

2. APTA PR-E-RP-002-98

Recommended Practice for Wiring of Passenger Equipment

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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, in order to establish a baseline for safety, electromagnetic compatibility, reliability, and maintainability.

Keywords: electrical safety, passenger rail vehicle, wiring

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Recommended Practice for Wiring of Passenger Equipment

1. Overview

1.1 Scope

This document provides recommended practices for the wiring of 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 December 31, 1999. The recommended practice took effect January 1, 2000.

1.2 Purpose

The recommended practices described in this document provide guidance for the design of 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.

2. References

AAR RP-585, “Wiring and Cable Specification”, 1994

AAR S-512, “Receptacle—Control Plug—Locomotive”, 1984

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”

APTA PR-E-RP-009-98, “Recommended Practice for Wire Used on Passenger Rolling Stock”, 1998

APTA RP-E-S-001-98, “Standard for Insulation Integrity”, 1998

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”, 1997 Edition.

UL 1059, “Standard for Terminal Blocks”, 1993

UL 797, “UL Standard for Electrical Metallic Tubing”, Sixth Edition, March 11, 1997

3. Definitions, abbreviations, and acronyms

3.1 Definitions

For the purpose of this recommended practice, the following terms and definitions apply. IEEE Std 100-1996, “The IEEE Standard Dictionary of Electrical and Electronics Terms”, should be referenced for terms not defined in this clause.

3.1.1 automatic train stop (ATS): A trackside system that works in conjunction with equipment installed on the vehicle to apply automatically the brakes and ensure a full train stop at designated restrictions or on a dispatcher’s signal, should the train violate defined operating limits or the operator not respond properly.

3.1.2 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.

3.1.3 carbody: The basic metallic structure of the rolling stock.

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

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

3.1.6 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.

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

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

3.1.9 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.

3.1.10 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.

3.1.11 wireway: A rigid rectangular raceway provided with a cover.

4. Technical information

4.1 Wiring separation

Separation should, at a minimum, be provided between wiring for:

- a) Traction power circuits;
- b) DC control circuits;
- c) AC power circuits;
- d) Unprotected wiring (e.g., battery or power trainline to circuit breaker);
- e) Different trainline types (e.g., MU control, car control, communications, power, etc.);
- f) Safety control circuits (e.g. cab signals, automatic train stops);
- g) Communication circuits;
- h) Low level signals in shielded cables;
- i) Wires connected to different sources of energy unless all wires are insulated for the highest rated voltage present; and
- j) Wires connected to electronic control apparatus and wires connected to a higher voltage source of energy than control voltage.

Wires may cross (at approximately a right angle) provided all wires are insulated for the highest rated voltage present.

4.2 Wiring installation

All wiring should be installed in accordance with the requirements of *NFPA 130, section 5-3.7, "Wiring."*¹

Wire runs isolated from other circuits should be provided for:

- a) Safety control circuits (e.g. cab signals, automatic train stops)
- b) Communication apparatus circuits.

4.3 Return path

The vehicle electrical systems should not use the carbody as a return path. For vehicles externally powered from a voltage source of 1500 vdc (nominal) or less and in which the running rails provide a part of the return path, primary power return should be with the cable or bus bar insulated from the carbody. For vehicles externally powered from a

¹ For references in Italics, see Section 2.

voltage source of 11,000 vac (nominal) or more, the primary power return should be solidly connected to the car body. The return bus or cable should be connected to axle ground brushes to return the power to the axles, wheels, and return rail. All equipment on the vehicle should be grounded to the vehicle structure. The vehicle structure and truck frames should be connected through ground brushes to the axles, wheels, and return rail. These brushes should be separate and electrically isolated from the power return brushes. Ground return circuits should be designed to prevent electrical damage and etching to wheel bearings.

4.4 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, looms. All wiring should terminate at terminal blocks, terminals of apparatus, or at connectors as specified.

4.5 Soldering

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

4.6 Connecting and terminal blocker

All connections 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 should be of the molded unit type and should comply with the requirements of *UL 1059, “Standard for Terminal Blocks”*². Terminal blocks, with stud or screw terminals, should be used only if they are dead front or provided with protective covers. Terminals at stud-type terminations should be fastened by a locking mechanism suitable for the operating environment. Modular terminal blocks should be secured to the mounting rail by end clamps having metallic hardware.

“Quick-removal”, knife type terminals, or connectors should be used where feasible on apparatus or circuits which 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*, and be a positive locking, quarter turn bayonet coupling with waterproof seals, and crimp style, gold- or silver-plated contacts. The coupling mechanism should provide extended coupling life of

² For references in Italics, see Section 2.

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. Non-metallic body, non-environmentally sealed connectors are limited for use on non-vital 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.

4.7 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.

4.8 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.

4.9 Wiring support

Conductors 6 AWG or larger or multi-conductor 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 multi-conductor 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 non-conductive, 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.

4.10 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 which 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.

4.11 Circuit overload protection

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

4.12 Wire identification

All wires should be properly marked with non-metallic sleeves, color coding, or by continuous wire designator marking at terminations and junction box locations. All connection points, terminal blocks, and connectors should be identified in a permanent manner.

4.13 Conductor size

All trainline conductors should be connected through equipment by way of terminal boards so that 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.*³ 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. Derating factors should be applied to accommodate for grouping and ambient temperatures greater than manufacturer's design value in accordance with criteria specified by the authority having jurisdiction. In the absence of specified criteria, the criteria contained in the National Electrical Code should be utilized.

Single-conductor wire sizes should be no smaller than as follows:

- No. 14 AWG - for wire that is pulled through conduits or wireways or installed exposed between enclosures;
- No. 18 AWG - for all other wire including wire laid in (rather than pulled through) wireways

4.14 Conduit

Conduit should be 3/8-inch (.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

³ For references in Italics, see Section 2.

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 inches (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 degrees 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 area unless approved by the authority, but in no case should exceed 60 percent.

4.15 Spare terminations and conductors

Spare terminations and conductors should be provided on terminal boards, in connectors, and in wire bundles and multi-conductor cables between major panels and junction boxes. A minimum of 10%, but not less than one (1), should be provided.

5. Wire specifications

All wire and cable should be in accordance with *APTA PR-E-RP-009-98, "Recommended Practice for Wire Used on Passenger Rolling Stock"*, *AAR RP-585, "Wiring and Cable Specification,"* or *APTA PR-E-S-001-98, "Standard for Insulation Integrity"* as appropriate for the application.

6. Conduit specifications

Rigid metal conduit is to be in accordance with *ANSI Specification C-80.1 "American National Standard for Rigid Steel Conduit-Zinc Coated."* Electrical metallic tubing is to 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 must be Liquid-tight Flexible Metal Conduit Type UA in accordance with *Underwriter's Laboratories, Inc. UL 797, "UL Standard for Electrical Metallic Tubing," Sixth Edition, March 11, 1997.* Non-metallic conduits should be subject to the approval of the authority having jurisdiction.

7. Wireway specifications

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

⁴⁴ For references in Italics, see Section 2.

8. 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.

9. 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.

10. Tests

All testing of vehicle wiring should adhere to *APTA PR-E-S-001-98, "Standard for Insulation Integrity."*⁵

⁵ For references in Italics, see Section 2.