APTA STANDARDS DEVELOPMENT PROGRAM
RECOMMENDED PRACTICE
American Public Transportation Association
1300 I Street, NW, Suite 1200 East, Washington, DC 20005

APTA PR-E-RP-002-98, Rev. 2
First Published: Jan. 22, 1998
First Revision: Feb. 13, 2004
Second Revision: May 28, 2021

PRESS Electrical Working Group

Installation of Wire and Cable on Passenger Rolling Stock

Abstract: The recommended practices described in this document provide guidance for the design of passenger rail vehicle wiring interconnecting the power, control, lighting and auxiliary subsystems of passenger rolling stock.

Keywords: electrical safety, installation of wire and cable, passenger rail vehicle

Summary: This recommended practice was titled “Wiring of Passenger Equipment” in the previous publication of this document. This recommended practice is used to guide the design of passenger rail vehicle wiring interconnecting the power, control, lighting and auxiliary subsystems of passenger rolling stock, in order to establish a baseline for safety, electromagnetic compatibility, reliability and maintainability.

Scope and purpose: This document provides recommended practices for the installation of wire and cable on passenger rolling stock. The internal wiring of subsystem enclosures is not covered by this document. The passenger rail industry phased this recommended practice into practice over the six-month period from July 1 to Dec. 31, 1999. The recommended practice took effect Jan. 1, 2000.

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Participants

The American Public Transportation Association greatly appreciates the contributions of the **PRESS Electrical Working Group**, which provided the primary effort in the drafting of this document.

At the time this recommended practice was revised, the working group included the following members:

Tammy Krause, Atkins NA, *Chair*
Brian Ley, WAGO Corp., *Vice Chair*

Ed Aberbach, *General Cable*
Leith Al-Nazer, *Federal Railroad Administration*
Mark Anderson, *Huber+Suhner Inc.*
Carl Atencio, *Denver Transit Operators*
Andrew Aubert, *TDG International*
Charles Bisson, *Hatch LTK*
Asa Briggs. *Huber+Suhner Inc.*
Richard Bruss, *retired (Amtrak)*
Joshua Callen, *Hatch LTK*
Dennis Carlson, *Clements National Company*
Mark DeLizio, *retired* (*Amtrak)*
Davinder Dhatt, *Metrolinx*
James Dietz, *Hatch LTK*
Sebastian Durzynski, *TDG International*
Phillippe Etchassahar, *Alstom*
Gary Fairbanks, *Federal Railroad Administration*
Robert Fauvelle, *Atkins NA*
Steve Finegan, *Atkins NA*
Marc Gagne, *TDG International*
Robert Gagne, *TDG International*
Yakov Goldin, *retired (Amtrak)*
Lowell Goudge, *Alstom*
Klause Gutzeit, *Hoppecke*
Lew Hoens, *MTA Metro-North Railroad*
Paul Jamieson, *retired*
Piotr Jedraszczak, *Metra*
Andrew Jensen, *Amtrak*
Nigel Jones, *Jacobs*
Praveen Kaul. *New Jersey Transit*
Victor Kelley, *Atkins NA*
Clifford Kim, *SEPTA*
Joerg Kuehne, *Huber+Suhner Inc.*
John Listar, *Wabtec*
Frank Maldari, *MTA Long Island Rail Road*
Liam Martin, *ABB Inc.*
Ted Mavronicolas, *Saft*
Marisa Nakajima, *Atkins NA*
James Notarfrancesco, *Rockbestos Surprenant Cable*
Alfonso Perez, *Huber+Suhner Inc.*
Martin Schroeder, *Jacobs*
Richard Seaton, *TDG International*
Sean Shim, *New Jersey Transit*
Gil Shoshani, *Rockbestos Surprenant Cable*
David Skillman, *Amtrak*
Nick Sorensen, *Utah Transit Authority*
Jeffrey St. Jean, *New Jersey Transit*
Daniel Swieca, *New Jersey Transit*
Jonathan Syfu, *STV Inc.*
Doug Warner, *Herzog Transit Services*
Steve Zuiderveen, *Federal Railroad Administration*

Project team

Nathan Leventon, *American Public Transportation Association*
Narayana Sundaram, *American Public Transportation Association*

Introduction

This introduction is not part of APTA PR-E-RP-002-98, Rev. 2, "Installation of Wire and Cable on Passenger Rolling Stock," formerly titled "Wiring of Passenger Equipment."

This recommended practice describes the requirements for the installation of wire and cable 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.

Installation of Wire and Cable on Passenger Rolling Stock

1. Technical information

> **NOTE:** The use of metric wire and cable is permitted in purchased subassemblies with the consent of the authority having jurisdiction.

1.1 Wiring separation

Separation is used to minimize electrical interference and electrical noise between circuits. The following recommendation uses the same three circuit categories and separation as used in EN 50343:2014, "Rules for installation of cabling."

Wiring is categorized dependent on its main purpose:

A. **Power wiring:** traction/dynamic brake, HVAC, HEP and auxiliaries
B. **Low-voltage wiring:** controls, lighting, LV battery
C. **Signal wiring:** PTC, CBTC, CCTV, ATC/P

It is recommended that consideration be given to the separation of wiring for traction/dynamic brake from wiring for HEP and auxiliary power circuits for the purposes of electromagnetic compatibility.

When running in parallel, wires in one category should be physically separated from the other circuit categories. Unless grounded barriers or separate conduits are used, the recommended separation is the following:

- **Between A and B:** 4 in. (100 mm)
- **Between A and C:** 8 in. (200 mm)
- **Between B and C:** 4 in. (100 mm)

When wires of one category cross with another category, the crossing angle should be approximately 90 deg.

All wiring connected to a piece of apparatus is recommended to be at the insulation level for the highest connected voltage. Wires of different potential circuits or categories are not to be cabled together and are not to be placed in the same conduit or junction box. Where it is impossible to avoid having wires of potential circuits in the same equipment enclosure, the wires are to be secured separately such that contact between wiring categories is not possible.

Circuit separation does not apply to a return conductor. The feed and the return wires of a circuit should be cabled, or laid as close together as practicable, particularly within category A wiring and within category C wiring. Running the feed and return wires of a circuit together minimizes their electrical interference and electrical noise.

1.2 Wiring installation

All wiring should be installed in accordance with the requirements of NFPA 130 (2017), Section 8.6.7, "Wiring."

Wire runs isolated from other circuits should be provided for the following:

- safety control circuits (e.g., cab signals, automatic train stops)
- communication apparatus circuits

1.3 Return paths

The vehicle electrical systems should not use the carbody as a return path.

Vehicle grounding is dependent on the design of the electrical supply system. For most DC systems, the supply authority's stray current requirement requires a central or substation ground point with insulated (floating) running rails. The grounding methodology for replacement vehicles should consider the arrangement used on the vehicles being replaced.

For all types of externally powered electrical vehicles, the return bus shall be connected to axle ground brushes to return the power to the running rail via the axles and wheels. The paths shall be designed to prevent electrical damage and etching of the wheel bearings:

- For vehicles externally powered from an AC high-voltage source, the primary power return to the rails should include more than one safety ground connection solidly connected to the carbody.
- For vehicles externally powered from a DC high-voltage source, separate return and grounding brushes should be used to reduce the risk of lightning damage to the vehicles HV equipment. Here the return path brushes should be separate and electrically isolated from the vehicle's structure grounding brushes.

1.4 Grounding

All equipment framework on the vehicle should be bonded to the vehicle structure. The vehicle structure and truck frames should be connected through ground brushes to the axles, wheels and return rail in accordance with Section 1.3 of this recommended practice.

For all types of vehicles running on electrified track, the grounding paths of the vehicle should also be designed to prevent electrical damage and etching of the wheel bearings. The ground brush rating may need to allow for it to carry part of any current flowing in the running rail, with the vehicle body acting as a conductor in parallel with the rail.

Grounding and bonding jumpers and straps should be sized to handle the heating energy ("Joule integral") associated with a catenary strike, a lightning discharge or an HV insulation failure (ground fault), as appropriate to the path of the current. All grounding and bonding jumpers and straps should be coordinated with the ground brush sizing and their locations to ensure that vehicle touch voltage does not exceed that specified in EN50122-1/A4:2017 Table 4, and EN50122-1/A4:2017 Section 9.2.2.3.

1.5 Splices and terminations

Splices may be used only when connecting circuits to apparatus equipped with "pigtail" or similar leads (e.g., lighting, communication speakers, threshold heaters, heat tapes). A service loop of wire allowing three re-terminations should be provided when splicing. No splices should be permitted within the wiring of any other

circuits or within conduits, raceways or looms. All wiring should terminate at terminal blocks, at terminals of apparatus or at connectors as specified.

In-line splices should be insulated such that the resultant voltage and temperature withstand capability is at least equivalent to that of the wires spliced together.

1.6 Soldering

No soldering or solder-type terminals should be permitted on wiring connected to terminal blocks or pieces of apparatus other than traction motors.

1.7 Connectors and terminal blocks

All connections made by terminations should be crimp-type including connector contacts. All terminations should be of the vibration-resistant, compression (crimp) type and are to be provided with a properly fitting insulation grip where feasible. All crimp terminations should be performed in accordance with the appropriate manufacturer's recommended procedure. Crimps should be made using certified, properly calibrated, manufacturer's recommended tools and dies. A service loop of wire allowing three re-terminations should be provided.

Terminal blocks shall be "touch-safe" using screwless-type spring or screw-type clamping to secure the wires. Each clamping mechanism of the terminal block shall be limited to the connection of one wire or conductor. The metallic clamping mechanism of the terminal block shall surround the wire on all sides to prevent wire strands from splaying outside the clamping area. Terminal blocks should be designed to accept solid or stranded conductors without requiring special wire preparation, such as crimps, ferrules or tinning, to ensure mechanical and electrical connection integrity without damage to conductors. If necessary to remove a stranded wire frequently from the terminal block, the use of a ferrule may be desirable. Due consideration should be given to the increase in conductor size when using a ferrule.

"Quick-removal," knife-type terminals or connectors should be used where feasible on apparatus or circuits that must be disconnected frequently for inspection and maintenance.

Connectors should in general meet the requirements of MIL-C-5015, Connectors, Electrical Circular Threaded General Specifications, Revision G or rectangular equivalent as approved by the authority having jurisdiction, and be positive locking, with crimp style, gold- or silver-plated contacts with waterproof seals. The coupling mechanism should provide extended coupling life of a minimum of 500 operations. Audible, visual and tactile indications of full coupling should be given. At a minimum, all connectors should operate at temperatures ranging from −40 °F (−40 °C) to +212 °F (+100 °C). Connectors rated for other temperatures should be used to meet specific design requirements. Nonmetallic body, non–environmentally sealed connectors are limited for use on nonvital interior applications such as lighting and speaker connections. Such connectors should be approved by the authority having jurisdiction.

Solder connections should not be permitted except for printed circuit applications within subsystems or components.

Power cables that are subjected to continuous motion during train operation (e.g., carbody-to-truck interfaces) should be terminated with heavy-duty cast-type lugs.

1.8 High-temperature environments

High-temperature insulated wiring (or equivalent protection or preparation) should be provided where resistors or power static devices expose conductors to high-heat radiation. Hardware and terminations used in such locations should be nickel-plated or stainless steel.

1.9 Conduit and wireway locations

All conduit and wireways should be located so as to preclude the entrance of water, oil or other contaminants, regardless of source.

1.10 Wiring support

Conductors 6 AWG or larger or multiconductor shielded cable of at least equivalent pull strength and exterior insulation properties, adequately supported throughout, may be cleated in place without conduit, duct or open wireways. Interconnecting wire smaller than 6 AWG and small multiconductor cable should be installed in conduit or wireways and should be adequately supported throughout.

All cable 6 AWG or larger exiting enclosures and raceways or cable that is not installed in a conduit should be adequately supported by split-block cleats made of a nonconductive, moisture-resistant, insulating material such as neoprene or equivalent. A minimum number of different size cleat blocks should be used. Tape or other methods should not be used on cables to enable them to fit into an oversized clamp. Cables should be adequately supported and protected where necessary (in wheel splash area) by open mesh or other approved guard. Separate securement should be provided for each individual cable.

Wire smaller than 6 AWG and small multiconductor cable exiting enclosures or in other transition areas may be supported by tie bars.

1.11 Protection from contamination

All electrical cabinets, apparatus, components, cabling and wiring should be designed to be protected from, or be compatible with, external contaminants such as dirt, oil, snow, rain and cleaning solutions and from contamination that might occur from failure of water, oil or fuel systems carried on the equipment. Within electrical cabinets, wiring should not rest on the bottom sheet of the cabinet.

1.12 Circuit overload protection

All control and auxiliary circuits should be protected by trip-free, thermal magnetic circuit breakers or by fuses; breakers are preferred over fuses unless specific applications dictate otherwise.

1.13 Wire identification

All wires should be properly marked with nonmetallic sleeves, color coding or by continuous wire designator marking at terminations and junction box locations. All new wire installed should be labeled continuously or at both ends with a label, preferably printed. If the labels are handwritten, they should be both permanent and legible. All connection points, terminal blocks and connectors should be identified in a permanent manner.

1.14 Conductor size

All trainline conductors should be connected through equipment by way of terminal boards so they may be readily used for spares or additional functions. All such wiring should utilize wire size (AWG) no smaller than that specified for the connector in AAR S-512, “Receptacle—Control Plug—Locomotive,” 1984. Larger wire sizes may be required for other considerations, such as allowable voltage drop.

Conductors should be sized based on the current-carrying capacity, mechanical strength, temperature, flexibility and voltage drop. Wires should be sized in accordance with APTA PR-E-RP-009-98, latest revision, "Ampacities for Wire and Cable Used on Passenger Rolling Stock with Flame Smoke and Toxicity Considerations."

In no case should AWG or metric wire smaller than the following sizes be used:

- Wire that is pulled through conduits or wireways: AWG No. 14
- Wire on electronic units, cards and card racks: AWG No. 24
- Undercar wires, secured with cleats: 2/0
- Wire within control compartments: AWG No. 18
- Multiconductor cables where current is not a factor in wire size selection: AWG No. 18
- All other wire, including wire that is not pulled through wireways and conduits: AWG No. 16
- Cables for communication, Ethernet and signal transmission for train backbone, sensory and equipment control: AWG No. 24 conductor size in a multiconductor configuration; otherwise AWG No. 22

NOTE: The use of metric wire and cable is permitted in purchased subassemblies with the consent of the authority having jurisdiction.

1.15 Conduit and wireways

Conduit should be ⅜ in. (0.95 cm) minimum size. Conductor area, including wire, insulation and jacket, is not to exceed 40 percent of the area of the conduit unless approved by the authority, but in no case should exceed 60 percent. Heavy wall rigid metallic conduit is to be used for all underfloor applications. Electrical metallic tubing may be used for above-floor applications. Flexible conduit may be used where it is not practical to use either of the types mentioned above. Use of flexible conduit should be kept to a minimum and should not normally be used in lengths exceeding 18 in. (45.72 cm).

A run of conduit between junction boxes and/or pulling outlets should not contain more than the equivalent of four quarter-bends (360 deg. total) including the outlet fittings. Bend radii at the inner edge of the bend should be no less than eight times the nominal inside diameter of the conduit.

In any wireway, conductor area, including wire, insulation and jacket, should not exceed 40 percent of the area unless approved by the authority, but in no case should exceed 60 percent.

1.16 Spare terminations and conductors

Spare terminations and conductors of control and signal wiring should be provided on terminal boards, in connectors, and in wire bundles including multiconductor cables between major panels and junction boxes. A minimum of 10 percent, but not fewer than one (pair), should be provided.

2. Wire specifications

All wire and cable (except data, communication and high-temperature cables) should be in accordance with APTA PR-E-RP-009-98, latest revision, "Ampacities for Wire and Cable Used on Passenger Rolling Stock with Flame, Smoke, and Toxicity Considerations," AAR RP-585, "Wiring and Cable Specification," or APTA PR-E-S-001-98, latest revision, "Insulation Integrity," as appropriate for the application.

3. Conduit specifications

Rigid metal conduit should be in accordance with ANSI Specification C-80.1, "American National Standard for Rigid Steel Conduit – Zinc Coated." Electrical metallic tubing should be in accordance with ANSI Specification C-80.3, "American National Standard for Electrical Metallic Tubing – Zinc Coated."

When flexible conduit is required for car and locomotive applications, it should be liquid-tight flexible metal conduit in accordance with Underwriters Laboratories' UL 360, "Liquid-Tight Flexible Metal Conduit," Seventh Edition, January 17, 2013. Nonmetallic conduits should be subject to the approval of the authority having jurisdiction.

4. Wireway specifications

All wireways are to be metal or approved nonmetallic material. Surfaces and edges of wireways should be designed to prevent abrasion and cutting of wire and cable insulation.

5. Alternative specifications

Alternative specifications to those listed above may be proposed so long as equivalence is established subject to the approval of the authority having jurisdiction.

6. Identification

All electrical devices (e.g., switches, relays, contractors, terminal blocks, circuit breakers, fuses) should be permanently identified on the surface to which they are mounted. Labels should not be attached to the device itself. Consistent labeling should be used among the device, schematics, wiring diagrams, and maintenance and operating manuals.

7. Tests

All testing of vehicle wiring should adhere to APTA PR-E-S-001-98, latest revision, "Insulation Integrity."

Related APTA standards

APTA PR-E-S-001-98, latest revision, "Electrical Insulation Integrity"
APTA PR-E-RP-009-98, latest revision, "Ampacities for Wire and Cable Used on Passenger Rolling Stock with Flame, Smoke, and Toxicity Considerations"

References

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

Association of American Railroads standards:
AAR RP-585, "Wiring and Cable Specification," 1994
AAR S-512, "Receptacle—Control Plug—Locomotive," 1984

American National Standards Institute standards:
ANSI Specification C-80.1, "American National Standard for Rigid Steel Conduit – Zinc Coated"
ANSI Specification C-80.3, "American National Standard for Electrical Metallic Tubing – Zinc Coated"

BS EN 50122-1:2011+A4:2017, "Railway applications. Fixed installations. Electrical safety, earthing and the return circuit. Protective provisions against electric shock"

EN 50343:2014, "Railway applications - Rolling stock - Rules for installation of cabling"

IEEE Standard 100-1996, "The IEEE Standard Dictionary of Electrical and Electronics Terms."

MIL-C-5015, "Connectors, Electrical, Circular, Threaded General Specification," Revision G

NFPA 130, "Standard for Fixed Guideway Transit Systems," 2017 edition.

UL standards:
UL 360, "Liquid-Tight Flexible Metal Conduit," Seventh Edition, January 17, 2013

Definitions

For the purpose of this recommended practice, the following definitions apply. The IEEE Standards Dictionary Online shall be consulted for terms not defined in this clause.

automatic train control (ATC): The system for automatically controlling train movement, enforcing train safety, and directing train operations. ATC includes automatic train protection (ATP) and may include automatic train operation (ATO), automatic train supervision (ATS) or both.

cab signal system: Electrical/electronic system interfaced with the trackside equipment to display the authorized speed to the operator and, if applicable, to provide authorized speed to the automatic train control (ATC) system.

carbody: The basic metallic structure of the rolling stock.

conductor: A material, usually in the form of a wire, cable or bus bar, suitable for carrying an electric current.

conduit: A tubular raceway for holding wires or cables. It is either rigid or flexible, metallic or nonmetallic tubing.

ground: A conducting connection, whether intentional or accidental, by which an electrical circuit or equipment is connected to the earth, or to some conductive body of relatively large extent that serves in place of the earth.

primary power: The third rail or catenary power supplied to externally powered rolling stock.

raceway: Any channel designed expressly and used solely for holding conductors, both electrical and fiber optic.

separation: Wires not cabled together or run in the same conduit, raceway, tubing, junction box or cable, and not touching wires connected to a higher-voltage source of energy.

trainline: Circuit that runs the complete length of the train, enabling the same control circuits in all cars to be active at the same time.

wireway: A rigid rectangular raceway provided with a cover.

Abbreviations and acronyms

AAR	Association of American Railroads
ATC	automatic train control
ATP	automatic train protection
AWG	American Wire Gauge
BS	British Standards
CBTC	communications-based train control
CCTV	closed-circuit television
EN	Euronorm
HEP	head-end power
HV	high voltage
HVAC	heating, ventilation, air conditioning
IEEE	Institute of Electrical and Electronic Engineers
LV	low voltage
NATSA	North American Transportation Services Association
NFPA	National Fire Protection Association
PRESS	Passenger Rail Equipment Safety Standards
PTC	positive train control
VAC	volts alternating current
VDC	volts direct current

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.
- Three new sections added: “Related APTA standards,” “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 1.1: Removed list of specific systems where separation should be required and replaced it with detailed separation requirements.
- Section 1.5: Added in-line splice insulation requirement.
- Section 1.6: Replaced second paragraph regarding terminal block requirements.
- Section 1.6: Added general requirements for connectors.
- Section 1.12: Added new language regarding the labeling of wire.
- Section 1.13: Replaced wire derating factor language with a reference to APTA PR-E-RP-009-98, latest revision, "Ampacities for Wire and Cable Used on Passenger Rolling Stock with Flame Smoke and Toxicity Considerations." Added minimum wire size requirements.
- Section 3: UL Reference changed to UL 360; Type UA requirement removed.
- Definitions: Replaced automatic train stop (ATS) definition with automatic train control (ATC) definition.

Document history

Document Version	Working Group Vote	Public Comment/ Technical Oversight	Rail CEO Approval	Policy & Planning Approval	Publish Date
First published	—	—	—	Jan. 22, 1998	March 17, 1999
First revision	—	—	—	—	Feb. 13, 2004
Second revision	Jan. 8, 2021	Mar. 31, 2021	Apr. 23, 2021	May 26, 2021	May 28, 2021

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