APTA STANDARDS DEVELOPMENT PROGRAM

STANDARD

American Public Transportation Association
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Fixed Structures Inspection and Maintenance Working Group

Traction Electrification Distribution System Inspection, Maintenance and Testing

Abstract: This sstandard provides minimum requirements for inspecting, maintaining and testing rail transit system traction electrification distribution systems and subsystems.

Keywords: distribution, inspection, maintenance, rail transit system, substation, traction electrification, training, qualifications

Summary: This document establishes a standard for the periodic inspection, maintenance and testing of alternating current (AC) and direct current (DC) traction electrification distribution systems. This includes periodic visual, electrical and mechanical inspections of components that affect safe and reliable operation. This standard also identifies the necessary qualifications for rail transit system employees or contractors who perform periodic inspection, maintenance and testing tasks.

Scope and purpose: This standard applies to rail transit systems that operate electrified light rail and/or heavy rail systems and applies to normal operating conditions. This standard does not apply to commuter railroads that operate on the general railroad system regulated by the Federal Railroad Administration (FRA). The purpose of this standard is to verify that traction electrification distribution systems are operating safely and as designed through periodic inspection, maintenance and testing, thereby increasing reliability and reducing the risk of hazards and failures.

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Participants

The American Public Transportation Association greatly appreciates the contributions of the **Rail Transit Standards Fixed Structures Inspection and Maintenance Working Group**, which provided the primary effort in the drafting of this document.

At the time this standard was completed, the working group included the following members:

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Introduction

This introduction is not part of APTA RT-FS-S-006-03, Rev. 2, "Traction Electrification Distribution System Inspection, Maintenance and Testing."

APTA rail transit safety standards represent an industry consensus on safety practices for rail transit systems to help achieve a high level of safety for passengers, employees and the general public. This document was created by and for those parties concerned with its provisions, namely rail transit systems (operating agencies), manufacturers, consultants, engineers and general interest groups. This standard provides procedures for inspecting, maintaining and testing rail transit traction electrification distribution systems.

APTA recommends this standard for the following:

- individuals or organizations that inspect, maintain and/or operate rail transit systems
- individuals or organizations that contract with others for the inspection, maintenance and/or operation of rail transit systems
- individuals or organizations that influence how rail transit systems are inspected, maintained and/or operated (including but not limited to consultants, designers and contractors)

This standard intends to meet the following objectives:

- to ensure special life/safety equipment is operational and reliable
- to help rail transit systems incorporate safety considerations during the inspection and maintenance process
- to identify inspection criteria and maintenance standards that provide a high level of passenger and personnel safety

Note on alternate practices

Individual rail transit systems may modify the practices in this standard to accommodate their specific equipment and mode of operation. APTA recognizes that some rail transit systems may have unique operating environments that make strict compliance with every provision of this standard impossible. As a result, certain rail transit systems may need to implement the standards and practices herein in ways that are more or less restrictive than this document prescribes. A rail transit system may develop alternates to APTA standards so long as the alternates are based on a safe operating history and are described and documented in the system's safety program plan (or another document that is referenced in the system safety program plan).

Documentation of alternate practices shall:

- identify the specific APTA rail transit safety standard requirements that cannot be met;
- state why each of these requirements cannot be met;
- describe the alternate methods used; and
- describe and substantiate how the alternate methods do not compromise safety and provide a level of safety equivalent to the practices in the APTA safety standard (operating histories or hazard analysis findings may be used to substantiate this claim).

Traction Electrification Distribution System Inspection, Maintenance and Testing

1. Frequency of tasks

The inspection, maintenance and testing procedures in this standard shall be performed as specified in **Table 1** below or as otherwise deemed necessary by the rail transit system. Since age, type, operating conditions and environment vary from system to system, and original equipment manufacturer (OEM) maintenance intervals may vary based on operating conditions, the rail transit system makes the final determination of inspection, maintenance and testing frequencies based on experience.

Following OEM-specified maintenance intervals for the equipment is recommended. Inspection frequency should be increased for severe operating conditions.

TABLE 1
Inspection and Maintenance Frequencies

Task	Recommended frequency (minimum)	Section
Cable visual and mechanical inspection	Once every five years	6.2.1.1, 6.2.2.1
Cable electrical tests	Once every five years	6.2.1.2, 6.2.2.2
Contact rail visual and mechanical inspection	As determined by the transit system	6.2.3
Overhead contact system walking inspection	Biannually (once every six months)	6.2.4.1
Overhead contact system aerial inspection	Annually	6.2.4.2
Bond inspection	As determined by the transit system	6.2.5

The rail transit system shall determine the need for additional inspection, maintenance and testing frequencies for traction electrification distribution systems. A review of the following factors may be useful in making this assessment:

- OEM-recommended testing intervals
- industry experience
- operating environment/conditions
- historical data
- reliability-centered maintenance program development
- failure analysis
- testing and experience
- regulatory requirements

The frequency of tasks shall comply with applicable federal, state and local regulations.

2. Qualifications of maintenance personnel

Due to the nature and hazards associated with electrical work on high-voltage AC and DC components, maintenance personnel must meet minimum recommended qualifications to perform many inspection, maintenance and testing tasks. Each rail transit system shall determine what its needs and resources are. For

example, systems may wish to consider a combination of written and practical experience, together with continuing education programs geared toward traction and electrification systems maintenance.

2.1 Skills and knowledge

Each rail transit system shall ensure that the employees and/or contractors who perform periodic inspection, maintenance and testing have the knowledge and skills necessary to safely and effectively perform the tasks assigned to them.

2.1.1 Basic inspection level

Inspectors must have a minimum of two years' experience working with electrical systems. All inspectors must be familiar with the installation and repair of the components associated with the electrical systems.

2.1.2 Maintenance level

Maintainers must have three or more years' experience working on high-voltage power distribution or related traction and electrification systems, either by in-house experience or a recognized trade school or apprenticeship training program.

2.1.3 Technician level

Technicians must have three or more years' experience working on high-voltage power distribution or related traction and electrification systems or possess an associate of applied science (AAS) degree in electrical systems or equivalent.

2.2 Continuing education

A rail transit system should establish a continuing education program for the above positions based upon its specific operation and requirements.

3. Tools

The following tools are required for inspection, maintenance and testing of traction electrification distribution systems:

- torque wrench
- multimeter*
- megohmmeter*
- gage-measuring device
- standard tools carried by electrical maintenance workers

NOTE: Tools designated with an asterisk (*) must be calibrated in accordance with OEM and/or rail transit system requirements.

4. Safety

Rail transit system safety rules, procedures and practices shall be followed at all times during inspection, maintenance and testing.

5. Personal protective equipment

Personal protective equipment, as required by the rail transit system, shall be worn at all times during inspection and testing.

6. Inspection, maintenance and testing

Rail transit systems shall evaluate their local operating environments and conditions to develop or formally adopt existing suitable inspection, maintenance and testing programs that include the following, as a minimum (where applicable):

> **NOTE:** Rail Transit Systems can supplement
> t the minimum requirements below with applicable Institute of Electrical and Electronics Engineers (IEEE) Standards.

6.1 Inspection, maintenance and testing categories

- **Periodic inspection and maintenance** shall be performed to verify proper system operation and general system upkeep.
- **Preventative maintenance (PM) and testing** may require removing the equipment from service and performing tests on the equipment or the materials to ensure proper operation. This type of maintenance occurs on a regularly scheduled basis.

6.2 Policies and procedures

Each rail transit system shall develop specific written policies and procedures that take into account specific equipment designs and local operating conditions to implement the inspection, maintenance and testing required by this standard. These policies and procedures shall give maintenance staff clear guidance and criteria for performing these activities.

6.2.1 Cables – 600 to 1500 VDC

6.2.1.1 Visual and mechanical inspections

The rail transit system shall perform the following inspections on all positive and negative cables when cable failure occurs in areas such as conduits, duct banks or troughs.

Annex A contains a sample inspection form for recording the results of cable inspections and tests.

a) Inspect exposed sections of cables for physical damage or evidence of overheating.
b) Inspect fireproofing in common cable area and firewall penetrations, if present.
c) Inspect terminations, jumpers and splices for evidence of physical damage or overheating.
d) Inspect bolted electrical connections for high resistance using one of the following methods:
    - Use the calibrated torque-wrench method in accordance with OEM published data to verify tightness of accessible bolted electrical connections.
    - Perform a thermo graphic survey of the equipment under loaded conditions.
e) Inspect the cable support and termination.

6.2.1.2 Electrical tests

a) Perform resistance measurements on bolted connections with a low-resistance ohmmeter capable of reading 2 μΩ, or with parallel cables use a clamp-on ammeter to verify nearly equal currents on all cables.

b) Perform an insulation resistance test, only when the integrity of a cable is suspect, with a megohmmeter using a voltage no greater than the cable insulation rating. Where there is more than one cable in parallel, test each individual cable.

6.2.1.3 Test values

a) Compare bolted connection resistances to values of similar connections.
b) Ensure that bolt-torque levels are in accordance with OEM recommendations.
c) Ensure microhm or millivolt drop values do not exceed the high levels of the normal range as indicated in the OEM published data. If OEM data is not available, then investigate any values that deviate from similar connections by more than 25 percent of the average value.
d) Compare test results with previously obtained results.

6.2.2 Cables – 600 VAC and above

6.2.2.1 Visual and mechanical inspections

The rail transit system shall perform the following inspections on line neutral and ground cables when cable failure occurs in areas such as conduits, duct banks or trough.

a) Inspect exposed sections of cables for physical damage, evidence of overheating or corona.
b) Inspect fireproofing in common cable area and firewall penetrations, if present.
c) Inspect terminations and splices for evidence of physical damage, overheating or corona.
d) Inspect all bolted electrical connections for high resistance using one of the following methods:
    - Use calibrated torque-wrench method in accordance with OEM published data to verify tightness of accessible bolted electrical connections.
    - Perform a thermo graphic survey of the equipment under loaded conditions.
e) Inspect the shield ground (if present), cable support and termination.

6.2.3 Electrical tests

a) Perform resistance measurements on bolted connections with a low-resistance ohmmeter capable of reading 2 μΩ.
b) Perform an insulation-resistance test, only when the integrity of a cable, is suspect with a megohmmeter using a voltage no greater than the cable rating. Where there is more than one conductor cable in parallel, test each individual conductor.

6.2.3.1 Test values

a) Compare bolted connection resistances to values of similar connections.
b) Ensure that bolt-torque levels are in accordance with OEM recommendations.
c) Ensure that microhm or millivolt drop values do not exceed the high levels of the normal range as indicated in the OEM published data. If OEM data is not available, then investigate any values that deviate from similar connections by more than 25 percent of the average value.
d) Compare test results to previously obtained results.

6.2.4 Contact rail

The rail transit system shall develop specific inspection criteria for contact rails based on the type of contact rail in service and system requirements. The rail transit system shall inspect the components listed in Section 6.2.3.1 through Section 6.2.3.8 as a minimum during each inspection interval.

Annex A provides an example of an inspection form that can be used to record the results of contact rail inspections and tests.

6.2.4.1 Contact rail integrity

a) Verify that the contact rail has proper horizontal and vertical relation to the adjoining running rail.
b) Inspect the contact rail for wear. Measure the wear on the head/ball of the rail. Compare the amount of contact rail material remaining with the original profile of the head/ball of the rail, using some form of gage measuring device. Replace rail in accordance with rail transit system requirements.

6.2.4.2 Expansion joints/gaps

Expansion joints/gaps are installed at various locations to allow for the thermal expansion and contraction of the contact rail.

a) Check for proper alignment and signs of movement.

6.2.4.3 Power section gaps

Section gaps provide a means of power isolation. Section gaps are designed to a specific minimum length to prevent energization of adjacent sections through the current collectors of a single rapid transit car.

a) Check the length of the section gap.

6.2.4.4 Inclines

a) Inspect inclines (also called approaches) for wear, height, gage and proper support.
b) Compare measurements taken with design standards.

6.2.4.5 Contact rail anchors

a) Inspect contact rail anchors for integrity.

6.2.4.6 Contact rail insulator

a) Inspect all contact rail insulators for cracked, loose and/or missing contact rail insulators, particularly in curves and at inclines.

6.2.4.7 Contact rail bonds

a) Inspect the physical condition of all contact rail bonds, including welds and mechanical connections.

6.2.4.8 Knife switches

a) Check the condition of the knife switch for arc burns, insulator integrity and freedom of movement, operating mechanism and connecting cables.

6.2.5 Overhead contact system (OCS)

Although all overhead contact systems consist of similar types of equipment, each type varies greatly depending on age, type and manufacturer. This standard cannot cover each type of installation. However, Section 6.2.4.1 and Section 6.2.4.2 contain procedures common to all types of overhead contact systems.

6.2.5.1 Walking inspection

a) Check foundations for visible cracks, spalling, base details and fasteners, deposits of trash, over growth of vegetation, and concrete condition.
b) Check poles (particularly termination poles) for loose nuts of bonding cables, broken or cracked welds, damaged galvanization, distortion, cracking, or corrosion.
c) Check the integrity of bonding cables.
d) Check the completeness, cleanliness and proper attachment of warning signs and pole number signs.
e) Check insulators and cable terminations for damage or dirt.

f) Check position of insulators, steady arms and contact wire clips.
g) Check for broken wires at contact wire supports.
h) Check catenary for broken or displaced hangers.
i) Check the position of contact wire bridges at crossovers and the position of wires at overlaps and crossovers.
j) Check frogs and switches, cantilever assemblies, and for slackened or missing jumpers.
k) Check the balance weight or tension spring assembly for corrosion of steel wire.
l) Check the free movement of the pulley wheel.
m) Check the position of the weight stack depending on the temperature and alignment of the wires on the pulley.
n) Check the condition of the disconnect switch for arc burns, insulator integrity, freedom of movement and connecting cables.
o) Check section insulator running skids for wear and correct adjustment. Wash off carbon deposits with a mild detergent.
p) Check tension spring assembly (where used) for corrosion of steel wire and free movement of the pulley wheel.
q) Check the length of the spring depending on the temperature and alignment of the wires on the pulley.

6.2.5.2 Aerial inspection

Perform the following as required during the high rail inspection:

a) Check the stagger of the contact wire at supports and at mid-span and adjust as necessary.
b) Check the steady arm inclination and adjust as necessary.
c) Check the adjustment of the outrunning wires in overlap sections and at crossovers.
d) Check the contact wire for twists, kinks and spots of arcing. If the cross sectional area is more than 30 percent worn, then replace the contact wire.
e) Check the messenger wires, head-span wires, dropper wires, ground wires and feeder wires for corrosion, damage, broken strands and evidence of arcing. Wires should be carefully monitored for arcing due to hard spots, particularly near clamps. Make adjustments as necessary.
f) Check the contact blades for dirt and arcing damage. Connecting wires and clamps should be free of cracks and arcing damage.
g) Check all movable parts of the switch assembly, operating link, contact blades and operating handle for free movement, and adjust if necessary.
h) Re-lubricate all movable parts of the switch assembly, operating link, contact blades and operating handle as required.
i) Check the correct position of the section insulators and the even wear of the runners.
j) Check the contact wire termination for cracks and excessive wear and for damaged suspension assembly. Adjust as necessary.
k) Check the catenary for:
    - contact wire height above top of rail;
    - contact wire stagger from centerline of track at supports and in center of span;
    - sag of the wire in relation to the temperature if a fixed terminated system is employed;
    - the position and condition of hangers, cantilevers, steady arms, clips and other attachments;
    - cantilever lateral movement according to design, if an auto-tension system is employed; and
    - proper clearance envelope.

6.2.6 Bonds

6.2.6.1 Running rail bonds

Running rail bonds are installed across the running rail joint to supplement the electrical connection for negative traction return currents and can affect signal system reliability.

a) Inspect the welds and mechanical connections for cracks and corrosion and fraying of the bond.

6.2.6.2 Structure bonds

Elevated structures are sometimes used to supplement the negative traction return current. Structure bonds are typically connected from the running rail to the structure and across a mechanical connection between structural elements.

a) Inspect the welds and mechanical connections for cracks and corrosion and fraying of the bond.

6.2.6.3 Cross bonds

Cross bonds are installed to supplement the electrical connection for enhanced negative return and reduction of stray current.

a) Inspect the welds and mechanical connections for cracks and corrosion and fraying of the bond.

6.2.6.4 Impedance bonds

Impedance bonds are installed to maintain the continuity of the traction return currents in signalized territory.

a) Inspect the welds and mechanical connections (particularly the rail end weld/pin/clamp connection) for cracks, corrosion and bond fraying.

6.2.6.5 Contact rail and running rail connections

Contact rail and running rail connections provide the electrical connection between the traction power distribution positive and negative cables and their respective rails. Contact rail and running rail connections are typically welded to the base of the rail or mechanically fastened to the rail.

a) Inspect the welds and mechanical connections for cracks and corrosion and fraying of the bond.
b) Inspect all mechanical support systems on elevated tracks.

7. Correction of deficiencies

Deficiencies identified during inspection, maintenance and testing shall be corrected and documented in accordance with OEM and/or rail transit system requirements. Some operational equipment may need to be taken out of service immediately until the problem is corrected. Other equipment may be left in service and corrected when parts, tools and/or appropriately skilled personnel are available.

The rail transit system shall designate a person responsible for deciding whether or not to leave defective equipment in service in order to operate. In the absence of a designated person, the rail transit system shall take the equipment out of service.

The rail transit system shall review and develop a corrective action plans for documented system defects monthly.

8. Priority ratings

The rail transit system shall develop a priority rating system to evaluate and determine the effects that any single defect will have on the system if it chooses to operate with a known defect.

The following are the recommended priority ratings:

- **Priority 1:** The defect will endanger the safety of patrons and personnel and/or continuation of revenue service. A permanent or temporary repair shall be made immediately.
- **Priority 2:** The defect may cause disruption of revenue service. The repair shall be made in a predetermined timeframe set by each system.
- **Priority 3:** The defect will not affect revenue service. The repair shall be made in a predetermined timeframe set by each system.

9. Documentation

The rail transit system shall develop and implement a fully auditable process for recording and tracking inspection, maintenance and testing activities and outstanding system defects. Such documentation shall be documented, reviewed and filed in accordance with rail transit system procedures and OEM recommendations. Documentation should be kept for the life of all in-service equipment and be readily available for review.

Annex A contains a sample checklist and recording form that rail transit systems can adapt to their specific equipment and operating environment.

Definitions

aerial inspection: An inspection done on an overhead electrical distribution system where the inspector is at the same level as the overhead equipment being inspected.

auto-tension system: A system tensioned by weight or spring to maintain an overhead contact system wire height and a constant wire tension within a defined temperature range.

contractor: Any individual(s) or entity under contract with the rail transit system (including rail transit system and subcontractor personnel) to install, inspect, maintain and/or test rail transit system vehicles, systems, and components. Also called a consultant.

fixed termination system: An overhead contact system with a contact wire tension that is fixed at a specific temperature and varies for all other temperatures.

heavy rail system: An electric railway capable of a "heavy volume" of traffic characterized by exclusive rights-of-way, multicar trains, high speed and rapid acceleration, sophisticated signaling and high-platform passenger loading. Also called an elevated railway, rapid rail, rapid transit or subway.

light rail system: An electric railway with a lighter volume of train traffic than heavy rail that may use shared or exclusive rights-of-way and may run trains intermingled with street traffic. Light rail systems frequently operate with low platform loading and single-car trains. Also called a street car, tram or trolley car.

original equipment manufacturer (OEM): The enterprise that initially designs and builds a piece of equipment.

personal protective equipment (PPE): All clothing and other work accessories designed to create a barrier against workplace hazards. Examples include safety goggles, blast shields, hard hats, hearing protectors, gloves, respirators, aprons and work boots.

rail transit: All forms of non-highway ground transportation that operate on rail including light rail, streetcars, trolleys and rapid rail transit systems.

rail transit system: The organization or portion of an organization that operates rail transit service and related activities. Also called an operating agency, operating authority, transit agency, transit authority or transit system.

shall: The word ***shall*** is used in standard documents to indicate mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted unless the transit system can demonstrate equivalent safety is achieved through an alternate approach.

should: The word ***should*** is used in recommended practice documents to indicate that, among several options, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not required.

Abbreviations and acronyms

µΩ	microhms
AAS	associate of applied science
AC	alternating current
DC	direct current

FRA Federal Railroad Administration
NATSA North America Transit Services Association
OCS overhead contact system
OEM original equipment manufacturer
PPE personal protective equipment
PM preventive maintenance
VAC volts alternating current
VDC volts direct current

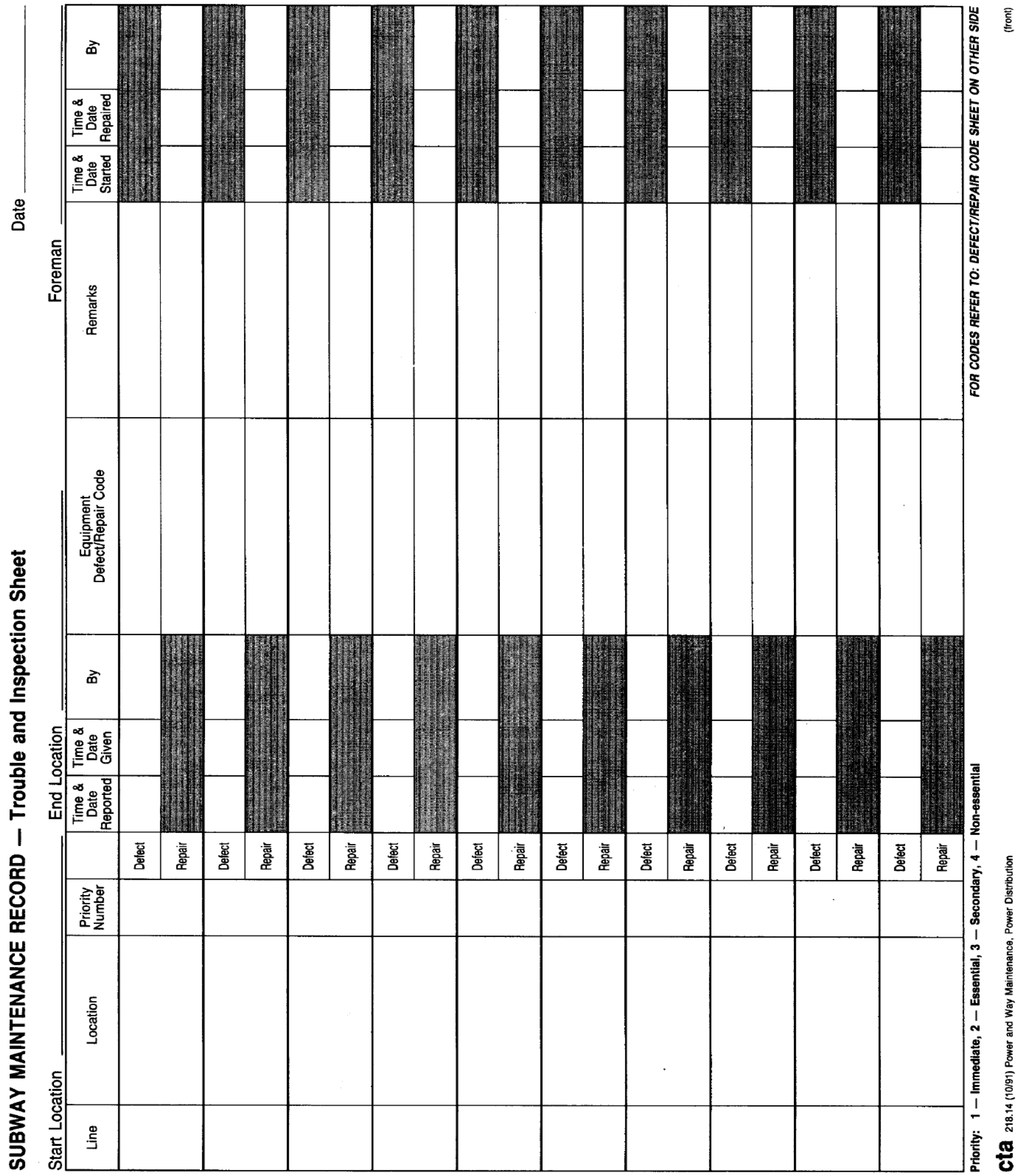
Summary of document changes

- Document formatted to the new APTA standard format.
- Sections have been moved and renumbered.
- Definitions, abbreviations and acronyms have been moved to the back 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, as well as other cosmetic changes, such as capitalization, punctuation, spelling, grammar and general flow of text.
- Section 6; Language added to allow Agencies to also incorporate IEEE standards into their inspection, maintenance and testing procedures
- Minor editorial changes.

Document history

Document Version	Working Group Vote	Public Comment/ Technical Oversight	Rail CEO Approval	Rail Policy & Planning Approval	Publish Date
First published	Nov. 22, 2013	—	—	Sept. 28, 2013	Sept. 28. 2003
First revision	—	—	—	—	July 26, 2004
Second Revision	July 14, 2017	August 1, 2017	Sept. 18, 2017	November 13, 2017	December 6, 2017

Appendix A (informative): Sample checklist/recording form



SUBWAY MAINTENANCE RECORD — Trouble and Inspection Sheet Date ____________

Start Location ____________ End Location ____________ Foreman ____________

Line	Location	Priority Number		Time & Date Reported	Time & Date Given	By	Equipment Defect/Repair Code	Remarks	Time & Date Started	Time & Date Repaired	By
			Defect								
			Repair								
			Defect								
			Repair								
			Defect								
			Repair								
			Defect								
			Repair								
			Defect								
			Repair								
			Defect								
			Repair								
			Defect								
			Repair								
			Defect								
			Repair								

Priority: 1 — Immediate, 2 — Essential, 3 — Secondary, 4 — Non-essential

FOR CODES REFER TO: DEFECT/REPAIR CODE SHEET ON OTHER SIDE

cta 218.14 (10/91) Power and Way Maintenance, Power Distribution

(front)

Date	Additional Remarks	By

GENERAL MAINTENANCE DEFECT/REPAIR CODES

Ventilation Fans - VFAN

FMS — Motor Starter
FMT — Motor
FSC — Supervisory Control
FFU — Fuses/Overloads

Drainage Pumps - DPUM

PMS — Motor Starter
PFL — Floats
PMT — Motor
PSC — Supervisory Control
PFU — Fuses/Overloads

Louver - LOUV

LMS — Motor Starter
LMT — Motor
LSW — Micro Switch
LFU — Fuses/Overloads

Supervisory Control - SUPV

SLN — Lines
SCU — Control Unit
SBT — Batteries
SBC — Battery Charger
SGD — Ground Detector
SFU — Fuses

AC Breakers - ACBK

ACT — Contacts
ATD — Trip Device

Air Compressors - ARCR

CFS — Float Switch
CMS — Motor Starter
CMT — Motor
CFU — Fuse/Overload

Sump/Ejector Pump - SEPM

SMS — Motor Starter
SVF — Vent Fan

Transfer Switch - TRSW

TSC — Contacts
TSM — Main AC Transfer Switch
TSA — AC Transfer Switch
TSD — DC Transfer Switch
TSS — Signal Transfer Switch
TSI — Supervisory Indication
TSF — Fuses
TSR — Relays

DC Breakers - DCBK

DRL — Relays
DRS — Resistors
DCL — Coils
DCT — Contacts
DSC — Supervisory Control
DFU — Fuses

Motor Operated Switch - MOS

SRL — Relays
SFS — Fuses
SRS — Resistors
SCT — Contacts
SSC — Supervisory Control

AC Inverter - ACIN

IPC — PC Board
IFU — Fuse

Repair Codes - REPCD

CLN — Cleaned
ADJ — Adjusted
LUB — Lubricated
RPL — Replaced
REP — Repaired
WIR — Wiring
REV — Re-evaluated
OOS — Out of Service
PNT — Painted