall continue for 5 minutes after the start of the test.
There is no set of ready, out-of-the-box rules to be followed universally. As with any unusual or emergency situation, controllers should exercise their best judgment and expertise when dealing with the consequences related to onboard electrical failures. A generic checklist for handling unusual situations is readily available from EUROCONTROL (see Further Reading below) but it is not intended to be exhaustive and is best used in conjunction with local ATC procedures.