5. APTA PR-PS-RP-005-00 Recommended Practice for Fire Safety Analysis of Existing Passenger Rail Equipment

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Abstract: This recommended practice addresses the fire safety analysis requirement contained in 49 CFR Section 238.103(d), for all categories of existing passenger railroad equipment and service. This recommended practice provides a logical succession of steps that a passenger railroad should use to perform the required fire safety analysis. This recommended practice provides guidance for making determinations as to which categories and levels of fire safety risks may be acceptable and unacceptable to that railroad for purposes of regulatory compliance.

Keywords: fire, fire safety analysis, hazard analysis, hazard assessment, hazard identification, MIL-STD-882-D, passenger rail equipment, risk, risk analysis, risk assessment

Introduction

(This introduction is not a part of APTA PR-PS-RP-005-00, Recommended Practice for Fire Safety Analysis of Existing Passenger Rail Equipment.)

On May 12, 1999 the Federal Railroad Administration (FRA) issued the final rule *49 Code of Federal Regulations (CFR), Part 238, Passenger Equipment Safety Standards. May 12, 1991.* As originally published, the fire safety analysis for existing passenger equipment in *49 CFR, Part 238.103 (d),* of this rule requires that each passenger railroad complete a preliminary fire safety analysis for its existing passenger equipment by July 10, 2000. This section of the rule also requires that railroads take remedial action for any fire risk deemed by the railroad to be unacceptable.

The preamble and section-by-section analysis of *49 CFR, Part 238,* provides general guidance to railroads for how to perform the fire safety analysis. In addition, the FRA final rule *49 CFR, Part 239, Passenger Train Emergency Preparedness* as issued on May 4 1998, includes a requirement for one fire extinguisher per rail car.

The Federal Register notice for *49 CFR, Part 238* notes that *MIL-STD-882-C, Military Standard System Safety Program Requirements* (which has since been superceded by *MIL-STD-882-D*) leads a railroad through the steps necessary to perform a fire safety analysis. Although *MIL-STD-882-C* does not itself define what an acceptable level of risk is once the analysis is performed, FRA explains that defining an acceptable level of risk is a judgment best left to each railroad based on its own unique circumstances (such as operating history, equipment design and operating environment characteristics).

On July 2, 1999, the American Public Transportation Association (APTA) submitted to FRA APTA Petition for Reconsideration, Docket Number FRA PCSS-1, Notice 5, July 2, 1999. As part of this petition, APTA noted that the required fire safety analysis would require railroads to make important subjective judgments and that railroads—particularly those without in-house engineering staffs—need more specific guidance to assist them in making these subjective judgments. Accordingly, APTA requested that FRA grant an additional six months in order to develop an industry practice for performing fire safety analyses.

FRA responded to the fire safety analysis concerns raised by *APTA's Petition for Reconsideration with FRA Letter from Jolene M. Molitoris to William W. Millar, dated October 8, 1999*. The FRA agreed to amend the final rule to provide a time extension until January 10, 2001 to the railroads to complete a preliminary fire safety analysis for each category of existing rail equipment and current service. FRA reiterated that for any category of equipment and service identified during the preliminary analysis as likely presenting unacceptable risk, a full analysis and any necessary remedial action to abate unacceptable risks are required by July 10, 2001. Further, a full fire safety analysis for all categories of equipment and service, and any necessary remedial action to mitigate unacceptable risks, are required by July 10, 2003.

1 For references in Italics, see Section 2 of this Standard.

FRA also stated its understanding that most commuter railroads intend to conduct full fire safety analyses for all categories of their rail equipment and service by January 10, 2001 instead of first performing separate, preliminary analyses. FRA therefore made clear that a railroad need not perform separate, preliminary fire safety analyses provided that by the same deadline of January 10, 2001 they complete fire safety analyses that fully cover and scrutinize all categories of their rail equipment and service. (Please read the *FRA Letter, October 8, 1999* for a full discussion of this issue.) The approach of this recommended practice is to guide a railroad through the performance of final fire safety analyses for all categories of its equipment and service by January 10, 2001, so as to determine whether any unacceptable fire safety risks exist with respect to its equipment and service.

In addition, FRA noted that any fire safety analysis required under *49 CFR, Part 238.103 (d)* must include consideration of relevant fire safety risks, including potential ignition sources, presence or absence of heat/smoke detection systems, known variations from the required material smoke/flame test performance criteria, and availability of rapid and safe egress to the exterior of a vehicle.

Lastly, FRA noted that railroads should consider, as appropriate, the following elements contained in the fire safety analysis for procuring new passenger equipment in *49 CFR, Part 238.103 (c)* in performing their fire safety analyses:

a) Identify, analyze and prioritize the fire hazards inherent in the design of the equipment;

b) Reasonably ensure that a ventilation system in the equipment does not contribute to the lethality of a fire;

c) Identify any components that pose a fire hazard due to overheating and analyze the benefit of overheat protection for these components;

d) Identify any unoccupied train compartment that poses a fire hazard and analyze the benefit of including a fire and/or smoke detector in that compartment;

e) Identify the need for fire extinguishers;

f) On a case-by-case basis, consider the benefit of fixed, automatic fire suppression systems.

This recommended practice incorporates these considerations and provides more detailed guidance for performing a fire safety analysis.

In addition, FRA responded to the *APTA Petition for Reconsideration* asking for clarification of the use of the "Table of Test Methods and Performance Criteria" published in Appendix B of *49 CFR, Part 238* with the *FRA Letter from Jolene M. Molitoris to William Millar, dated November 5, 1999*. The materials requirements as published *49 CFR, Part 238.103 (a),* state that on or after November 8, 1999, materials introduced in a passenger rail car or locomotive cab, as part of any rebuilt, refurbished, or overhauled piece of equipment, shall meet the performance criteria in *49, CFR, Part 238 Appendix B*. The FRA stated in the November 5 letter that for a transitional period (to be

specified in the *October 8 response letter to the APTA Petition For Reconsideration*), railroads could use the original table contained in the *Passenger Equipment Rule Notice of Proposed Rulemaking (NPRM) published on September 23, 1997* rather than the table published in Annex B of *49 CFR, Part, 238*. The FRA also explained that the requirements contained in each table as a whole were to be followed and that partial usage of either table to meet the rule was not permitted. (Please see the *November 5, 1999* letter for a more thorough discussion of these issues.)

49 CFR, Part 238.103 (d) makes clear, however, for the purpose of effecting any required remedial action to resolve an unacceptable fire safety risk, a railroad may not have to replace materials that do not comply with the required flammability and smoke emission criteria specified in Appendix B of *49 CFR, Part 238* if the risk from the material is negligible based on the railroad's operating environment and the material's size and/or location or the railroad takes other actions that reduce the risk to an acceptable level.

For the purposes of this recommended practice, the railroad's fire safety analysis should place categories of equipment and operating service into hazard classifications. Those fire hazards resulting in Category 1, "Unacceptable" risks as described in Section 10.3 of this recommended practice requiring priority remedial action, must be identified by January 10, 2001 and resolved by July 10, 2001. The list of all priority remedial actions developed by the railroads for all categories of equipment and service must be implemented by July 10, 2003.

The FRA rule also requires a fire analysis of existing equipment to be completed within 90 days of transferring equipment to a new category of service, taking into consideration the change in railroad operations and that the railroad take prompt action to reduce identified risk to an acceptable level. As adapted, this recommended practice may be used to complete such an analysis.

49 CFR, Part 238.103 (d) and this recommended practice provides a systems approach to fire safety beyond simple compliance with *49 CFR, Part 238 Annex B, Test Methods and Performance Criteria for the Flammability and Smoke Emission Characteristics of Materials Used in Passenger Cars and Locomotive Cabs*. Assessment of the following considerations may reduce the fire safety risk to an acceptable level and/or assure safe evacuation of the occupants prior to the development of lethal heat or smoke conditions:

- Type of material that is used
- Where the material is used
- How much of the material is used
- Material distribution in the car
- Proximity of material to ignition sources

However, to be complete, the fire safety analysis must be part of a systems approach to reducing/mitigating risk of personal injuries from other passenger rail car fire hazards, and consider:

- Fire containment;
- Fire detection and suppression;
- Passenger and crew emergency evacuation;
- Access by emergency responders.

On June 25, 2002, FRA issued a revision of the fire safety requirements contained in 49, CFR 238.103, as well as Appendix B of the rule. As stated in the correspondence between APTA and FRA, the deadline for the completion of final fire safety analyses was extended to July 10, 2003. The rule clarified certain definitions and provided an explanation of the waiver process. In addition, certain revisions were made to 238.103 238(d) to clarify that although the railroads must consider the presence of other passenger equipment such as baggage cars that operate in same trains with passenger cars and locomotives for the purpose of evaluating passenger car and locomotive occupant safety, the focus of the required fire safety analyses to be conducted by the railroads was passenger rail cars and locomotive cabs. In addition, certain revisions were made to the requirements for new equipment as contained in 238.103 (c). Although it may not be necessary that the railroad replace materials, based on the results of the fire safety analysis, it is noted that several revisions were also made to the table of tests and performance criteria included in Appendix B of the rule.

Participants

The American Public Transportation Association greatly appreciates the contributions of the following individual(s), who provided the primary effort in the drafting of the *Recommended Practice for Fire Safety Analysis of Existing Passenger Rail Equipment*:

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In addition, APTA would like to thank Stephanie Markos of the Volpe National Transportation Systems Center (Volpe Center), for her extensive technical research and assistance in the preparation of this document.

At the time that this recommended practice was completed, the Passenger Rail Equipment Safety Standards (PRESS) Passenger Systems Committee included the following members:

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1. Overview

The commuter railroads and Amtrak have voluntarily developed system safety program plans in accordance with the *American Public Transportation Association (APTA) Manual for the Development of Commuter Railroad System Safety Program Plans, Rev. 5/99*[2]. Accordingly, the completion of a fire safety analysis for existing equipment is a logical extension of a passenger railroad's system safety program plan.

Every effective system safety program has four essential elements:

a) A means to identify and prioritize safety risks (a hazard analysis);

b) An action plan that, over time, allocates resources to reduce the most severe risks;

c) A means to monitor, measure, and document the effectiveness of the action plan;

d) Periodic adjustment of the action plan based on the measured effectiveness and as service or equipment characteristics change.

Therefore, the process for performing the Federal Railroad Administration (FRA) required fire safety analysis described in this recommended practice would address these same essential elements.

This recommended practice

– Describes the federal requirement for the fire safety analysis of existing passenger rail equipment and service

– Provides a logical, systematic process that railroads can use to perform the required fire safety analysis

– Gives common meaning to key terms and concepts

1.1 Scope

This recommended practice addresses the fire safety analysis for existing passenger equipment required by *49 Code of Federal Regulations (CFR), Part 238.103 (d)*, for all categories of existing passenger railroad equipment and service. APTA considers a "category of equipment and service" to be a particular equipment design or group of designs with nearly identical fire safety characteristics in the context of the operating environment in which that equipment design is used.

2 For references in Italics, see Section 2.

49 CFR, Part 238.103 (d) considers that relevant fire risks for each category of equipment and service include:

a) Available ignition sources;

b) Presence or absence of heat/smoke detection systems;

c) Known variations from the material test fire performance criteria or other alternative standards approved by the FRA;

d) The availability of rapid and safe egress to the exterior of the vehicle under conditions secure from smoke and other hazards.

This recommended practice describes the process that railroads should use to address these fire risks, as well as others that may be identified during the fire safety analysis.

1.2 Purpose

Passenger railroads should use this recommended practice to assist engineering staff or to provide guidance in developing a statement of work in order to hire a consultant to perform a fire safety analysis consistent with the requirements of *49 CFR, Part 238, Section 238.103 (d)* for their existing equipment.

This recommended practice describes a logical succession of steps for a railroad to consider when performing a fire safety analysis on their existing passenger rail equipment. It contains guidance to specifically assist in the development of information as to what categories of fire safety risks are acceptable and which are unacceptable.

1.3 Responsibility for performing fire safety analysis

The Passenger Rail Equipment Safety Standards (PRESS) Task Force Passenger Systems Committee developed this recommended practice for performing a fire safety analysis of existing passenger railroad equipment to meet the intent of *49 CFR, Part 238.103 (d).* Whatever entity performs the overall fire safety analysis, responsible personnel should be designated by title, organization, phone number, etc., for each step of the process summarized in Section 4. This will help ensure that railroad and contractor accountability is maintained during the entire fire analysis process. Accountability is particularly important since the credibility and effectiveness of the fire safety analysis process relies on the meaningful hazard assessment and priority remedial action implementation to reduce the potential risk of personal injury due to fire incidents.

2. References

AAR-S-580, Standard for Locomotive Crashworthiness Requirements.

APTA, Manual for the Development of Commuter Railroad System Safety Program Plans, Rev. 5/99.

APTA, Petition for Reconsideration, Re: Docket Number FRA PCSS-1, Notice 5, July 2, 1999.

ASTM E 2061-00, Standard Guide for Fire Hazard Assessment Standards for Fire Hazard Assessment of Rail Passenger Vehicles, Conshohocken, PA.

49 CFR, Part 238, Passenger Equipment Safety Standards: Subpart A—General, Subsection 238.5, Definitions, May 12, 1999.

49 CFR, Part 238, Passenger Equipment Safety Standards: Subpart B—Safety Planning and General Requirements, Subpart A—General, Subsection 238.5, Definitions, Subsection 238.103, Fire Safety, and Appendix B, Test Methods and Performance Criteria for the Flammability and Smoke Emission Characteristics of Materials Used in Passenger Cars and Locomotive Cabs. May 12, 1999. **And as clarified by FRA on June 25, 2002 with revisions to Subection 238.103 and Appendix B of the rule**.

FRA, 49 CFR, Part 238, Passenger Equipment Safety Standards, Notice of Proposed Rulemaking (NPRM), September 23, 1997.

FRA, 49 CFR, Part 239, Passenger Train Emergency Preparedness, May 4, 1998.

FRA Letter, From Jolene M. Molitoris to William W. Millar, dated October 8, 1999.

FRA Letter, From Jolene M. Molitoris to William W. Millar, dated November 5, 1999.

FRA Railroad Safety Statistics Annual Reports, Accidents/Incidents, January 1985-December 1998.

MIL-STD-882-C, Military Standard System Safety Program Requirements.

MIL-STD-882-D, Standard Practice for System Safety February, 2000.

NFPA Society for Fire Protection Engineers (SPFE) Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings, Quincy, MA 2000.

NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems, Quincy, MA 2000.

Volpe Center/FTA, Fire Safety Countermeasures for Urban Rail Vehicles, Report No. FTA-MA-06-0200-92-1, July 1992.

Volpe Center/FTA, Fire Safety in Transit Systems Fault Tree Analysis, Report No. UM147-PM-81-51, September 1981.

Volpe Center/FTA Identification of the Fire Threat in Urban Transit Vehicles, Report No. UMTA-MA-06-0051-80-1, June 1980.

49 CFR, Part 225, Railroad Accidents/Incidents: Reports, Classification, and Investigations.

3. Definitions, abbreviations, and acronyms

3.1 Definitions

For the purposes of this standard, the following terms and definitions apply:

3.1.1 acceptable fire risk: A combination of available fire hazard severity information and fire scenario probability for a given category of equipment and service determined to be inside Category 4 "Acceptable" risk region of the fire risk matrix (see Section 10.3) requiring no corrective action.

3.1.2 category of equipment and service: A particular, specified equipment design or group of designs with nearly identical fire-resistance and evacuation characteristics when taken in combination with the operating environment in which the equipment is used.

3.1.3 fire hazard: The potential for harm that results in a given fire scenario. This potential for harm is a result of many variables that affect ease of ignition, rate of fire growth as expressed through flame spread, rate of heat release, smoke generation, and visual obscuration.

3.1.4 fire safety design features: Aspects of equipment design or other aspects of the railroad system design that are intended to reduce the severity and frequency of fire incidents; for example, the selection of flame-retardant materials.

3.1.5 fire risk: The potential for a given fire scenario that results in personal injury to occur, often expressed in terms of hazard severity and scenario probability.

3.1.6 fire risk matrix: A decision tool that can be used by railroads to determine whether a fire safety risk is acceptable or unacceptable.

NOTE--APTA developed the fire risk matrix by adapting the risk assessment methodology in *MIL-STD-882-D, Military Standard System Safety Program Requirements* to accommodate the passenger railroad-operating environment.

3.1.7 fire scenario: The sequence of events resulting from a fire hazard in a specific environment on a specific type of equipment.

3.1.8 hazard severity: A subjective measure of the worst credible consequences resulting from the hazard.

3.1.9 locomotive cab: The compartment or space where the control stand is located and which is normally occupied by the engineer when the locomotive is operated.

3.1.10 operating environment: The way equipment is used from a fire safety point-of-view. Operating environments are different only if some aspects of one environment pose a significant fire hazard or evacuation restriction that does not exist in another operating environment, e.g., a tunnel. If significant fire hazards and evacuation scenarios are the same, then two operating environments can be adjudged the same.

3.1.11 passenger equipment: All powered and unpowered passenger cars, locomotives used to haul a passenger car, and any other rail rolling equipment used in a train with one or more passenger cars (see *CFR, Part 238.5, Definitions*).

3.1.12 unacceptable fire safety risk: A combination of fire hazard severity and fire scenario probability for a given category of equipment and service determined to be outside the "no corrective action required" region of the fire safety risk matrix.

3.2 Abbreviations and acronyms

AAR	Association of American Railroads
APTA	American Public Transportation Association
ASTM	American Society for Testing and Materials
CFR	Code of Federal Regulations
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HVAC	heating, ventilation and air conditioning
LLEPM	low-location exit path marking
MARC	Maryland Rail Commuter Service
NFPA	National Fire Protection Association
NPRM	notice of proposed rule making
PRESS	Passenger Rail Equipment Safety Standards
RRT	rapid rail transit
SAMIS	safety management information statistics
SPFE	Society for Fire Protection Engineers
UMTA	Urban Mass Transportation Administration
Volpe Center	Volpe National Transportation Systems Center

4. Summary of recommended fire safety analysis steps

The following steps summarize the fire safety analysis and fire safety remedial action approach recommended by this document:

Step	Action required
1	Compile, as accurately as possible, an historic record of equipment fire incidents on your railroad. If necessary you may use operating histories of other railroads that operate similar equipment in similar fire safety environments.
2	Implement a program to keep complete and accurate fire incident records and establish reliable methods to retrieve and review such data.
3	Take an inventory, from a fire safety features point-of-view, of each type (design) of equipment used in passenger service. Determine the number of particular equipment design categories that the railroad operates.
4	Determine the number and characteristics of significantly different fire safety operating environments present on the railroad.

Step	Action required
5	Determine the number of categories of equipment and service in operation on the railroad. A separate fire safety analysis must be done on each category.
6	Develop a list of significant ignition sources for each category of equipment and service.
7	Assess the hazard severity and the impact of existing fire safety design features and other countermeasures for each category of equipment and service.
8	Identify fire scenarios that could result in personal injury to passengers and crewmembers.
9	Estimate the frequency of occurrence and the consequences of fire scenarios/incidents resulting from ignition source hazards not resolved in Step 8. Use these estimates to determine the priority of remedial action for remaining Category **1**, **2**, and **3** hazards (see Section 10.3). Repeat the process for each category of equipment.
10	Develop and execute a fire safety remedial action plan if any fire safety hazard for any category of equipment and service has an unacceptable fire risk rating.
11	Apply countermeasures to fire hazards that pose unacceptable risks in terms of the likelihood of the selected fire scenarios/incidents and re-evaluate.
12	Monitor, track and update the fire safety remedial action plans.

The basic steps of the Recommended Fire Safety Analysis process will be placed in bold-italic font highlighted by text boxes throughout the text of this recommended practice.

Fire Safety Analysis Step 1

Compile, as accurately as possible, a historic record of equipment fire incidents on your railroad. If necessary, you may use operating histories of other railroads that operate similar equipment in similar fire safety environments.

(see Section 5 below)

5. Existing fire incident statistics

5.1 General discussion of industry-wide fire incident statistics

As a starting point for the conduct of fire safety analysis for existing passenger railroad equipment, relevant passenger railroad fire incident reports and statistics must be examined. Four main sources of U.S. passenger railroad fire data are:

a) *FRA Accident/Incident Database*

b) Federal Transit Administration (FTA) safety management information statistics annual reports

c) The National Fire Protection Association (NFPA) data base

d) Maintenance record of individual passenger railroads

(Additional information can be found in Annex B.)

5.2 Guidance for using railroad-specific historical fire incident data

APTA has provided the FRA fire accident/incident data to each individual railroad. As the first step of a fire safety analysis of existing equipment and service, each railroad should search its own records for additional historical fire incident data, e.g., those incidents which did not meet federal reporting thresholds.

If a railroad has not been in operation long enough to establish a significant fire safety history, that railroad should use the fire safety histories of other railroads operating similar equipment in similar fire safety environments as part of its analysis.

Fire Safety Analysis Step 2

Implement a program to keep complete and accurate fire incident records and establish reliable methods to retrieve and review such data.

(see Section 5.3 below)

5.3 Guidance to railroads for fire incident statistics record keeping

Maintaining complete and accurate records of fire safety incidents will be crucial to determine the effectiveness of changes made as a result of the fire safety analysis. If a railroad does not keep such records, it needs to quickly adopt and enforce a policy to do so. Internal reports should be maintained as part of the record keeping to ensure that hazard and risk assessments are supported by accurate statistics. The incident reports should include, as a minimum:

– Date

– Location

- Time
- Equipment type
- Type and location of ignition source
- Type and quantity of material involved
- Method of extinguishment
- Repairs made
- Number of deaths and injuries

Fire Safety Analysis Step 3

Take an inventory, from a fire safety features point-of-view, of each type (design) of equipment used in passenger service. Determine the number of particular equipment design categories that the railroad operates.

(see Section 6 below)

6. Inventory of each category of existing equipment

As part of the foundation for the fire safety analysis, each railroad must develop an inventory of each equipment design that it operates in passenger service including coaches, food service and sleeping cars. Consideration should be given to fire safety features pertinent to the railroad including the following:

6.1 Construction materials

A materials matrix should be developed which indicates compliance with Appendix B of *49 CFR, Part 238*. The considerations below should be examined further if the materials do not meet the *49 CFR, Part 238 Appendix B* criteria.

- Type of material (including material safety data sheets)
- How much material used
- Location of materials
- Proximity to ignition source
- Distribution in the car

NOTE--*49 CFR, Part 238.103 (d)* states that it may not be necessary to remove materials that may not meet the performance criteria of *49 CFR, Part 238 Appendix B*, depending on the quantity, location and distribution of those materials and the proximity of ignitions sources.

6.2 Passenger car/locomotive cab design characteristics

Each railroad should describe the following:

a) Number, size and location of doors

b) Types of doors (power/manual/trap doors)

c) Car levels, separate rooms

d) Communications equipment used by passengers and/or crews

e) Car length

f) Compliance with the Association of American Railroads *(AAR) S-580, Standards for Locomotive Crashworthiness Requirements*

g) Ventilation system and control

h) Fire detection/suppression systems, including fire extinguishers as required by *49 CFR, Part 239, Passenger Train Emergency Preparedness*

i) Floor design/construction for fire delay

j) Distance between emergency exits

k) Number, width of stairways; other characteristics (e.g., spiral or turns)

l) Width of passageways

m) Number/size/location of emergency exits (e.g., windows, etc.)

n) Emergency light levels/duration

o) Emergency signage

p) Low-level exit path marking system (LLEPM)

q) Location and type of trash receptacles

The railroad should use this survey to determine the number of particular equipment designs that are included among the categories of equipment it operates.

Fire Safety Analysis Step 4

Determine the number and characteristics of significantly different fire safety operating environments present on the railroad.

(see Section 7 below)

7. Identify operating environments

Each passenger railroad also must determine the number of operating environments that it operates in. To do this, the railroad must define the operating environment(s) in which the equipment is used from a fire safety point-of-view. A railroad may have to consider more than one operating environment depending upon the presence of the following factors/conditions:

a) Operation through tunnels

b) Number and type of grade crossings

c) Potential exposure to hazardous material

d) Electric power lines

e) Third rail

f) Catenary

g) Proximity to pipelines

h) Shared rail line and right of way usage

i) Adjacent rail line/highway usage

j) Proximity to emergency responders

k) Other significant fire hazards posed by the operating environment (bridges, mountainous terrain, remote locations, etc.)

Fire Safety Analysis Step 5

Determine the number of categories of equipment and service in operation on the railroad. A separate fire safety analysis must be done for each category.

(see Section 8 below)

8. Determine categories of equipment fire safety design and service

The FRA requires a fire safety analysis for each category of equipment and service. Utilize the number of unique equipment fire safety designs determined in Fire Safety Analysis Step 3 (Section 6) and the number of fire safety operating environments determined in Step 4 (Section 7) to define the number of categories of equipment and service that are part of the railroad's operation (Step 5/Section 8). The railroad must perform a separate fire safety analysis for each category of equipment and service. If a railroad uses a particular equipment design in operating environments that are

significantly different, the railroad will have to perform more than one fire safety analysis for that category.

9. Fire hazard analysis

This section describes a formal, written, systematic process that railroads should use to resolve fire hazards that could result in the occurrence of fire scenarios leading to the potential personal injury of passenger and crew. This process is directed at identifying ignition source hazards, assessing their severity, and identifying countermeasures. This analysis uses the results of the collected fire incident data of Fire Safety Analysis Step 1 (Section 5) and the determined number of equipment and service categories in operation on each railroad (Step 5/Section 8) as a starting point.

While railroad incident statistic reports and maintenance records may provide information about past fire incidents, it is important that the analysis include not only past fire incidents, but also those that are possible but have not yet occurred. In order to ensure that the analysis is thorough, personal experience, maintenance records, judgment, and records of incidents at other railroads using similar equipment and operating environments must be utilized, in addition to any prior internal railroad fire analysis. The risk analysis described in Section 10 will only be meaningful if all potential fire scenarios have been considered.

To effectively reduce the occurrence of fire scenarios, a comprehensive fire hazard analysis will help ensure that

a) All potential fire hazards have been identified

b) Their impacts (i.e., severity) have been evaluated

c) Appropriate preventive countermeasures to eliminate or control hazards are applied in order to minimize personal injury

Fire Safety Analysis Step 6

Develop a list of significant ignition source hazards for each category of equipment and service.

(see Section 9.1 below)

9.1 Fire hazard identification

As a minimum, railroads should identify hazards associated with the following components, materials or ignition sources:

a) Traction motor

b) Group box

c) Power dissipation resistor

d) Reactors

e) Pantograph, Catenary

f) Current collector and third rail

g) Transformer

h) Braking system

i) 480 volt electrical system

j) heating, ventilation and air conditioning (HVAC)

k) Low voltage electrical system (lights, battery, doors, wire and cable, etc.)

l) Other electrical systems

m) Oil and hydraulic fluid leaks

n) Fuel (internal and external)

o) Food service equipment

p) Trash fires

q) Vandalism

r) Baggage, express or other cargo

s) Hazardous materials from freight trains or motor carrier operations

Other hazards, new combinations of hazards or new items not previously found in the rail environment must also be considered. Judgment and experience of the railroad is critical to ensure that all potential hazards are identified. As guidance:

– *Volpe National Transportation Systems Center (Volpe Center), Fire Safety in Transit Systems Fault Tree Analysis, Report No. UM147-PM-81-51*: contains a fault tree analysis identifying rail transit vehicle fire hazards. Numerous examples of fire hazards leading to the undesired event of a passenger/crew casualty are identified**.**

– Annex C (of this recommended practice) contains an example of a fault tree illustrated in that report

– *Volpe Center, Fire Safety Countermeasures for Urban Rail Vehicles, Report No. FTA-MA-06-0200-92-1*: provides an extensive discussion of rail transit fire ignition sources focusing on undercar equipment. The information in this reference and the documents noted above may be useful for identifying passenger

rail car hazards since many of the rail transit ignition sources could be the same for passenger rail cars.

– Annex D (of this recommended practice) contains a sample template that can be used as guidance for documenting the results of the fire hazard analysis. This template is intended to identify any countermeasures used to address any identified hazards and to provide documentation of the hazard severity for each hazard before and after any applied countermeasures.

Fire Safety Analysis Step 7

Assess the hazard severity and the impact of existing fire safety design features and other countermeasures for each category of equipment and service.

(see Section 9.2 and 9.3 below)

9.2 Fire hazard severity assessment

The location of the fire and the location of the train should be considered when evaluating the severity of hazards. For example, two major categories of rail car fires include:

a) Interior fires

b) Undercar or other exterior fires

The operation in a tunnel would increase the severity of hazard from either type of fire and thus increase the potential risk (i.e., probability) of passenger or crew injury.

The severity of the hazard may decrease due to the existing fire safety related design of the equipment as inventoried according to Fire Safety Analysis Step 3 (Section 6), additional countermeasures through car design/modifications and/or procedural adjustments, and the operating environment. With effective countermeasures, a hazard that is significant in severity may be reduced to an acceptable level. The following sections describe the hazard analysis process in more detail.

Identifying the severity of the potential established fire hazards can be based on engineering judgment, previous experience with similar hazards, or engineering calculations. Several references are available that provide guidance for determining the hazard resulting from potential ignition sources. The *American Society for Testing and Materials (ASTM) E 2061*-00, *Standard Guide for Fire Hazard Assessment of Rail Passenger Vehicles* provides a guide specific to passenger rail cars that can be used to predict or provide a quantitative measure of the fire hazard from a specified set of fire conditions involving specific materials, products, or assemblies in a railcar. The Society for Fire Protection Engineers (SPFE) Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings provides an overall engineering guide to performance-based fire protection. Both the ASTM and the SFPE guides identify the important considerations that should be included in fire hazard analyses. However, it is important to note that moving rail vehicles function in a totally different operating environment than stationary buildings. Accordingly, fire hazard assessments using either

the ASTM or SFPE provisions for meeting FRA passenger railroad fire safety regulations must be carefully tailored and evaluated to ensure that an equivalent level of safety to that required by the FRA regulation and provided for by the use of this APTA recommended practice is provided.

For categorizing hazard severity, the following numerical values and definitions are suggested:

- 1 Catastrophic: Fire involving loss of life or serious injury, usually due to impossibility of evacuation and/or lack of smoke control. Example: "Crash and burn" in which passengers are trapped in burning cars or major fire in a tunnel where smoke cannot be controlled. The difference between serious and catastrophic is likely to be evacuation, smoke control in tunnels and emergency response time.

- 2 Serious: Fire that may cause lost time injuries (such as smoke inhalation) or hospitalization. Evacuation required. Evacuation is possible in time to avoid fatalities. May involve significant property loss, such as an entire car or locomotive. Examples: major under-car, interior car fire or external fuel fed fire from which timely evacuation is possible. The key to this category is that evacuation is possible in time to avoid fatalities, although the fire is serious.

- 3 Significant: Limited fires that do not cause lost time injuries or hospitalization. Evacuation of vehicles may occur, but is not required for life safety. Example: Rectifier panel fire or other fire that may be large or smoky, but goes out when the power is removed. Under-car fires in this category will not penetrate the floor. Interior fires will be limited in extent, such as a duct heater fire that may produce smoke inside the car but goes out due to a fusible link opening. Fire department response will usually be needed for significant fires. Most grease fires and running gear fires will be in this category

- 4 Negligible: Small fires that do not cause any injuries or evacuation, for example, traction motor lead connection burns open, small trash fires that burn out quickly, third rail shoe beam fires that are extinguished by train crews. Fire department response is not necessary

NOTE--The injuries/deaths considered in the above hazard examples would be to passengers or on-duty employees. Property damage would not be a factor. Unoccupied or unattended vehicles not part of an in-service train would not be considered.

9.3 Equipment and other fire safety design features

For each category of the equipment and service, the railroad should identify the existing fire safety design features and other countermeasures that can be used to mitigate/control the severity of the hazard. Countermeasures could include one or more of the following:

a) Flame/smoke containment

b) Flame/smoke detection/notification

c) Flame/smoke suppression

d) Passenger and crew evacuation (if necessary)

The railroad should consider, as a minimum, some of the previously identified car design characteristics listed in Section 6.2. Other countermeasures should be considered that may not be part of the equipment design, such as emergency procedures and training, as specified in each passenger railroad's emergency preparedness plan as required by *49 CFR, Part 239*.

Volpe Center, Fire Safety Countermeasures for Urban Rail Vehicles, Report No. FTA-MA-06-002-92-1 provides an extensive discussion of rail transit fire safety countermeasures that could also be applied to passenger rail equipment fire ignition sources and other hazards. *NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems* also specifies design provisions that may be used as guidance in identifying countermeasures. Railroads may find the information in these documents useful in developing countermeasures for passenger rail equipment fire hazards since many commonalties could exist between urban rail vehicles and passenger rail systems.

The initial severity of the hazards can then be revised to reflect the result of applying the countermeasure(s). For any hazard still assigned a Category **1**, **2**, or **3** rating (see Section 10.3), the likelihood and consequences of the resulting fire scenario must be estimated to determine the fire risk and establish the priority for remedial action.

Fire Safety Analysis Step 8

Identify fire scenarios that could result in personal injury to passengers and crewmembers.

(see Section 10 below)

10. Fire risk assessment

A fire scenario is defined as the sequence of events resulting from a fire hazard in a specific environment on a specific type of equipment. In Fire Safety Analysis Step 8, any hazards previously identified that are not resolved by effective fire safety design features or other countermeasures must be analyzed in terms of their contribution to fire scenarios that could result in personal injury to passengers and crewmembers.

In order for this step to be manageable, similar fire hazards with their severity ratings should be combined into groups; for example: major undercar fires that do not penetrate the floor into the passenger occupied space. With the addition of fire department response time, probable evacuation time, and other aggravating or mitigating circumstances, groups of scenarios each with respective severity rating can be identified.

The location of the fire (interior or exterior) and of the train (e.g., in tunnel) and other complicating factors have an impact on the selected fire scenario. For example, a fire caused by an act of vandalism (e.g., throwing a lighted match into trash receptacle), could occur inside the car, be detected by a train crewmember, and then suppressed by a

crewmember (using an on-board fire extinguisher). A variation could be that the crewmember is unable to suppress the fire with the fire extinguisher, evacuation of the car is necessary, and emergency responders must be summoned to suppress the fire. The time to notify the fire department and their response time must be considered. Annex B of *Volpe Center, Identification of the Fire Threat in Urban Transit Vehicles, Report No. UMTA-MA-06-0051-80-1* describes several rail transit fire scenarios. Many of those scenarios are consistent with real and potential rail passenger equipment fire incidents. Annex E of the above Volpe report contains an example of a scenario. Passenger railroads may find such an approach helpful in their scenario review and rating process.

It is important that the railroad consider each possible variation of circumstances surrounding a potential fire when identifying fire scenarios and whether or not these variations have actually occurred or may possibly occur. Otherwise, the risk analysis will not be meaningful.

A fire risk assessment compares the likelihood of a scenario occurrence with the consequences (severity) of the fire hazard (i.e., ignition source). Risk assessment normalizes different hazards so that scenarios can be compared to produce a total risk index rating. For example, a scenario with serious consequences with low likelihood of occurrence and a scenario with low consequences but frequent occurrence may be said to represent equal risk.

To determine the acceptable risk of personal injury resulting from the identified fire scenarios, it is necessary to combine the severity of the ignition source and the likelihood of the scenario. The following sections provide guidance in determining how to assign priority to remedial actions to eliminate or mitigate the level of unacceptable risk posed by the high likelihood of fire scenarios involving a high severity hazard.

Fire Safety Analysis Step 9

Estimate the frequency of occurrence and the consequences of fire scenarios/incidents resulting from ignition source hazards not resolved in Step 8. Use these estimates to determine the priority of remedial action for remaining Category 1, 2 and 3 hazards. Repeat the process for each category of equipment.

(see Section 10.1 below)

10.1 Categorizing risk

The concept of "acceptable risk" is key to the fire safety analysis mandated by the FRA. The FRA regulation *49 CFR, Part 238.103(d)* refers to "risk of personal injury," however, what constitutes "acceptable risk" of personal injury must be defined by each railroad. The level of risk that our society accepts changes with time. Hazards that were willingly accepted at the beginning of railroad travel, such as fragile wooden cars with coal stoves for heat are now considered totally unacceptable. This section provides guidance to railroads for defining what an acceptable level of fire risk is for U.S. passenger rail service at this time.

MIL-STD 882-D and *APTA, Manual for the Development of Commuter Railroad System Safety Program Plans, Rev. 5/99* provide some guidance for risk assessment, but further judgment and interpretation is required to apply this guidance to passenger rail equipment fire safety.

One approach can be based on current safety and ridership statistics (e.g., the combination of no fire fatalities on passenger rail in the last two years and a general increase in ridership leads to the public perceiving passenger rail service as safe). This approach defines as acceptable a risk level likely to result in similar statistics in future years as those of the past two years. Note that this is not the same as saying that the current risk level is acceptable. Fire hazards may exist that, if not identified and resolved, may adversely affect the statistics.

Also note that this approach confirms that residual risk remains. Serious incidents, while improbable or only remotely probable, may occur. The following table, adapted from that contained in *MIL-STD 882-D* and *APTA, Manual for the Development of Commuter Railroad System Safety Program Plans* provides one alternative to assess the risk of personal injury resulting from a particular passenger rail equipment fire incident or scenario. The probability of the selected fire scenario and the severity of consequences (based on the ignition source hazard category assigned during the fire hazard analysis in Fire Safety Analysis Step 6/Section 9) are combined to provide a risk index rating (see Section 10.3). The severity categories are based on those listed in Section 9.2. The probability categories are described in Section 10.2 below.

10.2 Scenario probability

The probability of occurrence of a scenario is defined in terms relevant to commuter and inter-city railroads. The following guidelines are suggested:

- 1 Frequent: More than two occurrences per year or one occurrence per $6x10^6$ vehicle miles.
- 2 Probable: More than one occurrence per 3 years or $3.6xl0^7$ vehicle miles, but less than two occurrences/year or one per 6×10^6 vehicle miles.
- 3 Occasional: More than one occurrence per 15 years or 2×10^8 vehicle miles, but less than one occurrence per 3 years or 3.6×10^7 vehicle miles.
- 4 Remote: More than one occurrence per 75 years or 10^9 vehicle miles, but less than one occurrence per 15 years or $2x10^8$ vehicle miles.
- 5 Improbable: Less than one occurrence per 75 years or 10^9 vehicle miles.

The above probabilities may be modified by individual railroads to a relevant measure for the particular railroad. Passenger miles, vehicle miles, or other measures may be used.

10.3 Determination of risk acceptability

APTA believes that passenger railroads must recognize that a fundamental feature of this approach is that some residual risk must be accepted. For example, a catastrophic incident/scenario that is unlikely to occur within 75 years may be acceptable. In addition, such an event expected to occur no more often than every 15 years may be acceptable for a limited certain time, such as two or three years until old rolling stock is replaced with new.

Individual railroads may modify the parameters used to define the categories of frequency of occurrence and/or the categories of severity of hazard used to enter the fire risk assessment matrix. Individual railroads may not be able to use this fire risk assessment method. As an alternative, those railroads without significant historical data of their own could examine the fire safety history of similar categories of equipment operating in similar environments for purposes of determining fire risk acceptability level. If a similar category of equipment's fire safety record is better than that of the industry as a whole, and the railroad operating that equipment has determined that the risk is acceptable, then the railroad, even without significant historical data, may determine that its level of fire risk is acceptable as well. Some railroad passenger equipment industry-wide fire statistics are provided in Annex B.

Whatever method a railroad chooses to determine fire risk acceptability, the railroad bears the responsibility of defending the method against public scrutiny in the event that a serious fire incident occurs on that railroad. In other words, the method selected must be able to pass the "reasonable person test."

Once the risk of a scenario has been assessed, it should be assigned to one of the following categories:

- 1 Unacceptable: Poses immediate threat to personal safety. Correct or control immediately. Action to resolve must be completed by July 10, 2001.

- 2 Acceptable short-term: May pose threat to personal safety. Formulate corrective action plans and implement on a priority basis. Action to resolve must be completed by July 10, 2003.

- 3 Acceptable with management review: Deemed acceptable or unavoidable risk after review by person(s) with appropriate authority. Formal documentation of acceptance and sign-off necessary with documentation of risk analysis process completed by January 10, 2001. Nevertheless, correct the risk scenario if feasible.

- 4 Acceptable: Not deemed to be a risk. Documentation of the risk analysis process must be completed by January 10, 2001.

Thus, a scenario assigned with a severity value of **1** and a frequency value of **1** would be categorized as a **"1"** risk on the risk index matrix since it indicates the high likelihood of the selected scenario/incident occurrence as well as catastrophic consequences.

Accordingly, this risk index rating means that a high priority of remedial action must be taken to mitigate the hazard and thus reduce the risk of the scenario/incident occurrence.

Table 1—Risk index matrix

RISK INDEX MATRIX					
Probability	Severity				
		Catastrophic 1	Serious 2	Significant 3	Negligible 4
	Frequent 1	1	1	1	3
	Probable 2	1	1	2	3
	Occasional 3	1	2	2	4
	Remote 4	2	2	3	4
	Improbable 5	3	3	3	4

The procedure above could be a major undertaking, were it not for historical data. The use of this data should be maximized, both for likelihood and severity of fires on rolling stock. Ideally, all similar equipment and operating conditions throughout the United States would be considered when assessing risk for a given railroad.

After completion of this process, the passenger railroad should have a risk acceptability rating for each scenario and have identified associated ignition source hazards for each different category of equipment and service operated by that railroad.

Fire Safety Analysis Step 10

Develop and execute a fire safety remedial action plan if any fire safety hazard for any category of equipment and service has an unacceptable fire risk rating for the selected fire scenarios.

(see Section 11 below)

11. Equipment and service fire safety remedial action plan

If all the scenarios identified in Section 10 have been classified as an acceptable fire risk with no corrective action necessary (a fire safety risk rating of **4** from the fire risk index matrix in Section 10.3), the passenger railroad has completed the necessary fire safety analysis process on existing equipment. APTA believes that if the railroad generally followed the guidance in this recommended practice, the resulting fire safety analysis is so thorough that no further analysis is required on the part of the railroad.

However, if one or more of the fire scenarios identified in Section 10 is determined to be an unacceptable fire risk (a fire rating of **1**, **2**, or **3** from the fire risk index matrix in Section 10.3) the railroad must develop and execute an equipment and service fire safety remedial action plan. The plan should outline a logical approach to reduce the risk of personal injuries posed by all unacceptable fire hazards and, at minimum, should include the following:

a) Identify the strategy and specific countermeasure to be used to resolve each unacceptable hazard;

b) Identify the resources necessary to implement the plan;

c) Schedule the implementation of the plan;

d) Assign responsibility for implementation of the plan;

e) Describe how progress against the plan will be tracked and monitored;

f) Describe how the effectiveness of the strategy and countermeasure will be checked.

The remedial action schedule and resources should be tailored to reflect the risk index rating and address the resolution of hazards in order of priority. Thus, a hazard assigned a risk index rating of **1** must be addressed with much more urgency than a hazard with a risk rating of **3** (see Section 10.3). The objective is to mitigate hazards that result in the unacceptable high likelihood of a fire scenario/incident to occur.

Fire Safety Analysis Step 11

Apply hazard mitigation strategies to fire hazards that pose unacceptable risks in terms of the unacceptable likelihood of the selected fire scenario and re-evaluate.

(see Section 12 below)

12. Fire risk reduction

The cornerstone of the remedial action plan is the hazard mitigation strategy used to address each Category **1** or **2** (see Section 10.3) fire scenario identified in the plan and reduce the fire risk to an acceptable level. Remedial action to resolve Category **1** fire risks must be completed by July 10, 2001. Remedial action to resolve Category **2** fire risks must be completed by July 10, 2003. Typical hazard mitigation strategies for existing equipment and service are presented in the approximate order that they should be considered:

a) Eliminate/decrease sources of combustion

b) Slow fire/smoke spread/propagation by material selection, etc.

c) Improve probability of early detection

d) Increase amount of tenable evacuation time through design features such as floor endurance, fire suppression systems, etc.

e) Provide additional necessary passenger and crewmember evacuation time through emergency preparedness plan implementation (crew training, passenger education, signage, etc.) Tunnel and elevated operations require special consideration

f) Decrease emergency response time (e.g., improved railroad notification procedures)

g) Improve emergency response capability (e.g., emergency response drills)

The railroad should apply one or more specific countermeasures consistent with these mitigation strategies or other mitigation strategies developed by the railroad to each of the fire safety hazards identified as posing a Category **1** or **2** fire risk. The railroad should then repeat the analysis for the identified hazard, with the countermeasures implemented to demonstrate that the risk posed by that hazard has been reduced to the acceptable area of the fire risk matrix.

Fire Safety Analysis Step 12

Monitor, track and update the fire safety remedial action plan.

(see Section 13 below)

13. Fire safety remedial action plan maintenance/tracking

The passenger railroad should monitor and track progress made toward the completion of the remedial action plan. If the schedule slips or the actions taken prove to be ineffective, the railroad must keep the plan current to accurately reflect the true status of the fire risk reduction effort.

14. Fire safety analysis and fire safety remedial action plan approvals

Passenger railroads are not required to submit their fire safety analysis results or their fire safety remedial action plans to any outside authority for approval. *49 CFR, Part 238* does not require any submittals to or approvals by the FRA. APTA has no program to review the fire safety analysis results or the remedial action plans but will include the analysis and remedial action plan (if necessary) as part of the documentation checked during the railroad's system safety audit.

Each railroad bears the responsibility for the validity of its fire safety analysis and the implementation of its fire safety remedial action plan. Each may have to withstand public scrutiny and regulatory agency inspection in the event of a serious fire safety incident.

Annex A

(informative)

Bibliography

[B1] ASTM E 1546-93, Standard Guide for Development of Fire Hazard Assessment Standards, Conshohocken, PA.

[B2] ASTM E 1776-96, Standard Guide for Development of Fire Risk Assessment Standards, Conshohocken, PA.

[B3] FTA Office of Safety & Security, SAMIS Annual Reports, 1990-1997.

[B4] NFPA, Fire Analysis—U.S. Rail Passenger or Diner Car Fires, 1999.

[B5] NFPA 55, Guide to the Fire Safety Concepts Tree, 1995, Quincy, MA.

Annex B

(informative)

Passenger rail fire data

B.1 FRA data

Railroads are required by *49 CFR, Part 225, Railroad Accidents/Incidents: Reports Classification, and Investigations* to report accidents and incidents to the FRA on a monthly basis. For this purpose, accidents and incidents include:

a) Collisions, derailments, fires, explosions, and other events involving the operation of on-track equipment that cause property damage over an established threshold ($6,600 for 1999);

b) Impacts between railroad on-track equipment and highway users at highway/rail grade crossings;

c) All other incidents or exposures that cause a fatality or injury to any person;

d) An occupational illness to a railroad employee.

The type of accident or incident is determined by the first event of the incident.

APTA will furnish each passenger railroad with the *FRA Railroad Safety Statistics Annual Report, Accidents/Incidents,* for all railroads.

B.1.2 FRA data limitations

The FRA accidents and incidents data include only those fire/smoke-related events that were reported to FRA in a manner that identified such conditions. Accidents and incident reports submitted to FRA may not include other fire or smoke related incidents,. for example, any reports of accidents/incidents involving subsequent fire or smoke that did not include any note of fire or smoke in the narrative section. . Also, any fires that were not reported to FRA because they did not result in injuries, fatalities, or property damages that exceed the reporting threshold and thus are not listed in the database.

B.2 FTA data

The Federal Transit Administration (FTA) publishes a Transit Safety & Secruty Statitistics and Analysis Annual Report[3] which includes fire safety datra for commuter railroads.

3 Numbers in brackets correspond with those in the bibliography of Annex A.

B.2.1 FTA data limitations

Only commuter rail agencies and rail transit agencies receiving funding from FTA are required to report data regarding fire-related accidents and incidents to FTA. In addition, the data is not broken down into enough detail to be useful to individual railroads in performing a fire safety analysis of their existing rail equipment. However, it could be useful as a bench mark for the individual railroads to compare their own statistics to the industry average. Since Amtrak does not receive FTA funding, the FTA fire data does not reflect Amtrak fire-related accident/incident information. The FTA definition for fire is "an uncontrolled combustion made evident by smoke and/or flame which requires suppression by equipment or personnel. There are no thresholds; all fire are reported. However, in an effort to avoid double counting of injuries and fatalities, FTA does require commuter railroad and rail transit agencies to report injuries and fatalities for only the initial event that resulted in the casualties. Therefore, certain known fire-related fatalities are not included in the FTA report (e.g., the 8 fatalities resulting from the 1996 Maryland Rail Commuter Service (MARC)/Amtrak collision and fire). Because many fires occur subsequent to collisions and derailments, the FTA report does not accurately reflect the casualty levels resulting from fire-related accidents and incidents involving passenger trains.

B.3 NFPA passenger rail and diner data

A search of the *NFPA, Fire Analysis—U.S. Rail Passenger or Diner Car Fires, 1999* [B4] disclosed estimates that municipal fire departments responded to an annual average of 71 fires, 2 civilian deaths and a direct property damage of $986,000 in the category of rail passenger or diner fires. Annual average data was available for three groupings:

e) Ignition factor

f) Form of material first ignited

g) Type of material first ignited

Half of the average number of fires were caused by some form of mechanical failure or malfunction, with short-circuits or ground-faults and part failures, leaks or breaks leading the list. Incendiary or suspicious fires accounted for 17.1%.

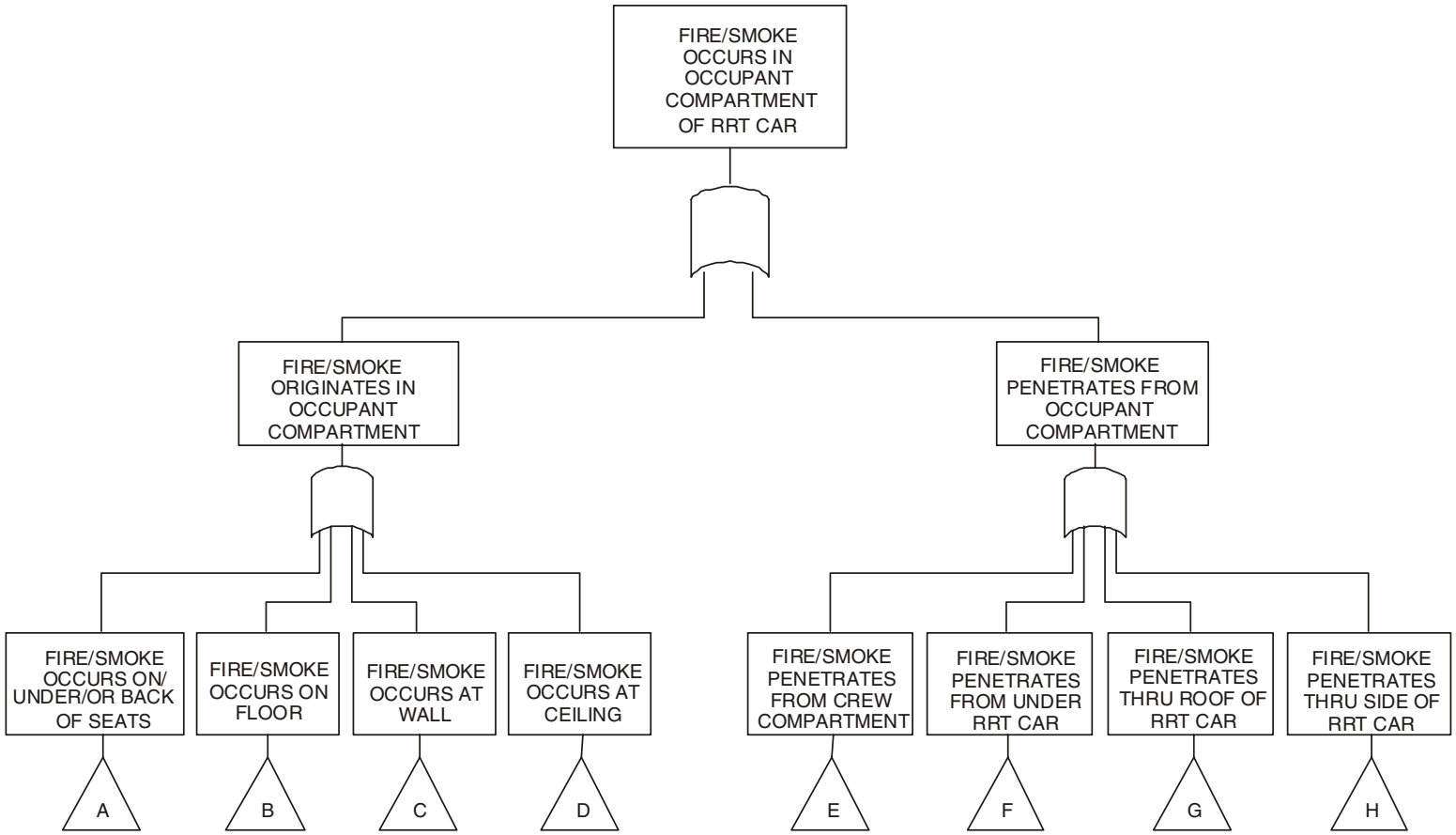
Electrical wire or cable insulation was the form of material first ignited in 18.3% of the average fires. Fuel was first ignited 16.4% of the incidents and upholstered furniture or vehicle seats were first ignited in 8.1% of reported incidents.

Flammable or combustible materials were first ignited in 20.4% of the average fires, with gasoline the most common type. Some type of plastic was first ignited in 18.7% of the incidents, wood or paper in 17.5%, fabrics, textiles or fur in 10.4%, and natural products were ignited in 14.2% of reported incidents.

B.3.1 NFPA data limitations

NFPA data exists only for those fire-related accidents that were reported to fire departments. To the extent that certain fire-related accidents/incidents were managed successfully by rail personnel and/or passengers without having to notify fire departments, these events do not appear in the NFPA report. Although it is likely that the more significant passenger train fires required assistance from fire departments, it is also possible that onboard passengers and/or crewmembers using fire extinguishers effectively and efficiently controlled smaller fires that resulted in injuries. Therefore, NFPA data does not reflect the actual number of fires and related casualties that may have occurred. In addition, it is not usually possible to obtain specific local fire department fire reports.

Annex C—Sample fault tree



RRT: Rapid rail transit

SOURCE: ***Volpe Center, Urban Mass Transportation Administration (UMTA) (FTA) Fire Safety in Transit Systems: Fault Tree Analysis, Report No. UM147-PM-81-51.***

Annex D—Sample fire hazard analysis worksheet

CATEGORY OF EQUIPMENT _____

SERVICE OPERATING ENVIRONMENT _____ **Route** _____

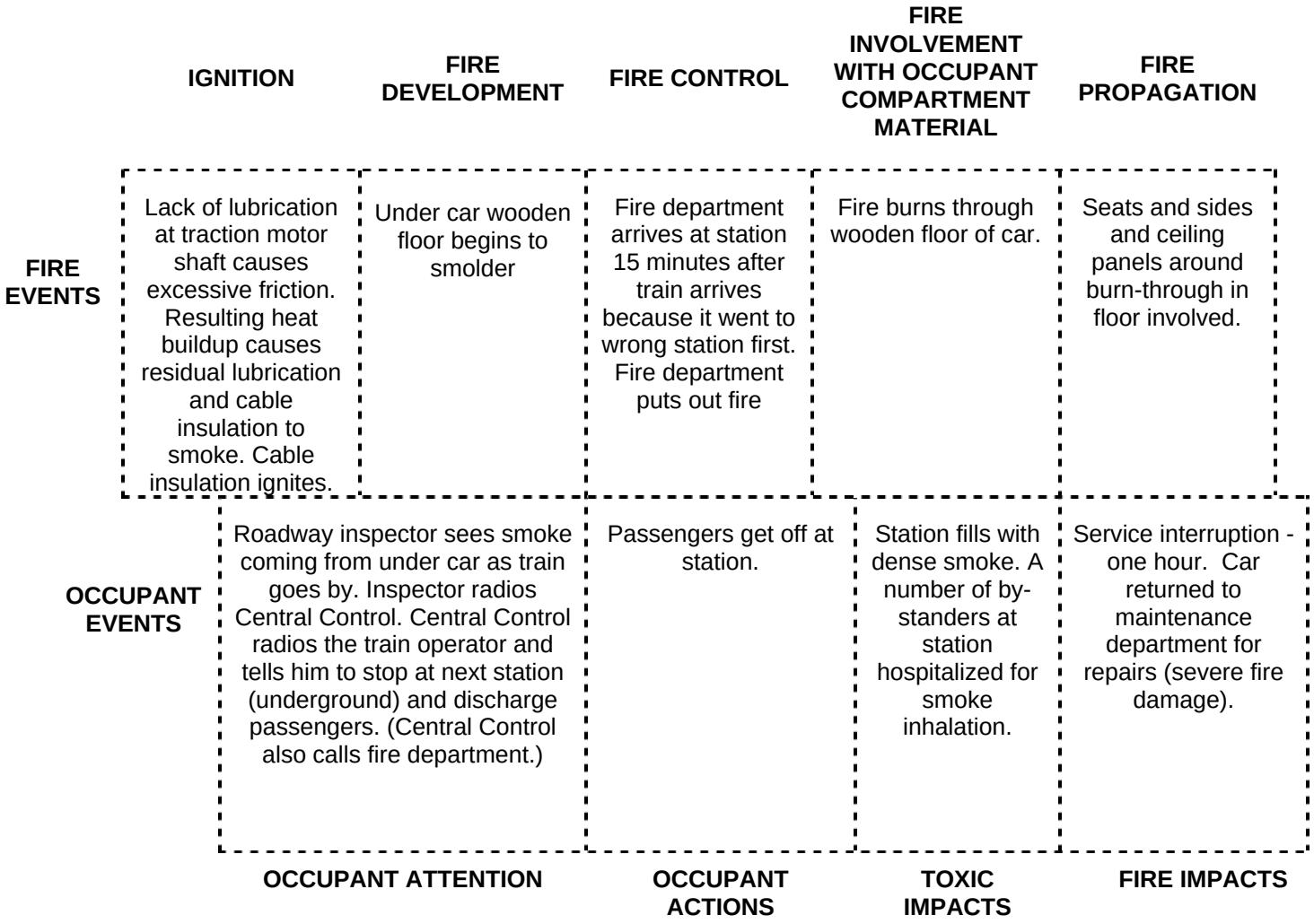
CAR Coach, Cab car (circle one) **Model/type** _____ **Builder** _____ **Year** _____

TYPE Single, Multi-level, Gallery (circle one) **POWER** Diesel, Catenary, Third Rail (circle one)

SYSTEM 1. Traction Motor **ANALYST** _____ **DATE** _____

POTENTIAL IGNITION SOURCE	HAZARD SEVERITY	*EVALUATION FACTORS*			REVISED HAZARD SEVERITY
		Fire location interior/exterior	Train location tunnel/other	Fire safety features/ countermeasures	

ANNEX E—Sample fire scenario



SOURCE: ***Volpe Center, (FTA) Identification of the Fire Threat in Urban Transit Vehicles, Report No. UMTA-MA-06-0051-80-1, June, 1980.***