APTA STANDARDS PROGRAM

STANDARD

APTA PR-E-S-005-98, Rev. 3
First Published: Jan. 22, 1998
First Revision: Feb. 13, 2004
Second Revision: June 15, 2006
Third Revision: November 18, 2025
PRESS Electrical Working Group

Grounding and Bonding

Abstract: This standard provides minimum requirements for grounding and bonding on passenger rail vehicles. It includes system grounding return connections, equipment grounding, ground brushes, bonding and passenger exposure. This standard also includes maximum design wheel-to-wheel resistance levels.

Keywords: bonding, electrical bonding, electrical grounding, ground brushes, grounding, grounding return connections, passenger exposure, wheel-to-wheel resistance

Summary: This standard defines a methodology for grounding and bonding for rail passenger vehicles.

Foreword

The American Public Transportation Association is a standards development organization in North America. The process of developing standards is managed by the APTA Standards Program's Standards Development Oversight Council (SDOC). These activities are carried out through several standards policy and planning committees that have been established to address specific transportation modes, safety and security requirements, interoperability, and other topics.

APTA used a consensus-based process to develop this document and its continued maintenance, which is detailed in the manual for the APTA Standards Program. This document was drafted in accordance with the approval criteria and editorial policy as described. Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

This document was prepared by the Electrical Working Group as directed by the Passenger Rail Equipment Safety Standards Policy & Planning Committee.

This document represents a common viewpoint of those parties concerned with its provisions, namely transit operating/planning agencies, manufacturers, consultants, engineers and general interest groups. APTA standards are mandatory to the extent incorporated by an applicable statute or regulation. In some cases, federal and/or state regulations govern portions of a transit system's operations. In cases where there is a conflict or contradiction between an applicable law or regulation and this document, consult with a legal adviser to determine which document takes precedence.

This document supersedes APTA PR-E-S-005-98, Rev. 2, which has been revised. Below is a summary of changes from the previous document version:

- Document formatted to the new APTA standard format.
- Sections have been moved and renumbered.
- Scope and summary moved to the front page.
- 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.
- Names of participants updated.
- Introduction updated.
- Section 1.1: Added prohibition to using the carbody as a primary power return path.
- Section 1.1: Added axle ground brush requirements, equipment framework bonding requirement, and design requirement for ground return circuits to prevent electrical damage and etching to the wheel bearings.
- Section 1.1: Added note on prevention of current passing through journal bearings of unpowered trailing equipment.
- Section 1.2: Changed name of section from "Grounding" to "Equipment grounding."
- Section 1.2: Added note regarding purpose-built grounding on covers of some access controllers and low-voltage power equipment.
- Section 1.2: Added exception to isolation requirement for circuits from mechanical structure in the case of lightning diversion.

- Section 1.4: Added allowance for covers used for regular maintenance to have metal-to metal contact instead of a strap or wire.
- Added new Section 1.7: Wheel/axle/wheel resistance.
- Added new Section 1.8: Ground brushes and brush holders.
- Added new Section 1.8.1: External wear indicators.
- Added new definition: return grounding.
- Used former ‘grounding’ definition to safety grounding.

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Introduction

This introduction is not part of APTA PR-E-S-005-98, Rev. 3, "Grounding and Bonding."

This standard applies to all:

- railroads that operate intercity or commuter passenger train service on the general railroad system of transportation; and
- 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 standard may apply to:

- rapid transit operations in an urban area that are not connected to the general railroad system of transportation;

This standard does not apply to:

- tourist, scenic, historic or excursion operations, whether on or off the general railroad system of transportation;
- operation of private cars, including business/office cars and circus trains; or
- railroads that operate only on track inside an installation that is not part of the general railroad system of transportation.

Scope and purpose

This standard provides minimum requirements for grounding and bonding on rail vehicles, including system grounding return connections, equipment grounding, bonding, passenger exposure mitigation, wheel-to-wheel resistance and ground brushes. It does not address vehicle-level ground fault protection, which varies according to application. The purpose of this document is to establish minimum safety standards for electrical grounding and bonding for rail passenger vehicles.

Grounding and Bonding

1. Technical requirements

1.1 System grounding return connections

The vehicle electrical systems shall not use the carbody as a primary power return path. All other grounding return connections to the vehicle body shall be made through ground pads. Different voltage classes of circuits (see APTA PR-E-RP-002-98, latest revision, "Installation of Wire and Cable on Passenger Rolling Stock," Section 1.1) shall not be grounded to the same ground pad. In all cases, there shall be ground cables between the truck frame and the vehicle body.

The primary return bus or cable shall be connected to axle ground brushes to return power to the axles, wheels and return rail. All equipment framework on the vehicle shall be bonded to the vehicle structure. The vehicle structure and truck frames shall be connected through ground brushes to the axles, wheels and return rail. These brushes shall be separate and electrically isolated from the power return brushes. Ground return circuits shall be designed to prevent electrical damage and etching to wheel bearings.

Each system or circuit fed from a circuit breaker or fuse shall have its own return wiring. Return wires for each voltage class on a vehicle shall be connected in such a way as to facilitate the troubleshooting of faults. Where the return circuits are grounded, each voltage class shall be grounded to a single point on the vehicle body or directly to ground brushes, as required by the railroad.

> **NOTE:** It has been noted that there have been instances where current has been recorded passing through the journal bearings of unpowered trailing equipment (e.g., push-pull consists) in electrified territory. The observed current rose and fell approaching and departing phase breaks. The employment of ground brushes on trailing equipment has been shown to mitigate this.

1.2 Equipment grounding

All electrical equipment or enclosures shall be grounded using a ground cable or strap or by a bond between a vehicle body grounding pad and the equipment's grounding pad. All shock-mounted electrical equipment shall be grounded using ground cables or straps. The ground termination method shall apply uniform pressure to the conductive surface, and the current density shall not exceed the bonding requirements of this standard.

Interior-mounted, low-voltage equipment shall be grounded according to the needs of the design.

> **NOTE:** Covers that are opened frequently to access controllers and low-voltage equipment may have a purpose-built grounding method incorporated into the cover.

All circuits shall be isolated from the mechanical structure of the equipment except for circuit-to-structure components for the purpose of transient absorption, lightning diversion (arrestors) and electromagnetic interference protection, where allowed by agreement with the railroad.

1.3 Bonding

The bonding method used shall be designed to produce a dc resistance not in excess of 0.0025 Ω across any bond, or not more than 0.025 Ω at 150 kHz for any applied ac voltage.

1.4 Grounding pads

All grounding connections shall be made through unpainted pads, except for interior-mounted, low-voltage electronic assemblies.

Grounding pads shall be made of copper or copper alloys, sized for the application, and silver soldered or brazed to the respective vehicle body and piece of equipment. The use of nickel or tin plating is recommended to ensure that the requirements of Section 1.3 are maintained over time. Transition (base) plates, if used, shall be made from the same alloy group as the respective vehicle body or equipment. The transition plate shall be welded to the vehicle body or equipment. By agreement with the railroad, welded steel grounding pads may be used. If so used, steel pads on the vehicle body shall be either nickel or tin-plated carbon steel or stainless steel. Grounding pads made of aluminum may be used on cars with aluminum car shells due to compatibility.

Pads shall include one or more tapped holes for securing connections. Pads using a stud arrangement may be used by agreement with the railroad. Metallic covers used for regular maintenance shall be grounded with a grounding strap or wire. An anticorrosive grease may be applied over connections.

1.5 Grounding jumpers and straps

All grounding jumpers and straps shall be sized to handle the available fault current without failure. Truck grounding jumpers and jumpers to the ground brush shall be sized to handle lightning discharge current once without failure.

All equipment subject to motion relative to the carbody and all shock-mounted equipment shall be grounded with flexible, strap-type grounding leads bolted between the carbody grounding pad and the equipment's grounding pad. Stranding shall be equivalent to or exceed the requirements of Insulated Cable Engineers Association Class M as per ANSI/NEMA WC 70/ICEA S-95-658-2021 "Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy."

All pads shall be visible and accessible for inspection and troubleshooting.

1.6 Passenger and personnel exposure

On new or rebuilt equipment, all receptacles meant for passenger use supplying 120 Vac, 60 Hz nominal power shall be ground fault protected and shall have a ground pin that is grounded to the vehicle body via dedicated wire.

1.7 Wheel/axle/wheel resistance

Vehicles shall be designed such that the wheel-to-wheel resistance of split or stub axle wheelsets shall not exceed 0.006 Ω (6 mΩ). This may be achieved through the use of ground brushes or other means. (The requirement is based on the Paper C & S Division, AAR, Committee Reports & Technical Papers, 1994 "Appendix A: Wheel/Axle/Wheel Resistance Recommendations: Conclusions and Recommendations for Wheel-to-Wheel Resistance Operating Performance.")

NOTE: As a historical note, some passenger equipment that was intended to operate in very short trains (such as rail diesel cars, EMUs or DMUs) has been equipped with "scrubbers," typically small metal blocks that rub lightly against the wheels of cars equipped only with disk brakes. This technique provides wheel cleaning in the absence of tread brakes and may enhance shunting performance.

1.8 Ground brushes and brush holders

Ground brushes shall be of the radially axle-mounted type. The ground brushes shall, in addition, meet the applicable requirements of APTA PR-E-RP-002-98, latest revision.

Note: The requirements in this section reflect the needs of rolling stock used on the general railroad system of transportation and may not reflect the needs of rail transit rolling stock, specifically low floor designs.

Ground brushes shall bear on a bronze or steel ground ring, which shall be pressed onto the axle or onto the gear unit quill. Carbody safety grounding and power return brushes shall be arranged to contact the same axle ground brush ring. The ground ring shall have a wear life not less than the overhaul interval of other wheelset components.

Brushes shall be made from metal graphite. Brush leads shall project from the top of the brush with no possibility of brush leads impeding brush travel before the brush is fully worn. Each brush shall be delivered with the working face profiled to match the ground ring radius. The brush shall be keyed or otherwise designed in such a way that installation in an incorrect orientation is precluded. The brush shall have a molded-in or machined-in wear indicator providing a direct visual indication that the brush has insufficient wear life remaining to continue in service until its next scheduled inspection. All radial axle-mounted brushes on the same vehicle (both carbody grounding and power return) shall be identical.

Power return ground brush holders shall be electrically insulated from carbody and truck equipment and shall be electrically connected only to the ground bus described in Section 1.1. For vehicles externally powered from a voltage source of 3000 Vdc (nominal) or less, power return ground brush holder insulation shall be rated to withstand the maximum sustained line voltage of the application, in order to avoid energization of the carbody or truck in the event that primary power is inadvertently applied in the absence of ground brushes.

Carbody grounding brush holders shall be electrically insulated from carbody and truck equipment in a manner consistent with the grounding scheme described herein.

Each ground brush holder shall be readily accessible from under the car for maintenance and shall be arranged for inspection and brush replacement by a single worker. Each ground brush holder shall be internally arranged to preclude entanglement between brush leads and other internal components, especially brush springs. Each brush spring shall be captive to the ground brush holder cover. All exposed components in the interior of the ground brush holder shall be at the same electrical potential. All ground brush holder details that require disassembly or removal in the course of inspection or brush replacement—including but not limited to covers, springs and electrical connections—shall be identical for all ground brush holders (both carbody grounding and power return).

All ground brushes, both carbody grounding and power return, shall have a wear life of at least one year, based on an inspection interval of not fewer than 92 days.

The ground circuits, for both primary power return and safety grounding, including wires and brushes, shall be sized fully redundant, so 50% of brush circuits can safely carry the maximum fault or operational return

current, without damage, while limiting the steady state voltage difference between the carbody or return bus and the running rail to less than 50 V.

For short term short circuits of the primary power supply, 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

1.8.1 External wear indicator

The contractor shall propose for railroad approval a means to indicate brush wear status without requiring the brush holder cover to be removed.

Related APTA standards

APTA PR-E-RP-002-98, "Installation of Wire and Cable on Passenger Rolling Stock"

References

Association of American Railroads, Paper C & S Division, Committee Reports & Technical Papers, 1994 "Appendix A: Wheel/Axle/Wheel Resistance Recommendations: Conclusions and Recommendations for Wheel-to-Wheel Resistance Operating Performance."

ANSI/NEMA WC 70/ICEA S-95-658-2021 "Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy."

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

Definitions

bonding: The establishment of a low-impedance current path between two adjacent components through an intimate interface surface.

return grounding: The establishment of a low-impedance circuit or path to the return rail.

safety grounding: The establishment of a low-impedance circuit or path to a designated ground plane or location.

> **NOTE:** Grounding may involve one or more bonds as well as an additional circuit element such as a cable or strap.

Abbreviations and acronyms

Ω	ohms
DMU	diesel multiple unit
EMU	electric multiple unit
Hz	hertz
kHz	kilohertz
mΩ	milliohms
V	volts
Vac	volts alternating current
Vdc	volts direct current

Document history

Document Version	Working Group Vote	Public Comment/ Technical Oversight	CEO Approval	Policy & Planning Approval	Publish Date
First published	—	—	—	Jan. 22, 1998	March 17, 1999
First revision	—	—	—	—	Feb. 13, 2004
Second revision	—	—	—	—	June 15, 2006
Third revision	July 17, 2025	Aug. 31, 2025	Sep. 30, 2025	Oct. 31, 2025	Nov. 18, 2025

