APTA STANDARDS DEVELOPMENT PROGRAM

STANDARD

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Fixed Structures Inspection and Maintenance Working Group

Traction Electrification Substation Inspection, Maintenance and Testing

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

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

Summary: This document establishes a standard for the periodic inspection, maintenance and testing of the major components of traction electrification substations for direct current (DC) rail transit 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 that perform periodic inspection, maintenance and testing tasks. Annex A contains samples of checklists and/or recording forms used by rail transit systems to perform inspections.

Scope and purpose: This standard applies to rail transit systems that operate light rail, heavy rail or rail subway systems and applies to normal operating conditions. The purpose of this standard is to verify that traction electrification substations 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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Introduction

This introduction is not part of APTA RT-FS-S-004-03, Rev. 2, "Traction Electrification Substation 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 Substation 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** and or as otherwise deemed necessary by the rail transit system. Since age, type, operating conditions and environment vary from system to system and 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
Periodic inspection	Monthly	7.2
Preventative maintenance	Annually	7.3
Condition based maintenance	As failures require	7.4

The rail transit system shall determine the need for additional inspection, maintenance and testing frequencies for traction electrification substations. 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
- rail transit system 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 traction and electrification systems. All inspectors must be familiar with the installation and repair of the components associated with traction and electrification 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 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 in applied science (AAS) degree in electrical systems or the 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 substations:

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

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

4. Equipment lockout/tagout

Proper lockout/tagout procedures shall be followed as required by the rail transit system.

5. Safety

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

6. Personal protective equipment

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

Conductive personal articles shall not be worn when working on or about equipment.

Properly inspected and voltage-regulated insulating protective covers shall be used when working on or near energized conductors and equipment. Insulating protective covers are to be used only for their designated purpose.

7. Inspection, maintenance and testing

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

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

7.1 Inspection, maintenance and testing categories

- **Periodic inspection and maintenance** shall be performed to verify proper system operation and general system upkeep.
- **Preventive 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.
- **Condition-based maintenance** shall be performed following a fault condition, an excessive number of operations of equipment, or any abnormalities found.

7.2 Periodic inspection and maintenance

Monthly inspections and maintenance shall consist of the following:

a) Verify cleanliness of the substation site inside and outside. Particular attention should be given to combustible rubbish material, such as newspapers, drawings and storage of materials not related to substation operations and maintenance in the same room.
b) Check for the presence of oil, dust or other material generated from traction power equipment inside or outside the equipment room or building.
c) Inspect and replace air filters.
d) Verify correct operation of any oil/water separators.
e) Check for presence of water or other material leaking into the substation from elsewhere.
f) Check for the presence of any “burning” smell, fumes, scorch marks or other material that could be signs of a future breakdown.
g) Test emergency exit lighting and doors to verify that they meet all applicable codes.
h) Verify operation of all lamps. Replace as necessary.
i) Verify operation of all alarms.
j) Verify operation of heating and ventilation systems.
k) Verify that the DC switchgear enclosure is not energized except where applicable.
l) Verify that voltmeters/ammeters/wattmeters (and battery chargers and inverters if present) give expected readings. Investigate any unexpected readings.
m) Record all counter readings where available.

7.3 Preventative maintenance and testing

Preventative maintenance shall include all items in Section 7.2 and Section 7.5.2 of this document.

7.4 Condition-based maintenance

7.4.1 Post-fault conditions

A post-fault condition is defined as any condition where a system failure occurred that has caused either repetitive faults or lockout trip of any subsystem.

Example: A DC circuit short circuit would require a thorough check of the circuit breaker, distribution system, ground and associated devices.

7.4.2 Other conditions

a) Exceeding the recommended number of operations under load conditions for circuit breakers.
b) Defects found during monthly inspections that would generate a priority 1 or 2 as listed in Section 9 of this standard.
c) Any abnormal conditions found.

7.5 Procedures

The rail transit system shall perform inspection, maintenance and testing in accordance with this standard and develop local policies and procedures to meet the requirements herein.

No work shall be performed unless proper procedures, documentation and authorization have been obtained from the rail transit system designated authority to perform the prescribed task at the designated location. Upon completion of the work, the rail transit system designated authority must be informed that the prescribed task is completed.

7.5.1 Written 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.

7.5.2 Procedures for inspecting, maintaining and testing substations

7.5.2.1 High-voltage equipment: AC vacuum breaker

Visual and mechanical inspection

a) Thoroughly clean the unit prior to testing.
b) Inspect the physical and mechanical condition.
c) Inspect anchorage, alignment and grounding.
d) Perform all mechanical operations tests on both the circuit breaker and its operating mechanism.
e) Verify the operation of heaters, if applicable.
f) Measure critical distances as recommended by the OEM. Make necessary adjustments.
g) Inspect bolted electrical connections using any one of the following methods:
    - Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with OEM recommendations. If a connection shows any sign of corrosion, then the connection shall be cleaned or replaced.
    - Perform a thermographic survey of equipment.

h) Verify appropriate contact lubrication per OEM recommendations on:
   - moving current-carrying parts; and
   - moving and sliding surfaces.

i) Record as-found and as-left operation counter readings.

Electrical tests

a) Perform a contact resistance test using a low-resistance ohmmeter capable of reading 2 μΩ. The maximum reading is to be established by the rail transit system.
b) Verify trip, close, trip-free and anti-pump operations.
c) Trip the circuit breaker by operation of each of the protective devices.
d) Perform resistance measurements on bolted connections with a low-resistance ohmmeter.
e) Perform insulation-resistance tests pole-to-pole, pole-to-ground and across open poles in accordance with the OEM manual.
f) Perform vacuum bottle integrity (over-potential) test across each vacuum bottle with the breaker in the open positions in strict accordance with OEM published data. Do not exceed maximum voltage stipulated for this test. Provide adequate barriers and protection against x-radiation during this test. Do not perform this test unless the contact displacement of each interrupter is within OEM tolerance.

   NOTE: Be aware that some DC high-potential test sets are half-wave rectified and may produce peak voltages in excess of the breaker OEM-recommended maximum.

g) Perform insulation-resistance test at 1000 VDC on all control wiring. For units with solid-state components, follow OEM recommendations.

Operation checks

a) Check each circuit breaker for proper operation. Perform the following checks as a minimum:
   - Open and close the breaker via local control.
   - Open and close the breaker via remote control (SCADA if applicable).
   - Open and close the breaker while in the test position.
   - Verify mechanical trip features where applicable.

b) For each operation check, verify the following (when applicable):
   - Local breaker indication: Ensure that the indication lamps and any mechanical indications function properly.
   - Remote breaker indications: Ensure that the control center receives the proper indications regarding breaker position if applicable (i.e., open/closed and remote/local condition).

Test values

a) Compare bolted connection resistance to values of similar connections.
b) Ensure 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 the OEM data is not available, then investigate any values that deviate from adjacent poles or similar breakers by more than 25 percent of the lowest value.
d) Ensure circuit breaker insulation resistance is in accordance with the OEM published data.
e) Contact displacement shall be in accordance with the factory-recorded data marked on the nameplate of each vacuum breaker or bottle.
f) Ensure that the interrupter withstands the over-potential voltage applied.
g) Ensure that control wiring insulation resistance is a minimum of 2 MΩ.
h) Ensure that the insulation withstands the over-potential test voltage applied.

7.5.2.2 High-voltage equipment: AC switch

Visual and mechanical inspection

a) Inspect physical and mechanical condition.
b) Verify appropriate anchorage and required area clearances.
c) Verify appropriate equipment grounding.
d) Verify correct blade alignment, blade penetration, travel stops and mechanical operation.
e) Verify that fuse sizes and types (if applicable) are in accordance with the drawings.
f) Verify that expulsion-limiting devices are in place on all holders having expulsion-type elements.
g) Verify that each fuse holder (if applicable) has adequate mechanical support.
h) Inspect bolted electrical connections using one of the following methods:
    - Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with OEM published data.
    - Perform a thermographic survey of the equipment.
i) Test all interlocking systems for correct operation and sequencing.
j) Inspect insulating assemblies for evidence of physical damage or contaminated surfaces.
k) Exercise all active components.
l) Compare switchblade clearances with OEM recommendations.
m) Verify all indicating and control devices for correct operation.
n) Verify operation of heaters, if applicable.
o) Verify appropriate contact lubrication per OEM recommendation on:
    - current-carrying parts; and
    - moving and sliding surfaces.

Electrical test

a) Perform insulation-resistance tests on each pole, phase-to-phase and phase-to-ground, with the switch closed and across each open pole for 1 min. Test voltage shall be in accordance with OEM published data.
b) Perform an over-potential test on each pole with the switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with OEM published data.
c) Perform resistance measurements through each bolted connection with a low-resistance ohmmeter.
d) Perform a contact resistance test using a low-resistance ohmmeter capable of reading 2 μΩ. Maximum reading to be established by the rail transit system.
e) Measure the fuse resistance, if applicable.

Test values

a) Compare bolted connection resistances to values of similar connections.
b) Ensure bolt-torque levels are as specified in OEM published data.
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 adjacent poles or similar switches by more than 25 percent of the lowest value.
d) Ensure that the insulation withstands the over-potential test voltage applied.
e) Ensure that insulation resistance is in accordance with the OEM published data.
f) Investigate fuse resistance values that deviate from each other by more than 15 percent.

7.5.2.3 Transformers: Dry type (VPI/cast coil)

Visual and mechanical inspection

a) Thoroughly clean the unit prior to testing.
b) Inspect physical, electrical and mechanical condition including evidence of moisture, corona or brittleness.
c) Verify that control and alarm settings on temperature indicators are as specified.
d) Verify that cooling fans operate, where applicable.
e) Inspect all bolted electrical connections using one of the following methods:
    - Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with OEM published data.
    - Perform thermographic survey.
f) Perform specific inspections and mechanical tests as recommended by the OEM.
g) Verify that the core, frame and enclosure are grounded.
h) While de-energized, operate any off-load or on-load tap changer through its complete range three times.
i) Verify that as-left tap connections meet system requirements.

Electrical tests

a) Perform insulation-resistance tests winding-to-winding and each winding-to-ground; with the proper test voltage (see References, ANSI/IEEE C57.12.91).
b) Perform resistance measurements through each bolted connection with a low-resistance ohmmeter.
c) Measure core insulation-resistance if the core is insulated and if the core ground strap is removable.

Test values

a) Compare bolted connection resistance to values of similar connections.
b) Ensure bolt-torque levels are in accordance with the 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 the OEM data isn't available, then investigate any values that deviate from similar connections by more than 25 percent of the lowest value.
d) Ensure that insulation-resistance test values are no less than the values recommended in ANSI/IEEE C57.12.91.
e) Ensure that core insulation resistance values are comparable to previously obtained results but not less than 1 MΩ.

7.5.2.4 Transformers: Liquid filled

Visual and mechanical inspection

a) Inspect physical and mechanical condition.
b) Verify that control and alarm settings on temperature indicators are as specified.
c) Verify that cooling fans and/or pumps operate correctly.
d) Verify operation of all alarms, controls and trip circuits from temperature and level indicators, pressure relief devices and fault pressure relays.
e) Inspect all bolted electrical connections using one of the following methods at a frequency of no more than every five years:
    - Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with OEM published data.
    - Perform thermographic survey.
f) Verify correct liquid level in all tanks and bushings.
g) Verify that positive pressure is maintained on nitrogen-blanketed transformers.

h) Verify that PCB concentration levels are visible.
i) While de-energized, operate any off-load or on-load tap changer through its complete range three times.
j) Verify that as-left tap connections meet system requirements.

Electrical tests

a) Perform insulation-resistance tests winding-to-winding and each winding-to-ground; with the proper test voltage (see References, ANSI/IEEEC57.12.90).
b) Perform resistance measurements through all bolted connections with a low-resistance ohmmeter.
c) Remove a sample of insulating liquid in accordance with ASTM D923. Samples should be sent to a certified test facility for all required testing.

Test values

a) Compare bolted connection resistance to values of similar connections.
b) Ensure that bolt-torque levels are in accordance with the 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 the OEM data isn't available, then investigate any values that deviate from similar connections by more than 25 percent of the lowest value.
d) Ensure that insulation-resistance test values are no less than the values recommended in ANSI/IEEEC57.12.90.
e) Investigate for the presence of dissolved gas in nitrogen gas blanket.
f) Evaluate and trend recommendations and test results from transformer liquid analysis.

7.5.2.5 Rectifiers

Visual and mechanical inspection

a) Thoroughly clean all apparatus and surrounding enclosure.
b) Inspect physical and mechanical connections.
c) Inspect anchorage and alignment.
d) Inspect all bolted connections and verify that bolt-torque values are consistent with OEM published data.
e) Check fuse holders for adequate support.
f) Verify that fuse-blown indicators (where applicable) are properly mounted.
g) Inspect insulating assemblies for evidence of physical damage or contaminated surfaces.
h) Inspect all control wiring for integrity.
i) Test all electrical and mechanical interlocks for correct operation.
j) Replace filters (if applicable) when required.

7.5.2.6 Negative return switch

Visual and mechanical inspection

a) Thoroughly clean the unit prior to testing.
b) Inspect physical and mechanical condition.
c) Verify appropriate anchorage and required area clearances.
d) Verify correct blade alignment, blade penetration, travel stops and mechanical operation.
e) Inspect all bolted electrical connections using one of the following methods:
    - Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with OEM published data.
    - Perform thermographic survey.
f) Test all interlocking systems for correct operation and sequencing.

g) Inspect insulating assemblies for evidence of physical damage or contaminated surfaces.
h) Exercise all active components.
i) Verify the correct operation of all indicating and control devices for correct operation.
j) Verify appropriate contact lubrication per OEM recommendation on:
    - moving current-carrying parts; and
    - moving and sliding surfaces.

Electrical test

a) Perform resistance measurements through all bolted connections with a low-resistance ohmmeter.
b) Measure contact resistance across each switchblade using a low-resistance ohmmeter capable of reading 2 μΩ. Maximum reading to be established by the rail transit system.

Test values

a) Compare bolted connection resistances to values of similar connections.
b) Ensure that bolt-torque levels are as per OEM published data.
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 the OEM data is not available, then investigate any values that deviate from adjacent poles or similar switches by more than 25 percent of the lowest value.

7.5.2.7 DC traction circuit breakers

Visual and mechanical inspection

a) Thoroughly clean the breaker prior to testing.
b) Inspect physical and mechanical condition.
c) Inspect anchorage and alignment.
d) Perform all mechanical operations tests on both the circuit breaker and its operating mechanism.
e) Verify operation of heaters, if applicable.
f) Measure critical distances such as contact gap as recommended by the OEM.
g) Inspect bolted electrical connections and verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with OEM recommendations. If connection shows any signs of corrosion, then it shall be cleaned or replaced.
h) Verify appropriate contact lubrication per OEM recommendation on:
    - moving current-carrying parts; and
    - moving and sliding surfaces.
i) Record as-found and as-left operation counter readings.
j) Inspect all DC traction circuit breaker contacts. Contacts include but are not limited to:
    - main contacts;
    - arcing contacts;
    - secondary contacts and/or disconnects; and
    - auxiliary contacts.
k) Where applicable, check contacts for the following:
    - Cleanliness: Ensure the contact surface is clean and kept free of any burrs and “spits.” Use care if contacts are coated with silver or a silver alloy and when cleaning and/or deburring the contact surface. To avoid damage to the contact surface, consult the OEM-recommended procedure to determine the proper cleaning method.
    - Wipe: Check contacts for proper wipe. Adhere to the OEM-recommended procedure for checking contact wipe. Make necessary adjustments according to the OEM-recommended practice.

- Pressure: Check contacts for proper pressure. Adhere to the OEM-recommended procedure for checking contact pressure. Make necessary adjustments in accordance with the OEM-recommended practice.

l) Clean arc chutes by performing the following tasks as a minimum:
- Inspect for any breakage to the inside sheet, arc plates or arc runner.
- Inspect the interrupting structure for the presence of foreign particles such as chips of insulation and metal.
- Inspect the exterior of the arc chute for any damage or deformation to the outside sheets.
- Remove any foreign bodies or objects.
- Wipe the arc runner and arc horn with a dry cloth to remove dirt and dust accumulation.
- Wipe all insulated parts with a cloth saturated with an oil-free solvent to remove any oil vapor film.

CAUTION: Use care when cleaning any arc chute. Some older arc chutes may contain asbestos materials.

- Check to ensure that each puffer provides a moderate amount of air at the contact when the breaker is opened. Use a suitable medium such as a piece of paper to detect air movement. If the puffers do not show signs of puffing action, then do not place the breaker in service.

CAUTION: Care shall be exercised when performing this check. Keep clear of all moving parts to avoid injury.

Electrical tests

a) Measure the contact resistance using a low-resistance ohmmeter capable of reading 2 μΩ. Maximum reading to be established by the rail transit system.
b) Perform a contact-resistance test.
c) Verify trip, close, trip-free and anti-pump operations.
d) Trip the circuit breaker by operation of each of the protective devices.
e) Perform resistance measurements on each bolted connection with a low-resistance ohmmeter.
f) Perform insulation-resistance tests pole-to-pole, pole-to-ground and across open poles in accordance with the OEM manual.
g) Perform an insulation-resistance test at 1000 VDC on all control wiring. For units with solid-state components, follow the OEM recommendations.

Operation checks

a) Check each DC traction circuit breaker for proper operation. Check the following as a minimum:
- Open and close the breaker via local control.
- Open and close the breaker via remote control (SCADA if applicable).
- Open and close the breaker while in the test position.
- Verify mechanical trip features where applicable.

b) For each operation check, verify the following (when applicable):
- Local breaker indication: Ensure that the indication lamps and any mechanical indications function properly.
- Remote breaker indications: Ensure that the control center receives the proper indications regarding breaker position if applicable (i.e., open/closed and remote/local condition).

7.5.2.8 Batteries and chargers

Visual and mechanical inspection

a) Inspect physical and mechanical condition.
b) Inspect all bolted electrical connections using one of the following methods:
   - Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with OEM published data.
   - Perform thermographic survey.
c) Clean corroded/oxidized terminals and apply an oxide inhibitor.
d) Verify proper electrolyte level (omit on sealed batteries).
e) Verify presence of flame arresters (omit on sealed batteries).
f) Verify adequacy of battery support racks, mounting, anchorage and clearances.
g) Verify the ventilation of battery room or enclosure.
h) Verify existence of suitable eyewash equipment.

Electrical tests

a) Perform resistance measurements through all bolted connections with a low-resistance ohmmeter capable of reading 2 μΩ. Maximum reading to be established by the rail transit system.
b) Measure electrolyte specific gravity and temperature (omit on sealed batteries).
c) Measure charger float and equalizing voltage levels.
d) Verify all charger functions and alarms.
e) Measure each cell voltage and total battery voltage with charger energized and in float mode of operation.
f) Verify operation of system equipment with power to the charger removed.

Test values

a) Compare bolted connection resistances to values of similar connections.
b) Ensure that bolt-torque levels are in accordance with OEM specifications.
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 the OEM data is not available, then investigate any values that deviate from similar connections by more than 25 percent of the lowest value.
d) Ensure that charger float and equalize voltage levels are in accordance with the OEM published data.
e) Ensure that specific gravity is in accordance with the OEM-recommended values.
f) Ensure that electrolyte level is within normal limits.
g) Ensure than cell voltages are within 0.05 V of each other or in accordance with the OEM published data.

7.5.2.9 Protective relays

Visual and mechanical inspection

a) Inspect physical and mechanical condition.
b) Inspect the relay contacts for burns, damage, misalignment, corrosion or other contamination.
c) Verify that settings are as intended.

Electrical tests

a) Perform OEM-recommended maintenance.

Test values

a) Ensure that test values are in accordance with OEM manuals.

8. 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 plan for documented system defects monthly.

9. 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. Recommended priority ratings are the following:

- **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.

10. 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.

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

References

This document shall be used in conjunction with the most recent version of the following publications:

American National Standards Institute:

ANSI/IEEE C57.12.90 (2010 or most current), Standard Test Code for Liquid Immersed Distribution Power and Regulating Transformers and Guide for Short Circuit Testing of Distribution and Power Transformers.

ANSI/IEEE C57.12.91 (2011 or most current), Test Code for Dry Type Distribution and Power Transformers.

NFPA 70E, Standard for Electrical Safety Requirements.

Definitions

arc: An electrical spark that occurs when current jumps across an air gap as a result of a number of conditions. Arcing is a common electrical hazard.

conductive personal article: A personal item that can conduct electricity. Examples of conductive personal articles are metal watch bands, metal-framed safety glasses, finger rings, jewelry, metal belt buckles, hearing aids with external wiring, etc.

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

heavy rail system: An electric railway capable of a heavy volume of traffic characterized by exclusive rights-of-way, multicar trains, high speeds, rapid acceleration, sophisticated signaling and high-platform passenger loading. Also called 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 streetcars, trams or trolley cars.

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.

post-fault condition: Any condition caused by a system failure that causes either repetitive faults or lockout trip of any subsystem.

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.

Abbreviations and acronyms

µΩ	microhms
AAS	associate in applied science
AC	alternating current
ANSI	American National Standards Institute
DC	direct current
IEEE	Institute of Electrical and Electronic Engineers
MΩ	megohms
NATSA	North American Transit Services Association
NFPA	National Fire Protection Agency
OEM	original equipment manufacturer
PCB	polychlorinated biphenyls
PPE	personal protective equipment
PM	preventive maintenance
SCADA	supervisory control and data acquisition system
V	volts
VDC	volts direct current
VPI	vacuum pressure impregnated

Summary of document changes

- 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 7; Language added to allow Agencies to also incorporate IEEE standards into their inspection, maintenance and testing procedures.
- Section 7: Removed IEEE standard dates from the text body.
- Updated References; Modified ANSI/IEEE C57.12.90 to (2010 or most current) and ANSI/IEEE C57.12.91 to (2011 or most current) to allow the use of the specified year or the most current as they become adopted by IEEE.
- 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	June 25, 2002	—	—	Sept. 28, 2003	September 2003
First revision	—	—	—	—	July 26, 2004
Second Revision	June 14, 2017	August 1, 2017	Sept. 18, 2017	November 2, 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								
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			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