Region of Waterloo
Stage 1 Light Rail Transit Project

Design and Construction Performance Output Specifications
Article 17
Corrosion Control and Grounding

Table of Contents

ARTICLE 17 CORROSION CONTROL AND GROUNDING

17.1 General

(a) This Article shall apply to corrosion control design for underground metallic structures and pipes, storage facilities, and any other facilities where corrosive conditions can occur. Types of corrosion control include stray currents mitigation, protective coating, and cathodic protection. The purpose of this Article is to provide design guidelines for corrosion control and grounding. Project Co's solutions to corrosion control and grounding issues shall expand on these guidelines. Project Co shall prepare a Basis of Design Report – Corrosion Control and Grounding which explains Project Co's approach to corrosion control and grounding in greater detail and in a site specific manner. The presentation of specific corrosion control and grounding requirements within this Article must not be construed to limit or modify in any way Project Co's responsibility to provide a holistic, comprehensive, and fully functional solutions to all corrosion control and grounding functions and corrosion control and grounding related appurtenances. The Basis of Design Report – Corrosion Control and Grounding shall address every aspect of the corrosion control and grounding design requirements cited in this Article. The rationale for all deviations or variances from any requirement cited this Article must be fully described in the Basis of Design Report – Corrosion Control and Grounding. As a supporting design document, Project Co shall prepare a Baseline Soil, Atmospheric and Existing Stray Current Condition Report and submit the draft report as part of Project Co's Phase 1 submittal. The final report is due 60 days after the Phase 1 submission and shall be augmented to reflect any testing that may occur after the final submission of the report.

(b) The Basis of Design Report – Corrosion Control and Grounding shall be prepared by Project Co's corrosion control engineer. Corrosion engineer shall be certified by NACE International as a Corrosion Specialist. This report will be used to guide the design of the LRT system and shall contain at a minimum:

(i) Results of all environmental condition investigations with a narrative discussing the implications of the investigations. The results shall be included in the Baseline Soil, Atmospheric and Existing Stray Current Condition Report.

(ii) A review and recommendations for all trackwork related components and materials that are intended be used to isolate the running rails from earth ground and provide the acceptance testing requirements for those materials prior to being installed on the LRT system.

(iii) The testing procedure(s) and basis for resistance to earth values that will be used for acceptance testing of all newly constructed trackwork

(iv) The testing procedure(s) that will be used for measuring existing stray current conditions and the corrosive potential of soil and atmospheric conditions.

(v) The testing procedure(s) that will be used monitor the in-service resistance to earth condition for all in-service trackwork

(vi) A review and recommendations for all elements in the immediate vicinity of the running rail such as poured in place or precast concrete, asphalt materials, other materials that may be used to fill in voids around the running rails, reinforcing steel, and provide the acceptance testing requirements for those materials prior to be installed on the LRT system.

(vii) A review and recommendations for utility corrosion control designs whether those designs are prepared by Project Co or by the utility which is impacted by the Stage 1 LRT Project.

(viii) A review and recommendations for electrical grounding for OCS poles and other project structures.

17.2 Purpose

(a) (a) These criteria describe design requirements necessary to accomplish corrosion control measures for Region of Waterloo Stage 1 Light Rail Transit Project. Design factors to consider for each system include plans to minimize stray current at the source, prevent premature failures of Light Rail Transit (LRT) facilities, and other underground structures to be installed, operated, and maintained in a cost effective manner. Corrosion control requirements shall be coordinated with all applicable engineering disciplines and neighbouring utility companies.

17.3 Scope

(a) General

(i) These criteria are separated into three areas, namely stray current corrosion control, soil corrosion control, and atmospheric corrosion control. The design criteria for each of these categories and its implementation shall meet the following objectives.

A. Realize the design life of LRT facilities by avoiding premature failure caused by corrosion,

B. Minimize annual operating and maintenance costs associated with material deterioration,

C. Ensure continuity of operations by reducing or eliminating corrosion related failures of LRT facilities and subsystems,

D. Minimize detrimental effects to facilities belonging to others as may be caused by stray currents from transit operations.

(b) Stray Current Corrosion Control

(i) Stray current control shall be based on the following principals:

A. Increasing the conductivity of the return circuit,

B. Increasing the resistance between the return circuit and the earth,

C. Increasing the resistance between the earth and underground metallic structures,

D. Increasing the resistance of underground metallic structures.

(ii) Stray current control measures shall be installed to traction power and trackwork systems to obtain minimal flow of direct current (dc) stray current into the surrounding environment. Protection measures shall be applied to assure that stray earth currents are maintained within acceptable ranges to avoid deterioration of buried metallic structures. Project Co shall provide recording charts as part of Project Co's program to measure existing stray currents to determine effects/magnitude of existing stray currents, if present, on existing utility installations, and to serve as documented reference for future investigations. The results of Project Co's program to measure existing stray currents shall be included in the Baseline Soil, Atmospheric and Existing Stray Current Condition Report.

(c) Soil Corrosion Control

(i) Soil and ground water corrosive characteristics shall be determined and documented during the Baseline Stray Current Surveys. This effort shall include an assessment of the de-icing chemicals used by each municipality as well as any de-icing or anti-icing chemicals, lubricants or other chemical that may be applied by Project Co in the vicinity of the trackway. Analysis of the data obtained, or from supplemental on-site measurements shall be the basis for corrosion control designs. Structures shall be protected against the environmental conditions by the use of coatings, insulation, cathodic protection, and electrical continuity as appropriate.

(d) Atmospheric Corrosion Control

(i) The atmospheric corrosion conditions such as temperature, relative humidity, and amount of rainfall shall be determined during the Baseline Stray Current Survey. The areas with corrosive atmospheres (industrial, marine, rural, etc.) shall be identified. This condition assessment shall also include identification of areas where salt spray or spray from other de-icing or anti-icing chemicals may present a corrosion control issue. Materials selection, designs, and associated coatings shall be based on recommendations of the survey and shall be used to prevent metallic structures and hardware from atmospheric corrosion.

(e) Grounding

(i) Due to the natural difference between safety grounding and corrosion control requirements, the guidelines provided in these criteria shall be followed. Grounding designs for Traction Power Substations, passenger stations, shops and yards, aerial structures, and other wayside locations, shall be reviewed by corrosion control personnel to assure corrosion control designs are not compromised.

17.4 Interfaces

(a) Corrosion control shall be interfaced and coordinated with other engineering disciplines and designs, including the utility, mechanical, civil, structural, electrical, trackwork, traction electrification, environmental, geotechnical, architectural, signals, communications, and safety and security designs. The Project Co's corrosion control engineer shall review and provide recommendations on corrosion control mitigation measures on design work being performed by utilities, municipalities or other public or private entities that are in the vicinity of the LRT.

17.5 Applicability of Criteria

(a) Since the LRT system will be designed and constructed in segments, corrosion control criteria shall be applicable throughout the design, installation, and start-up process of all segments.

17.6 Expansion Capability

(a) Corrosion control systems shall be easily expandable to the entire system without major reconfiguration, reconstruction, redundancy, and duplication of equipment. Experimental designs, equipment, and prototypes of a research nature are discouraged and must be reviewed and approved by the Region prior to their implementation and prior to incurring any costs.

17.7 Standards and Codes

(a) Standards, codes, and recommended practices for corrosion control include the following publications and/or codes by:

- (i) The National Association of Corrosion Engineers International
- (ii) National Fire Protection Association
- (iii) American National Standard Institute
- (iv) American Standards for Testing Materials
- (v) American Water Works Association
- (vi) American Electric Railway Association
- (vii) Department of Transportation
- (viii) Steel Structures Painting Council
- (ix) Institute of Electrical and Electronic Engineers
- (x) Underwriters Laboratories, Inc.
- (xi) The Occupational Safety and Health Act of Ontario
- (xii) Ontario Electrical Code
- (xiii) Military Specifications
- (xiv) National Electrical Manufacturer's Association
- (xv) Ontario Electrical Safety Code
- (xvi) Canadian Standards Association

(b) Other codes or regulations may also apply and the designers shall consult these publications and provide systems in accordance with the most stringent applicable code, or industry practice.

17.8 Special Design Provisions

(a) During the pre-design and design phases of the project, the corrosion control designer shall identify unique and special design cases such as existing building foundations, paralleling power lines, and unusual soil conditions. In these cases, the corrosion control designer shall evaluate and recommend special design measures as appropriate.

17.9 Stray Current Corrosion Prevention

(a) Purpose

- (i) The purpose of this section is to provide criteria for designs to minimize the corrosion impact of stray currents from the LRT system which would impact LRT structures and adjacent structures. By the application of the appropriate design criteria, the magnitude of stray currents can be reduced to such low levels that their corrosive effect on buried structures is negligible. The basic requirements for stray current control are as follows:

A. Under normal conditions, operate the LRT system without direct or indirect electrical connections between either the positive or negative traction power distribution circuits and ground.

B. Traction power and the trackwork shall be designed to minimize stray currents from the LRT system during normal revenue operations.

C. Ballast shall be clean, well drained, high resistivity material.

(b) Scope

(i) Structures and systems that may be affected by stray currents shall be identified. Typically these include, but are not limited to:

A. Trackwork components

B. Traction electrification system components

C. Metallic pipes and casings

D. Reinforced concrete structures.

(ii) Designs and design review efforts shall be coordinated with the outside agencies through the Region.

17.10 Stray Current Corrosion Prevention Systems

(a) General

(i) Stray current designs shall reduce or limit the level of stray current at the source, and provide a means to mitigate and monitor stray current activity on buried and embedded metallic structures.

(ii) The primary requirements for stray current control are:

A. To operate the system with no direct or indirect electrical connections between the positive and negative traction power distribution circuits and ground.

B. To minimize the electrical resistance of the negative return facilities.

C. To establish electrical continuity of steel reinforcement in cast-in-place concrete structures by selective tack welding of the reinforcement bars or using an equivalent means to establish the required electrical continuity.

D. To provide accessible test facilities capable of monitoring stray current activity on the bonded reinforcement or equivalent medium during revenue operations.

(b) Traction Power Substations

(i) The traction power distribution system shall be separated into three electrically isolated sections: the mainline, yards, and shops. Traction power substations shall be spaced at intervals such that track-to-earth potentials along the mainline will be within safe operating levels.

(ii) The Traction Power Substation shall include a separate dc traction ground electrode. The dc ground electrode shall be electrically isolated from facilities in the substation. The spacing between substations should be no more than 1.93 km.

(iii) Substations shall be provided with access to the dc negative bus for stray current monitoring, utilizing corrosion control junction boxes. The location of these boxes shall provide ready access for LRT and utility personnel.

(c) Positive Distribution System

(i) The positive distribution system shall be normally operated as an electrically continuous bus, with no breaks, except during emergency or fault conditions. Intentional electrical segregation of mainline, yard and shop positive distribution systems is the only type of segregation permitted.

(d) Electrical Ground Connections, Overhead Contact System (OCS) Support Poles.

(i) For locations other than at aerial structures, electrical ground facilities for adjacent OCS support poles shall not be interconnected. This will eliminate the possible transference of stray earth currents, from one portion of the transit system to another, because of an electrically continuous ground system. Where OCS poles are to be located on aerial structures, provision shall be made to interconnect these electrically and connect them to a ground electrode.

(e) Other Electrical Ground Connections

(i) The corrosion control engineer shall review all other LRT grounding systems for the possible transference of stray earth currents, from one portion of the transit system to another and recommend mitigation measures. These systems shall include grounds for communication and train control systems, traffic control induction loops, power supply grounds, and elements such as rail lubricators, switch heaters, and switch machines.

(f) Negative Distribution System

(i) The following industry accepted standards shall be included in designs to afford an electrically isolated rail system to control stray current at the source:

A. Continuously welded rail;

B. Rail bond jumpers at mechanical rail connections for special trackwork;

C. Insulating pads and clips on concrete ties;

D. Insulated rail fastening system for wood ties at a special trackwork installation;

E. Ballast on at-grade sections maintained a minimum of 25 mm below the bottom of the rail and the ballast specification shall require a well draining aggregate and an aggregated with a high electrical resistance;

F. Insulating direct fixation fasteners on concrete aerial structures;

G. Using a service proven rubber boot system in embedded tracks or at roadway and pedestrian crossings. In minor roadways or pedestrian crossings if a rubber boot system is not used, coat the rail with coal tar epoxy or equivalent coating.

H. Cross-bonding cables installed between the rails to maintain equal potentials on all rails;

I. Insulation of the impedance bond tap connections from the housing case;

J. Insulation of switch machines at the switch rods;

K. Rail insulating joints installed prior to bumping posts;

L. Rail insulators to electrically isolate the main line rails from freight sidings or connections to other rail systems.

M. Resistance-to-Earth Criteria. The mainline running rails, including special trackwork and all ancillary system connections shall be designed to have the following desirable in-service values for resistance to earth per 300 meters of track (2 rails):

1. At-grade ballasted track with cross-ties (wood or concrete) - 300 ohms
2. Embedded track – 200 ohms.
3. Direct Fixation track – 500 ohms

The corrosion control engineer shall identify the resistance to earth criteria for acceptance testing of new track to ensure that the above in-service resistance levels are readily maintained.

(ii) Resistance may be attained by use of insulating track fastening devices such as insulated tie plates, rail clips. Individual mainline rail fixation fasteners (insulated) shall have a minimum resistance of 10 megaohms dry and 500 kilohms within two hours of wetting

(iii) All devices such as switch machines, train control installations or other systems shall be electrically insulated from the rails by use of dielectric materials.

(g) Grade Crossings, Embedded Track

(i) Rails, rail fasteners and related metallic components shall be electrically isolated from ground by coatings and insulating components.

(h) Yard

(i) The yard/mainline traction power segregation point shall be located such that yard/mainline track are electrically isolated from each other and from ground connections.

(ii) Yard track shall include the following provisions:

A. Ballast shall be clean, well drained, high-resistivity material;

B. A 25.4 mm minimum clearance between the ballast and all rail surfaces and electrically connected metallic track components;

C. All dead-ended tracks shall have insulated joints installed to isolate bumping posts or similar devices that are electrically grounded.

(i) Maintenance Shop

(i) Shop traction power shall be provided by a separate dedicated DC power supply electrically segregated in both the positive and negative circuits from the yard traction power system.

(ii) Shop tracks shall be electrically grounded to the shop grounding system.

(iii) Shop tracks shall be electrically isolated from yard tracks by the use of rail insulated joints. Actual locations of insulating joints shall be placed such that parked vehicles will not electrically short the shop and yard separate traction electrification systems for periods of time longer than that required to move a vehicle in or out of the shop.

(j) Water Drainage

(i) Water drainage system shall be designed to prevent water accumulation from contacting the rails, rail insulating joints, rail metallic components and insulators and rail ties.

(k) Railroad Spurs

(i) Rail insulating joints shall be installed at all track crossing, sidings or other existing railroad interconnection to LRT system. The insulating joints shall be installed as close to the mainline as practicable and the insulating joints shall be electrically isolated from ground in a manner comparable to the mainline rails. Electrical detection connections shall be made on the railroad side of the insulating joints.

(l) Electrical Bonding

(i) Aerial Structures

A. All longitudinal bars in the top layer of reinforcement shall be tack welded at all overlaps to insure electrical continuity or electrically connected by an equivalent means.

B. Collector bars of the same size as the transverse reinforcement shall be tack welded to the longitudinal reinforcement at expansion/contraction joints, ends of construction segments and ends of contractual sections.

C. A minimum of two bonding cables shall be installed on each side of an electrical break in the structure.

D. Where possible structural deck members shall be electrically insulated from support piers and abutments.

E. A ground system, and related test stations, shall be provided at each end of the structure and at intermediate points as required.

(ii) Retaining Walls

A. All longitudinal bars overlaps in both faces of the wall, including the top and bottom bars of the footing, shall be tack welded to insure electrical continuity. Longitudinal bars in the footing shall be made electrically continuous to the longitudinal bars of the walls.

(iii) Utility Structures

A. All piping and conduit shall be non-metallic, unless metallic facilities are required for specific engineering purposes. There are no special provisions required if non-metallic materials are used.

B. To reduce the stray current effects on underground utilities nonmetallic materials, jackets or high quality coatings may be used. LRT owned utility structures such as buried metallic pipes and conduits shall be provided with electrical continuity. Pressure piping that penetrates structural walls shall be electrically insulated from the outside service piping and from watering wall sleeves. Dielectric insulation shall be made on the interior of the structural wall.

C. Replaced, relocated, and maintained in placed utility structures, owned by others, shall be provided with corrosion measures required by the utility.

(m) Quality Control

(i) Corrosion control designs shall be coordinated with all other engineering disciplines to ensure that they do not conflict with other installations. Shop drawings, material catalog cuts, and additional information related to the corrosion control designs shall be submitted for review and approval by the Region. Testing of materials prior to their delivery from a manufacturer, or during construction, shall be conducted, as required, to ensure compliance to corrosion control designs.

17.11 Soil Corrosion Control (Buried Structures)

(a) General

(i) This section provides criteria for the design of systems and measures to prevent corrosion from soils and ground waters on LRT fixed facilities. The design guidelines including the design life for public utilities is available from the Region. For other buried structures, designs shall be based on achieving a 50-year design life for buried structures through consideration of the following:

A. Materials of Construction

1. All piping (pressure and non-pressure) and conduit shall be non-metallic unless metallic materials are required for specific engineering purposes. Use of metallic materials shall be supported by engineering calculations when used in lieu of non-metallic materials. Aluminum and its alloys shall not be used for direct burial purposes.

B. Safety and Continuity of Operations

1. Corrosion control provisions shall be required for all facilities, regardless of location or material when failure of such facilities caused by corrosion will affect safety or interrupt continuity of operations.

(b) Scope

(i) The structures which may be affected by soil and water corrosion shall be identified. Typically, these include, but are not limited to:

A. Ferrous pressure piping (water, fire water, gas, sewage ejectors, etc.)

B. Buried and on-grade reinforced concrete structures

C. Hydraulic elevator cylinders

D. Support pilings

E. Underground storage tanks

F. Other underground structures

(ii) Corrosion control measures for structures owned by others shall be coordinated with the interested owner. This coordination shall be required to resolve design conflicts and to minimize impact of other designs, such as interference of cathodic protection. All contacts with owners of other structures shall be coordinated through the Region.

17.12 Soil Corrosion Prevention Systems

(a) General

(i) Protection of metal structures shall include, but not be limited to, corrosion control techniques, such as coating, electrical isolation, electrical continuity, and cathodic protection. The corrosion control designer shall also coordinate the designs to identify reinforced concrete structures subject to corrosion attack and specify cement types in accordance with ASTM C150. For severe environments, supplemental coatings shall be specified.

(b) Materials and Structures

(i) Ferrous Pressure Piping

A. All Region and City owned buried cast iron, ductile iron and steel pressure piping shall be cathodically protected. Designs shall include the following:

1. Application of a protective coating to the external surfaces of the pipe;

2. Electrical insulation from interconnecting piping, other structures, and segregation into discrete electrically insulated sections depending upon the total length of the piping;

3. Electrical continuity through installation of insulated copper wires, across all mechanical joints except for joints that are intended to be insulated joints;

4. Permanent test/access facilities, to allow for verification of continuity, effectiveness of insulators and coating, and evaluation of protection levels; shall be installed at all insulated connections and at intervals not greater than 61 metres;

5. Impressed current anodes and rectifier units or sacrificial anodes; the number of anodes and size of rectifier shall be determined on an individual structure basis.

(ii) Reinforced/Prestressed Concrete Pressure Pipe

A. Design and fabrication of reinforced concrete pipe and steel cylinder prestressed concrete pipe shall include the following:

1. Establish a low permeability concrete by controlling the water/cement ratio, ratios of 0.3 for core concrete and 0.25 for mortar are preferred, industry practices may result in significant increases and wide variations to these levels;

2. Maximum of 200 ppm chloride concentration in mixing water for concrete;

3. Use of Type I Portland Cement generally. Type II Portland Cement should be used in selected locations.

(iii) Concrete/Reinforced Concrete

A. Design shall be based on the following for concrete in contact with soils:

1. Use of Type I Portland Cement or Type II Portland Cement in selected locations;

2. Maximum water/cement ratio of 0.45 by weight;

3. Maximum 200 ppm chloride concentration in mixing water and admixtures combined;

4. Minimum 58.8 mm concrete cover on the soil side of all steel reinforcement when the concrete is poured within a form or a minimum 86.2 mm cover when the concrete is poured directly against soils.

5. The concrete used for all embedded track construction shall be based on recommendations developed by the corrosion control engineer and a test program to ensure compliance with these recommendations shall be implemented by Project Co. This information shall be included in the Basis of Design Report – Corrosion Control and Grounding.

(iv) Support Pilings

A. Preferred design shall be based on using a steel shell filled with reinforced concrete with the concrete as the load bearing member for maximum corrosion protection.

B. Design based on the used of metallic supports exposed to the soil such as H-beams shall consider the use of protective coatings and cathodic protection. The need for special measures shall be based on the type of structures, analysis of soil borings for the corrosive characteristics of soils, and the degree of anticipated structural deterioration caused by corrosion.

(v) Non-Metallic Materials

A. Plastics, fiberglass, and other non-metallic materials for pressurized piping may be appropriate to aid in corrosion control. The corrosion control design shall consider the following characteristics of proposed materials:

1. Manufacturer's recommendations

2. Mechanical strength and internal pressure limitations

3. Elasticity/expansion characteristics

4. Comparative costs
5. Expected life
6. Failure modes
7. Local codes
8. Prior experiences with the proposed non-metallic material in similar applications

(vi) Mechanically Stabilized Earth Walls

A. Non-metallic reinforcing material shall be used for Mechanically Stabilized Earth (MSE) walls if structurally permissible:

1. Embedded and buried steel reinforcing members of the modules should be constructed without special provisions for establishing electrical continuity.
2. Steel reinforcing strips of adjacent modules should not be electrically interconnected. The reinforcing strips should be coated with a fluidized-bed epoxy resin system or coal-tar epoxy system.
3. Tie strips should be coated with a fluidized-bed epoxy resin system or coal-tar epoxy system prior to module construction.
4. Longitudinal reinforcing steel within precast concrete parapets and cast-in-place junction slabs should not be made electrically continuous.

(vii) Hydraulic Elevator Cylinders

A. Steel hydraulic elevator cylinders shall be designed, fabricated, and installed to meet the following criteria:

1. External protective coating resistant to deterioration by petroleum products (hydraulic fluid);
2. Outer concentric fiberglass-reinforced plastic (FRP) casing. Casing thickness, diameter and resistivity shall be designed to prevent moisture intrusion (including the bottom) and to minimize electrical insulation between the cylinder and earth;
3. Sand fill between the cylinder and FRP casing with a minimum resistivity of 25,000 Ohm-centimeters, a pH of between 6 and 8 and maximum chloride content of 200 ppm;
4. Cathodic protection through the use of sacrificial anodes installed in the sand fill or galvanic ribbon anode wrapped around cylinder shall be used, however, cathodic protection of hydraulic elevator cylinder is not necessary if hydraulic casing will be installed within a sealed PVC enclosure including an inspection port inside an outer concentric fiberglass-reinforced plastic (FRP) casing, or inside a high density polyethylene (HDPE) casing at locations where an exterior hydrocarbon-resistant membrane is required for elevator pit. Casing thickness, joints, and diameter shall be designed to prevent moisture intrusion (including the

bottom), to maximize electrical insulation between the cylinder and earth, and to provide secondary containment when considered necessary or required in the design of the hydraulic elevator system. Any type of corrosion control of hydraulic elevator shall be approved by the Region.

5. Permanent test facilities installed on the cylinder, anodes and earth reference to permit evaluation, activation, and periodic retesting of the protection system;

6. Removable moisture-proof sealing lid installed on the top of the casing prior to installation of the cylinder. The top of the casing shall be permanently sealed against moisture intrusion after installation of the cylinder.

(viii) Electrical Conduits

A. Buried metallic conduits shall include the following minimum provisions:

1. Galvanized steel with a PVC topcoat or other coating acceptable for direct burial, including coupling and fittings;

2. Galvanized steel with a minimum of 76.2 mm concrete cover on soil sides within duct banks;

3. Electrical continuity through use of standard threaded joints or bond wires installed across non-threaded joints.

(c) Coatings

(i) Buried metal structures requiring coating shall be provided with coal tar, coal tar tape, or coal tar epoxy coating systems having high electrical resistance. Mill-applied coatings shall be specified whenever possible with use of compatible tape coatings for joints and field touch-up. The corrosion control design shall specify surface preparation, application procedure, primer, number of coats, and minimum dry film thickness for each coating system.

(d) Electrical Insulation

(i) Devices used for electrical insulators for corrosion control shall include non-metallic inserts, insulating flanges, coupling, unions, and concentric support spacers. Devices shall meet the following minimum criteria:

A. Devices shall have a minimum of 10 megaohms prior to installation and shall have mechanical and temperature rating equivalent to the structure in which it is installed;

B. Devices shall have sufficient electrical resistance after insertion into the operating piping system such that no more than two percent of a test current applied across the device flows through the insulator, including flow through conductive fluids if present;

C. Devices installed in chamber or otherwise exposed to partial immersion or high humidity shall have a protective coating applied over all components.

(ii) Design shall specify the need for, and location of, insulating devices. All devices shall be equipped with permanent test facilities when they are not accessible or when specialized equipment is necessary for access.

(iii) Wherever possible, a minimum clearance of 152.4 mm shall be provided between new and existing structures. When field conditions prohibit a 152.4 mm clearance, the design shall include special provisions to prevent electrical contact with the existing structure(s).

(e) Electrical Continuity

(i) Electrical continuity shall be provided for all underground non-welded pipe joints and shall meet the following minimum criteria:

A. Use direct burial insulated, stranded copper wires with the minimum length necessary to span the device being bonded;

B. Wire size shall be based on the electrical characteristics of the structure and resulting network to minimize attenuation and allow for cathodic protection;

C. A minimum of two wires shall be used per joint for redundancy.

(f) Cathodic Protection

(i) Protection Methods

A. Cathodic protection systems shall be provided for buried metallic structures consistent with the structure life objectives. Wherever feasible, cathodic protection shall be accomplished by sacrificial galvanic anodes to minimize corrosion interaction with other underground utilities. Impressed current systems shall be used only when use of sacrificial systems is not technically and economically feasible. The Region shall approve use of these systems at the conceptual stage prior to detail design. Cathodic protection schemes, using forced drainage of transit induced stray dc currents that require connections to the negative system, shall not be used.

(ii) Design Criteria

A. Cathodic protection system design shall be based on theoretical calculations for each system including the following minimum parameters:

1. Cathodic current density (minimum 10.8 mA/sq.m. of bare area)
2. Current requirements
3. Anticipated current output/anode
4. Assumed percentage bare surface area (minimum 1%)
5. Indicated total number of anodes, size, spacing
6. Anticipated anode life
7. Anticipated anode bed resistance

B. The sum of the anticipated anode life and time to failure based on corrosion rates anticipated at 90 percent cumulative probability level, shall not be less than 50 years.

(iii) Rectifier Design Criteria

A. Impressed current rectifier systems shall be completely designed using variable voltage and current output rectifiers. Rectifiers shall be rated a minimum 50 percent above calculated operating levels to overcome a higher than anticipated ground bed resistance, lower than anticipated coating resistance, or presence of interference bonds. Other conditions which may result in increased voltage and current requirements shall be considered.

(g) Test Facilities/Testing

(i) Test stations consisting of two structure cables, one reference electrode, conduits, and termination boxes shall be designed to permit initial and periodic tests of cathodic protection levels, interference currents, and system components (anodes, insulated fittings, and continuity bonds). The Basis of Design Report – Corrosion Control and Grounding shall specify the locations and types of test facilities for each cathodic protection system.

(h) Water Treatment

(i) For heating and air conditioning systems, chemical treatment of chiller, condenser and boiler supply and return system shall be designed to minimize internal corrosion and to prevent component fouling. Water treatment systems shall be designed to prevent corrosion rates in excess of 0.05 mm per year for steel and 0.025 mm per year for copper. Provisions for corrosion rate measurements shall be made in the return lines. All chemical treatment systems shall comply with environmental protection requirements. The corrosion control design shall include appropriate measures and provide space requirements for treatment equipment.

17.13 Atmospheric Corrosion Prevention

(a) General

(i) The purpose of this section is to provide criteria for designs that will ensure the necessary function and appearance of LRT structures exposed to the environment. Criteria for atmospheric corrosion control are based on prevention of appearance and reduction of maintenance costs. System wide criteria for all areas shall include the following:

A. Materials selection: Materials shall have established performance records for the service intended;

B. Sealants: Sealants shall be used in crevices to prevent the accumulation of moisture;

C. Protective coatings: Barrier or sacrificial coatings shall be used on steel;

D. Design: Use of dissimilar metals and recesses or crevices that might trap moisture shall be avoided.

(b) Scope

(i) The structures which may be affected by atmospheric corrosion shall be identified. Typically, these include, but are not limited to:

A. Catenary structures and hardware

B. Vehicles

C. Exposed metal surfaces on aerial and mainline structures

D. Exposed metal at passenger stations

E. Right-of-way and enclosure fences

F. Shop and yard exposed metal surfaces

G. Electrical, mechanical, signal and communication devices and equipment and traction power substation housings.

17.14 Atmospheric Corrosion Prevention Systems

(a) Materials

(i) Metals exposed to the atmospheric environments shall be selected and provided as follows:

A. Steels and Ferrous Alloys

1. Carbon steel and cast iron exposed to the atmosphere shall have a coating applied to all external surfaces. Rail and rail fasteners in open track typically do not require coatings. High strength low alloy steels shall be protected similarly to carbon steels except where used as weathering steel exposed to the outside environment. Coating of metallic contacting surfaces, crevice sealing and surface drainage shall be addressed in the designs. Staining of adjacent structures shall be considered. Series 200 and 300 stainless steels are suitable for use in any exposed situation without future protection. Series 400 stainless steels are acceptable, but must be evaluated due to possible staining. Stainless steel surfaces shall be cleaned and passivated after fabrication.

B. Aluminum Alloys

1. Use an anodized finish to provide the best weather resistant surface.

C. Copper Alloys

1. Copper and its alloys can be used where exposed to the weather without additional protection. Bimetallic couplings shall be avoided.

D. Magnesium Alloys

1. Magnesium alloys shall have a barrier coating applied when long term appearance is critical. Bimetallic coupling shall be avoided.

E. Zinc Alloys

1. Zinc alloys can be used without additional protection. Bimetallic coupling shall be avoided.

(b) Coatings

(i) Coatings shall have a proven past performance records and be compatible with the metallic surface to be coated. Resistance to chalking, and color and gloss retention shall be satisfactorily established for the life of the coating.

(ii) Organic Coatings

A. Organic coating systems shall consist of a wash primer (if substrate requires), a primer, intermediate coat(s) and a finish coat. Acceptable organic coatings for use are as follows:

1. Aliphatic polyurethanes
2. Vinyl copolymers
3. Epoxy - as a primer where exposed in the atmosphere or as the complete coating system where protected from direct sunlight
4. Acrylic - where there is not exposure to direct sunlight
5. Alkyd - where there is not exposure to direct sunlight

(iii) Metallic Coatings (for Carbon and Alloy Steel)

A. Acceptable coatings are as follows:

1. Zinc (hot dip galvanizing)
2. Aluminum
3. Aluminum-zinc

(iv) Barrier Coating Systems

A. Use one of the following barrier coating systems where corrosion protection is needed but appearance is not a primary concern:

1. Near white blast surface according to SSPC-SP 10. Follow with a three coat epoxy system.
2. Near white blast surface according to SSPC-SP 10. Follow with a three coat epoxy zinc, high build epoxy system.
3. Apply all coatings according to manufacturer's specifications.

B. Use one of the following barrier coating systems where corrosion protection and good appearance are needed:

1. Near white blast surface according to SSPC-SP 10. Follow with a three coat inorganic zinc, high build epoxy, polyester urethane system.
2. Near white blast surface according to SSPC-SP 10. Follow with a three coat vinyl system.
3. Commercial blast surface according to SSPC-SP 6. Follow with a three coat epoxy zinc, high build epoxy and polyester urethane system.

4. Commercial blast surface according to SSPC-SP 6. Follow with a three coat epoxy zinc, high build epoxy and acrylic urethane system.

5. Apply all coatings according to manufacturer's specifications.

17.15 Grounding

(a) Purpose

(i) The purpose is to insure that grounding and corrosion control requirements do not conflict so as the render either system ineffective. The key to accomplishing complementary systems is proper location of insulation points and proper means of grounding systems.

(b) Scope

(i) Facilities addressed include the following:

A. Traction Power Substations

B. Aerial/Catenary Structures

17.16 Design and Coordination of Grounding System

(a) Aerial/Catenary Structures

(i) General Requirements

A. Structures on the aerial structure such as catenary poles, handrails, cable trough components, and other metal components shall be electrically isolated from the top layer of reinforcing steel in the deck. At each end of the structure, insulated cables shall be exothermically welded to the reinforcing steel and terminated in an appropriately sized and conveniently located weatherproof junction box or manhole. Support piers and abutments shall be insulated from the structural deck members.

(ii) Coordination Requirements

A. In order to provide compatible aerial grounding systems and corrosion control systems, the following items shall be coordinated:

1. Ground electrode component materials

2. Ground electrode locations

3. Aerial component electrical continuity details

4. Pier support/insulation details

(b) Traction Power Substation

(i) Corrosion control installations will be coordinated with grounding electrodes, grounding standards, grounding requirements and IEEE Standards.

17.17 Corrosion Control Operation and Maintenance Manual

(a) Project Co shall prepare a "Corrosion Control Operation and Maintenance Manual" which shall include the following tests:

(i) Voltage-to-ground on metallic utilities and reinforced concrete structures

(ii) Rail-to-earth resistance

(iii) Electrical continuity of reinforced concrete structures

(iv) Substation-to-ground resistance

(b) Project Co shall describe the test procedure and frequency of each test. The minimum frequency for testing rail-to-earth resistance and electrical continuity of structures is every 5 years. The minimum frequency for voltage measurements at test stations installed on structures and for substation grounding is once a year.