APTA STANDARDS DEVELOPMENT PROGRAM
RECOMMENDED PRACTICE
American Public Transportation Association
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APTA PR-E-RP-009-98, Rev. 2
First Published: June 15, 1998
First Revision: Feb. 13, 2004
Second Revision: May 28, 2021

PRESS Electrical Working Group

Ampacities for Wire and Cable Used on Passenger Rolling Stock with Flame, Smoke and Toxicity Considerations

Abstract: This recommended practice provides guidance on wire sizes, ampacities, derating and spacing for rail passenger equipment applications. It also includes flame, smoke and toxicity requirements.

Keywords: 22759/6, ampacity, cable, cross-linked polyolefin (XLPO), derating, irradiation, multifunction vehicle bus (MVB), wire, wired train bus (WTB)

Summary: This recommended practice was titled “Wiring Used on Passenger Equipment” in the previous publication of this document. This recommended practice is used for determining the correct wire rating for wire and cable used on passenger rail vehicles.

Scope and purpose: This recommended practice addresses wire sizing parameters, including ampacities and derating values for temperature and spacing, as well as flame, smoke, and toxicity (FST) requirements for wire and cable used on passenger rail vehicles. The FST requirements do not apply to flexible intercar jumper cables including 480 VAC head end power and 27-point control and communication trainline connector cables.

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Introduction

This introduction is not part of APTA PR-E-RP-009-98, Rev. 2, "Ampacities for Wire and Cable Used on Passenger Rolling Stock with Flame, Smoke, and Toxicity Considerations," formerly titled "Wire Used on Passenger Equipment."

This recommended practice describes the requirements for wire used on passenger railroad rolling stock. It applies to all:

1. Railroads that operate intercity or commuter passenger train service on the general railroad system of transportation; and
2. Railroads that provide commuter or other short-haul rail passenger train service in a metropolitan or suburban area, including public authorities operating passenger train service.

This recommended practice may not apply to:

1. Rapid transit operations in an urban area that are not connected to the general railroad system of transportation;
2. Tourist, scenic, historic or excursion operations, whether on or off the general railroad system of transportation;
3. Operation of private cars, including business/office cars and circus trains; or
4. Railroads that operate only on track inside an installation that is not part of the general railroad system of transportation.

Ampacities for Wire and Cable Used on Passenger Rolling Stock with Flame, Smoke and Toxicity Considerations

1. Wire and cable types and applications

This document covers four types of insulated wire and cables used in North America rolling stock applications.

1.1 Full insulation thickness 110 °C

The following applies to all full insulation thickness XLPO irradiated cross-linked polyolefin, 110 °C, 600V or 2000V, 22 AWG–1111 Kcmil wiring.

All full insulation thickness 110 °C XLPO irradiated cross-linked polyolefin wiring (600V, 2000V) used on rolling stock should meet the requirements of the Association of American Railroads, Recommended Practice RP-585, 2008. AAR RP-585 and the information contained herein should be used when specifying wire for use on rolling stock.

1.2 Reduced diameter 125 °C

The following applies to all reduced-diameter and insulation wiring XLPO irradiated cross-linked polyolefin insulation (10 mils) and irradiated cross-linked fluoropolymer jacket (5 mils) 125 °C, 600V, 22 AWG–10 AWG wiring.

All reduced-diameter and insulation thickness wiring 125 °C XLPO irradiated cross-linked polyolefin insulation (10 mils) and irradiated cross-linked fluoropolymer jacket (5 mils), 600V, 22 AWG–10 AWG used on rolling stock should be tested to the requirements of the Association of American Railroads, Recommended Practice RP-585, 2008, and approved by the authority having jurisdiction and car builder. AAR RP-585 and the information contained herein should be used when specifying wire for use on rolling stock.

Metric wire and cables that comply with EN50264 or EN 50306 may be used in components (smoke detector sensor, battery charger, traction converter, etc.) as approved by the authority having jurisdiction.

1.3 Communication cables

Communication cables such as category cables (CAT 5, CAT 5E, CAT 6, CAT 6A, CAT 7, etc.) including multifunction vehicle bus (MVB) and wired train bus (WTB) cables, should meet the FST requirements of this document. Consult the cable manufacturer for the ampacity and physical, electrical and mechanical characteristics of these cables. Data and communication cables should be rated at 90 °C or higher.

1.4 High-temperature wire

High-temperature 600V and 1000V wire made in accordance with SAE-AS22759/6A (formerly Mil-W22759/6) or silicone insulated wire to AAR RP-587 should also meet the FST requirements of this document. Consult the cable manufacturer for the ampacity and physical, electrical and mechanical characteristics of these cables.

2. Insulation temperature

Wire insulation systems used on rolling stock (except data cable as noted in Section 1.3 of this recommended practice) should be at a minimum rated at 230 °F (110 °C). Higher temperature insulation should be used as required by design applications.

3. Current-carrying capacity for wire

Table 1 contains the ampacity values for standard sizes of wire used on rolling stock. The table includes a column for not more than three current-carrying wires in a raceway and a second column for single insulated conductors, in free air. All values in **Table 1** are based on an ambient temperature of 104 °F (40 °C). For ambient temperatures other than 104 °F (40 °C), the given ampacities from either column of **Table 1** must be adjusted using the proper multiplier from **Table 2**. The values in **Table 1** are without derating for higher ambient temperatures or adjacent cables and bundling.

> **NOTE:** The numbers in the following tables were derived by using the most conservative ampacity values from manufacturer specifications successfully used in the North American passenger rail industry. These values have been generally accepted and utilized since the 1970s, as applied to circuits in normal use. They do not apply to transient and surge suppression applications or short circuit calculations. Other methodologies with comparative calculations may be considered on a case-by-case basis.

TABLE 1
Ampacities of Copper Conductors (104 °F [40 °C] Ambient)

Size AWG Kcmil	Not More Than Three Conductors in a Raceway	Single Insulated Conductors, in Free Air
AWG Kcmil	Copper Conductor Temp 230 °F (110 °C) Above Ambient	Copper Conductor Temp 230 °F (110 °C) Above Ambient
22	7	9
20	9	12
18	13	17
16	17	23
14	29	39
12	36	51
10	46	67
8	64	85

TABLE 1

Ampacities of Copper Conductors (104 °F [40 °C] Ambient)

Size AWG Kcmil	Not More Than Three Conductors in a Raceway	Single Insulated Conductors, in Free Air
AWG Kcmil	Copper Conductor Temp 230 °F (110 °C) Above Ambient	Copper Conductor Temp 230 °F (110 °C) Above Ambient
6	81	120
4	109	160
3	129	180
2	143	214
1	168	247
1/0	193	286
2/0	229	329
3/0	263	380
4/0	301	446
250	345	493
262	348	524
300	391	552
313	393	590
350	436	611
373	444	657
400	468	663
444	483	734
500	531	767
535	540	828
600	588	860
646	600	931
700	645	953
750	673	1000
777	678	1047
800	699	1039
929	755	1140
1000	785	1197
1111	810	1254

TABLE 2
Temperature Correction Factors (104 °F [40 °C] Ambient)

Ambient Temperature (°C)	Multiplier
41–50	0.93
51–60	0.85
61–70	0.76
71–80	0.65
81–90	0.53
91–100	0.38

The following is a sample calculation for one 2/0 wire, routed in free air, with an ambient temperature of 149 °F (65 °C):

$$Adjusted\ Ampacity = 329\ Amps \times 0.76 = 250\ Amps$$

4. Adjustment factors

Where the number of current-carrying wires in a raceway exceeds three, the allowable ampacities should be reduced, as shown in **Table 3**. These multipliers should be applied to the values from the "Not More Than Three Conductors in a Raceway" column.

> **NOTE:** The following correction factors do not apply to conductors in nipples having a length not exceeding 24 in. (61 cm).

TABLE 3
Correction Factors for More Than Three Current-Carrying Conductors in a Raceway with Load Diversity

Number of Current-Carrying Wires	Multiplier
4 through 6	0.80
7 through 9	0.70
10 through 24*	0.70
25 through 42*	0.60
43 and above*	0.50

* These factors include the effects of a load diversity of 50 percent.

The following is a sample calculation for eight AWG #12 current-carrying wires in a conduit, with an ambient temperature of 104 °F (40 °C):

$$Adjusted\ Ampacity = 36\ Amps \times 0.70 = 25.2\ Amps$$

The ampacities for wire in air, or wire in conduit in air, are based on a single insulated wire or conduit. Where the spacing between wire or conduit surfaces is not greater than the diameter of the largest adjacent wire or conduit, the current ratings should be reduced in accordance with the values given in **Table 4** for wires and those in **Table 5** for conduits.

TABLE 4
Group Correction Factors: Number of Wires in Air

	Horizontally					
Vertically	**1**	**2**	**3**	**4**	**5**	**6**
1	1.00	0.93	0.87	0.84	0.83	0.82
2	0.89	0.83	0.79	0.76	0.75	0.74
3	0.80	0.76	0.72	0.70	0.69	0.68

TABLE 5
Group Correction Factors: Number of Conduits in Air

	Horizontally					
Vertically	**1**	**2**	**3**	**4**	**5**	**6**
1	1.00	0.94	0.91	0.88	0.87	0.86
2	0.92	0.87	0.84	0.81	0.80	0.79
3	0.85	0.81	0.78	0.76	0.75	0.74

The following is a sample calculation for six 2/0 wires in air, with a cleating arrangement of three horizontal and two vertical, and less than 1d (d = the diameter of the largest adjacent wire or conduit) between wire surfaces, with an ambient temperature of 104 °F (40 °C):

$$Adjusted\ Ampacity = 329\ Amps \times 0.79 = 260\ Amps$$

5. Multiple deratings

In situations where wire must be derated for more than one factor, such as high ambient temperature and a large number of wires in a conduit, these ratings must be combined.

6. Flame, smoke and toxicity (FST) requirements

All rolling stock wiring and cable should comply with the FST criteria in this section.

6.1 Flame and smoke (NFPA 130)

All wire and cable should pass the spread of fire and smoke emissions test requirements for low-voltage wire and cable in accordance with NFPA 130-2020, Article 8.6.7.1.1, for transit vehicle application. This requires that the wire and cable pass the 70,000 Btu/hr Vertical Cable Tray Flame Test, UL 1685, FT4/IEEE 1202, by having a flame travel distance that does not exceed 1.5 m (4 ft, 11 in.). In order to pass the aforementioned test, the total smoke released should be less than or equal to 150 m^2 (1615 sq. ft), and the peak smoke release rate should be less than or equal to 0.40 m^2/s (4.3 sq. ft/s).

> **NOTE:** In NFPA 130 2020, Article 8.6.7.1.1, the total smoke release and peak smoke release rates are given in the form of "less than." However, in the document cited in the same article, UL 1685, FT4/IEEE 1202, the total smoke release and peak smoke release rate are given in the form "less than or equal to."

Alternatively, wires and cables listed as having adequate fire resistant and low-smoke-producing characteristics, by having a flame travel distance that does not exceed 1.5 m (5 ft) and generating a maximum

peak optical density of smoke of 0.50 and a maximum average optical density of smoke of 0.15 when tested in accordance with NFPA 262.

6.2 Toxicity

All wire and cable shall pass the Toxicity Test requirements when tested in accordance with Boeing Specification Support (BSS) Standard 7239 or Bombardier SMP 800C, performance criteria of which can be found in **Table 6**. The toxicity test procedure requires 3"x3" test specimens which can be made using wire sheathing placard at 3"x3" or by successive insulated wires grouped or wrapped to provide proper test specimen face area.

TABLE 6
Toxicity Test Maximum Particle Concentrations

Chemical Name	Chemical Formula	Maximum Concentration Allowable (parts per million)
Carbon monoxide	CO	3500
Hydrogen fluoride	HF	200
Hydrogen chloride	HCl	500
Nitrogen dioxide	NO_2	100
Sulfur dioxide	SO_2	100
Hydrogen cyanide	HCN	150

NOTE: Local authority specifications may have additional or other FST requirements.

6.3 Calorimetry

Testing of wire and cable insulation material to ASTM E-1354 "Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter" may be required by the authority having jurisdiction.

References

This standard shall be used in conjunction with the following publications. The most recent revision shall apply.

Association of American Railroads,

Recommended Practice RP-585, "AAR Manual of Standards and Recommended Practices: Locomotives and Locomotive Interchange Equipment."

Recommended Practice RP-587, "AAR Manual of Standards and Recommended Practices: Wire and Cable Insulating Material."

ASTM E1354, "Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter."

Bombardier SMP 800C, "Toxic Gas Generation."

BSS 7239, "Boeing Specification Support Standard for Test Method for Toxic Gas Generation by Materials on Combustion."

European Standard (Euronorm)

EN 50264, "Railway applications - Railway rolling stock power and control cables having special fire performance."

EN 50306, "Railway applications - Railway rolling stock cables having special fire performance - thin wall."

IEEE 16, "Standard for Electrical and Electronic Control Apparatus on Rail Vehicles."

NFPA 130, "Standard for Fixed Guideway Transit and Passenger Rail Systems," chapter on Vehicles

NFPA 262, "Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces"

SAE-AS22759/6A, "Wire, Electric, Fluorocarbon-Insulated, Abrasion Resistant Extruded PTFE, Nickel-Coated Copper Conductor, 600 VOLT, ROHS."

Definitions

ambient temperature: The environmental temperature surrounding the object under consideration. Where electrical heating wire is enclosed in thermal insulation, the ambient temperature is the temperature exterior to the thermal insulation.

ampacity: Current-carrying capacity, expressed in amperes, of an electrical conductor under stated thermal conditions.

AWG: The American Wire Gage is used in the U.S. as a unit for sizing wire.

cable: A grouping of two or more conductors, regardless of size.

component: A standalone, prewired device within an assembly not including external wire harnesses (smoke detector sensor, battery charger, traction converter, etc.).

cross-linking: The establishment of chemical bonds between polymer molecule chains.

irradiation: The exposure of high-energy electron beam emissions to cross-link insulation and jacketing polymer materials for wire and cables for the purpose of favorably altering the molecular structure and providing enhanced performance.

raceway: Any channel designed and used expressly for supporting wires, cables or bus bars. Raceways consist primarily of, but are not restricted to, cable trays, conduits and wireways.

wire: All insulated single-conductors, regardless of size.

Abbreviations and acronyms

AAR	Association of American Railroads
AWG	American Wire Gauge
CFR	Code of Federal Regulations
FST	flame, smoke and toxicity
ICEA	Insulated Cable Engineers Association
IEEE	Institute of Electrical and Electronic Engineers
Kcmil	thousands of circular mils
MVB	multifunction vehicle bus
NATSA	North American Transportation Services Association
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
PRESS	Passenger Rail Equipment Safety Standards
WTB	wired train bus
XLPO	cross-linked polyolefin

Summary of document changes

- Document retitled.
- Document formatted to the new APTA standard format.
- Sections have been moved and renumbered.
- Scope and summary moved to the front page.
- Sections of definitions, abbreviations and acronyms moved to the rear of the document.
- Two new sections added: “Summary of document changes” and “Document history.”
- Some global changes to section headings and numberings resulted when sections dealing with references and acronyms were moved to the end of the document, along with other cosmetic changes, such as capitalization, punctuation, spelling, grammar and general flow of text.
- Section 1: New section added detailing wire and cable types and applications including full insulation thickness 110 °C (Section 1.1), reduced diameter 125 °C (Section 1.2), communication cables (Section 1.3) and high-temperature wire (Section 1.4).
- Section 1.2: Added metric wire and cable exceptions for components.
- Section 3: Added note above Table 1 detailing the methodology used to obtain the table values.
- Table 1: Added 22, 20 and 929 sizes. Added raceway values for 262, 313, 373, 444, 535, 646, 777, and 1111 sizes.
- Section 6: Added sections on flame, smoke, and toxicity requirements and Table 6 detailing toxicity test maximum particle concentrations.
- References: Added ASTM E1354, BSS 7239, IEEE 16 and NFPA 130.

- Definitions: Added cable, component, cross-linking and irradiation definitions. Moved Kcmil definition to "Abbreviations and acronyms" section.

Document history

Document Version	Working Group Vote	Public Comment/ Technical Oversight	Rail CEO Approval	Policy & Planning Approval	Publish Date
First published	—	—	—	June 15, 1998	March 17, 1999
First revision	—	—	—	—	Feb. 13, 2004
Second revision	Mar. 8, 2021	Apr. 9, 2021	Apr. 23, 2021	May 26, 2021	May 28, 2021

This document was retitled to its current title from "Wiring Used on Passenger Equipment" as part of Rev. 2. For all previous publications of this document prior to Rev. 2, this document was titled "Wiring Used on Passenger Equipment."

Appendix A: Bibliography (informative)

[B1] Institute of Electrical and Electronics Engineers, IEEE Std. 835, “Power Cable Ampacities.”

