

# 4. Standard for Traction Electrification Substation Inspection, Maintenance and Testing

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

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

## Introduction

(This introduction is not a part of APTA RT-FS-S-004-03, *Standard for 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 systems), original equipment manufacturers, consultants, engineers, and general interest groups. This standard provides procedures for inspecting, maintaining, and testing rail transit traction electrification substations.

APTA recommends this standard for:

- 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, maintenance, and testing process
- To identify inspection criteria and maintenance standards that provide a high level of passenger and personnel safety

The application of any standards, practices, or guidelines contained herein is voluntary. In some cases, federal and/or state regulations govern portions of how an RTS operates. In such cases, the government regulations override any conflicting practices this document requires or recommends.

## Participants

APTA greatly appreciates the contributions of the following members of the Transit Standards Fixed Structures Inspection and Maintenance Committee who provided the primary effort in drafting the *Standard for Traction Electrification Substation Inspection, Maintenance and Testing*:

|                     |                 |            |
|---------------------|-----------------|------------|
| Roger Avery         | Robert Chappell | Carol Rose |
| Steven Bezner, P.E. | Frank Machara   |            |
| Ray Borge           | David Rankin    |            |

The following members of the Rail Transit Standards Fixed Structures Inspection and Maintenance Committee contributed to the review and approval process of the *Standard Traction Electrification Substation Inspection, Maintenance and Testing*:

**Robert Chappell, Chair**  
**Frank Cihak, Vice Chair**

|                           |                     |                       |
|---------------------------|---------------------|-----------------------|
| Anthony Adams             | David Dunderdale    | Bill Petit            |
| Carlton "Don" Allen, P.E. | James Dunn          | David Rankin          |
| Sal Arceo                 | James Dwyer         | Pingali Rao, P.E.     |
| Roger Avery               | William Early, P.E. | Richard Raschke       |
| Peter Bertozzi            | Percy Erves         | James Redding         |
| Steven Bezner, P.E.       | Michael Esford      | Stephen Roberts       |
| Raymond Borge             | Richard Falcon      | Charles Slavis, P.E.  |
| Michael Brown             | Ray Favetti         | Frederick Smith, P.E. |
| John Bumanis              | Peter Fedun, P.E.   | Richard Spatz         |
| Clay Bunting              | Steve Feil          | Charles Stanford      |
| R. Sean Burgess           | Robert Fiore        | F. Brian Steets       |
| Paul Camera               | John Gaito          | Paul Swanson, P.E.    |
| David Cappa, P.E.         | Ricky Green         | Steven Thompson       |
| Gricelda Cespedes         | Mohammad Irshad     | Fred Tijan            |
| Robert Chappell           | Patrick Lavin       | Gary Touryan          |
| Frank Cihak               | Harry Lupia         | Carey Vaughn          |
| Catherine Cronin          | Frank Machara       | James Wang, P.E.      |
| Lenny De Meyer            | Ruben Madrigal      |                       |
| Tom Devenny               | Michael Monastero   |                       |

APTA Rail Transit Standards Fixed Structures Inspection and Maintenance Committee project consultants:

Peter Gentle, PE., *STV Incorporated*  
Carol Rose, *STV Incorporated*

APTA Rail Transit Standards project team:

Gabrielle Bayme, *Standards Development Program Specialist and Project Editor*  
Saahir Brewington, *Administrative Assistant and Project Editor*  
Antoinette Hankins, *Program Assistant*  
Thomas Peacock, *Director-Operations & Technical Services*  
David Phelps, *Senior Project Manager - Rail Programs*

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# Standard for Traction Electrification Substation Inspection, Maintenance, and Testing

## 1. Overview

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 (RTS) 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.

### 1.1 Purpose

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.

### 1.2 Scope

This standard applies to rail transit systems that operate light rail, heavy rail, or rail subway systems and applies to normal operating conditions.

### 1.3 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. An individual RTS may develop alternates to the 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:

- a) Identify the specific APTA rail transit safety standard requirements that cannot be met
- b) State why each of these requirements cannot be met

- c) Describe the alternate methods used
- d) 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)

## 2. References

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

ANSI/IEEE C57.12.90 (1993), 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 (1995), Test Code for Dry Type Distribution and Power Transformers.

NFPA 70E, Standard for Electrical Safety Requirements.

## 3. Definitions and acronyms

For the purposes of this standard, the following definitions and acronyms apply:

### 3.1 Definitions

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

**3.1.2 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.

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

**3.1.4 heavy rail system:** An electric railway capable of a “heavy volume” of traffic characterized by exclusive rights-of-way, multi-car trains, high speed and rapid acceleration, sophisticated signaling, and high platform passenger loading. *Syn:* **elevated railway, rapid rail, rapid transit, subway.**

**3.1.5 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. *Syn:* **street car, tram, trolley car.**

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

**3.1.7 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.

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

**3.1.9 rail transit system (RTS):** The organization or portion of an organization that operates rail transit service and related activities. *Syn:* **operating agency, operating authority, transit agency, transit authority, transit system.**

### 3.2 Acronyms

|              |  |
|--------------|--|
| <b>AAS</b>   | Associate in Applied Science                     |
| <b>AC</b>    | alternating current                              |
| <b>ANSI</b>  | American National Standards Institute            |
| <b>APTA</b>  | American Public Transportation Association       |
| <b>DC</b>    | direct current                                   |
| <b>IEEE</b>  | Institute of Electrical and Electronic Engineers |
| <b>NFPA</b>  | National Fire Protection Agency                  |
| <b>OEM</b>   | original equipment manufacturer                  |
| <b>PPE</b>   | personal protective equipment                    |
| <b>PM</b>    | preventive maintenance                           |
| <b>RTS</b>   | rail transit system                              |
| <b>SCADA</b> | supervisory control and data acquisition system  |
| <b>VPI</b>   | vacuum pressure impregnated                      |

## 4. Frequency of tasks

The inspection, maintenance, and testing procedures in this standard shall be performed as specified in Table 1 below as otherwise deemed necessary by the RTS. Since age, type, operating conditions, and environment vary from system to system and OEM maintenance intervals may vary based on operating conditions, the RTS 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<br>(minimum) | Section |
|-----------------------------|------------------------------------|---------|
| Periodic inspection         | Monthly                            | 6.5     |
| Preventative maintenance    | Annually                           | 6.6/7.0 |
| Condition based maintenance | As failures require                | 6.7     |

The RTS 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
- RTS testing and experience
- Regulatory requirements

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

## **5. 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 system shall determine what their 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.

### **5.1 Skills and knowledge**

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

#### **5.1.1 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.

#### **5.1.2 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.

### **5.1.3 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 equivalent.

### **5.2 Continuing education**

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

## **6. Tools**

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

- Torque wrench
- Multi-meter\*
- Megohm-meter\*
- Standard tools carried by electrical maintenance workers

\* Calibrate in accordance with OEM and/or RTS requirements.

## **7. Equipment lockout/tagout**

Proper lockout/tagout procedures shall be followed as required by the RTS.

## **8. Safety**

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

## **9. Personal protective equipment**

Personal protective equipment, as required by the RTS, 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.

## **10. Inspection, maintenance, and testing**

Rail transit systems shall evaluate their local operating environment and conditions to develop suitable inspection, maintenance, and testing programs.

## 10.1 Inspection, maintenance, and testing categories

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

## 10.2 Periodic inspection and maintenance

Monthly inspections and maintenance shall consist of the following:

- a) Verify cleanliness of 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 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 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.

## 10.3 Preventative maintenance and testing

Preventative maintenance shall include all items in Section 10.2 and Section 10.5.2 of this document.

## **10.4 Condition-based maintenance**

### **10.4.1 Post fault conditions**

Post-fault conditions are 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.

### **10.4.2 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 12 of this standard.
- c) Any abnormal conditions found.

## **10.5 Procedures**

The RTS 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 RTS-designated authority to perform the prescribed task at the designated location. Upon completion of the work, the RTS-designated authority must be informed that the prescribed task is completed.

### **10.5.1 Written policies and procedures**

Each RTS 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.

### **10.5.2 Procedures for inspecting, maintaining, and testing substations**

#### **10.5.2.1 High voltage equipment: AC vacuum breaker**

##### **10.5.2.1.1 Visual and mechanical inspection**

- a) Thoroughly clean unit prior to testing.
- b) Inspect 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 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 the connection shall be cleaned or replaced.
  - Perform thermographic survey of equipment.
- h) Verify appropriate contact lubrication per OEM recommendation on:
  - Moving current-carrying parts
  - Moving and sliding surfaces.
- i) Record as-found and as-left operation counter readings.

#### **10.5.2.1.2 Electrical tests**

- a) Perform a contact resistance test using a low-resistance ohmmeter capable of reading 2 microhms. Maximum reading to be established by the RTS.
- 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 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 volts DC on all control wiring. For units with solid-state components, follow OEM recommendations.

#### **10.5.2.1.3 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)

#### **10.5.2.1.4 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 milivolt 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, 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 control wiring insulation resistance is a minimum of two megohms.
- h) Ensure the insulation withstands the over-potential test voltage applied.

#### **10.5.2.2 High voltage equipment: AC switch**

##### **10.5.2.2.1 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
  - Moving and sliding surfaces

#### **10.5.2.2.2 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 one minute. 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 microhms. Maximum reading to be established by the RTS.
- e) Measure fuse resistance, if applicable.

#### **10.5.2.2.3 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 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, investigate any values that deviate from adjacent poles or similar switches by more than 25 percent of the lowest value.
- d) Ensure the insulation withstands the over-potential test voltage applied.
- e) Ensure 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.

### **10.5.2.3 Transformers: dry type (vpi/cast coil)**

#### **10.5.2.3.1 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.

#### **10.5.2.3.2 Electrical tests**

- a) Perform insulation-resistance tests winding-to-winding and each winding-to-ground, with the proper test voltage. (See *ANSI/IEEE C57.12.91 – 1995*<sup>1</sup>)
- b) Perform resistance measurements through each bolted connection with a low-resistance ohmmeter.

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<sup>1</sup> For references in italics, see Section 2.

- c) Measure core insulation-resistance if core is insulated and if the core ground strap is removable.

#### **10.5.2.3.3 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, investigate any values that deviate from similar connections by more than 25 percent of the lowest value.
- d) Ensure insulation-resistance test values are no less than the values recommended in *ANSI/IEEE C57.12.91 - 1995*.
- e) Ensure core insulation resistance values are comparable to previously obtained results but not less than one megohm.

#### **10.5.2.4 Transformers: liquid filled**

##### **10.5.2.4.1 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 five (5) 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.

#### **10.5.2.4.2 Electrical tests**

- a) Perform insulation-resistance tests winding-to-winding and each winding-to-ground, with the proper test voltage. (See *ANSI/IEEE C57.12.90 – 1993*).
- b) Perform resistance measurements through all bolted connections with a low-resistance ohmmeter.
- c) Remove a sample of insulating liquid in accordance with the ASTM D923. Samples should be sent to a certified test facility for all required testing.

#### **10.5.2.4.3 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, investigate any values that deviate from similar connections by more than 25 percent of the lowest value.
- d) Ensure insulation-resistance test values are no less than the values recommended in *ANSI/IEEE C57.12.90 – 1993*.
- e) Investigate for the presence of dissolved gas in nitrogen gas blanket.
- f) Evaluate and trend recommendations and tests results from transformer liquid analysis.

#### **10.5.2.5 Rectifiers**

##### **10.5.2.5.1 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.

#### **10.5.2.6 Negative return switch**

##### **10.5.2.6.1 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 correct operation of all indicating and control devices for correct operation.
- j) Verify appropriate contact lubrication per OEM recommendation on:
  - Moving current-carrying parts
  - Moving and sliding surfaces

##### **10.5.2.6.2 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 microhms. Maximum reading to be established by the RTS.

##### **10.5.2.6.3 Test values**

- a) Compare bolted connection resistances to values of similar connections.
- b) Ensure bolt-torque levels are as per OEM published data.

- 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, investigate any values that deviate from adjacent poles or similar switches by more than 25 percent of the lowest value.

### **10.5.2.7 DC traction circuit breakers**

#### **10.5.2.7.1 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 test 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 it shall be cleaned or replaced.
- h) Verify appropriate contact lubrication per OEM recommendation on:
  - Moving current-carrying parts
  - 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
  - auxiliary contacts
- k) Where applicable, check contacts for:
  - 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.**

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

#### 10.5.2.7.2 Electrical tests

- a) Measure the contact resistance using a low-resistance ohmmeter capable of reading 2 microhm. Maximum reading to be established by the RTS.
- 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 device.
- 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 OEM manual.
- g) Perform insulation-resistance test at 1000 volts DC on all control wiring. For units with solid-state components, follow the OEM recommendations.

#### **10.5.2.7.3 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)

#### **10.5.2.8 Batteries and chargers**

##### **10.5.2.8.1 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.

#### **10.5.2.8.2 Electrical tests**

- a) Perform resistance measurements through all bolted connections a low-resistance ohmmeter capable of reading 2 microhm. Maximum reading to be established by the RTS.
- 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.

#### **10.5.2.8.3 Test values**

- a) Compare bolted connection resistances to values of similar connections.
- b) Bolt-torque levels shall be in accordance with the OEM specifications.
- 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, investigate any values that deviate from similar connections by more than 25 percent of the lowest value.
- d) Ensure charger float and equalize voltage levels are in accordance with the OEM published data.
- e) Ensure specific gravity is in accordance with the OEM-recommended values.
- f) Ensure electrolyte level is within normal limits.
- g) Ensure cell voltages are within 0.05 volt of each other or in accordance with the OEM published data.

#### **10.5.2.9 Protective relays**

##### **10.5.2.9.1 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 settings are as intended

##### **10.5.2.9.2 Electrical tests**

Perform OEM-recommended maintenance.

#### **10.5.2.9.3 Test values**

In accordance with OEM manuals.

### **11. Correction of deficiencies**

Deficiencies identified during inspection, maintenance, and testing shall be corrected and documented in accordance with OEM and/or RTS 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 manpower are available.

The RTS 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 RTS shall take the equipment out of service.

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

### **12. Priority ratings**

The RTS shall develop a priority rating system to evaluate and determine the effects that any single defect will have on the system if they choose to operate with a known defect.

Recommended priority ratings are:

- 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.

### **13. Documentation**

The RTS 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 RTS 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.

Annex A

(Informative)

Sample checklist/recording form

PART I SECTION 4  
 REVISED MAY 23, 20013

(non)

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

(non)

Priority: 1 - Immediate, 2 - Essential, 3 - Secondary, 4 - Non-essential  
 218.14 (1091) Power and Wire Maintenance, Power Distribution

**cta**

Date \_\_\_\_\_

Foreman \_\_\_\_\_

End Location \_\_\_\_\_

Start Location \_\_\_\_\_

| Line | Location | Priority Number | Time & Date Reported | 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               |    |                              |         |                     |                      |    |
|      |          |                 | Defect               |    |                              |         |                     |                      |    |
|      |          |                 | Repair               |    |                              |         |                     |                      |    |
|      |          |                 | Defect               |    |                              |         |                     |                      |    |
|      |          |                 | Repair               |    |                              |         |                     |                      |    |

