VOLUME III – AERIAL GUIDEWAY

CHAPTER 4 – ELECTRICAL DESIGN CRITERIA

REVISION 1

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<table>
<thead>
<tr>
<th>ISSUE NO.</th>
<th>DATE</th>
<th>REVISION DESCRIPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5-8-07</td>
<td>Interim Release</td>
</tr>
<tr>
<td>1</td>
<td>10-30-08</td>
<td>Revisions to incorporate MIC-EH design specifications that have been adopted by MDT.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ISSUE NO.</th>
<th>SECTIONS CHANGED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.05.1.1 Corrosion Control -Scope- (grammar correction)</td>
</tr>
<tr>
<td></td>
<td>4.05.1.2 Corrosion Control -Scope- included other utilities within list</td>
</tr>
<tr>
<td></td>
<td>4.05.2.3 Corrosion Control -Electrical Equipment - FRE only for Traction Power.</td>
</tr>
<tr>
<td></td>
<td>4.05.3.1.A.1 Corrosion Control - Stray Current Corrosion Control - Stray Current</td>
</tr>
<tr>
<td></td>
<td>Control - Stray Current Control - (grammar correction)</td>
</tr>
<tr>
<td></td>
<td>4.05.3.1.A.5a&amp;b Corrosion Control - Stray Current Corrosion Control - Stray Current</td>
</tr>
<tr>
<td></td>
<td>Control - Stray Current Control - (formatting correction)</td>
</tr>
<tr>
<td></td>
<td>4.05.3.2.F Corrosion Control - Stray Current Corrosion Control - Utilities -</td>
</tr>
<tr>
<td></td>
<td>(formatting correction)</td>
</tr>
<tr>
<td></td>
<td>4.05.5.2 Corrosion Control - Test Stations - Ground Fault Monitoring Stations</td>
</tr>
<tr>
<td></td>
<td>4.06.1 Systems-Facilities Interface Raceway - Scope</td>
</tr>
<tr>
<td></td>
<td>4.06.2.9.B Systems-Facilities Interface Raceway - Physical Relationships - Wayside</td>
</tr>
<tr>
<td></td>
<td>Facilities</td>
</tr>
<tr>
<td></td>
<td>4.06.2.10.B Systems-Facilities Interface Raceway - Physical Relationships - Raceway</td>
</tr>
<tr>
<td></td>
<td>Transitional Areas</td>
</tr>
<tr>
<td></td>
<td>4.06.3.2.C Systems-Facilities Interface Raceway - Physical Installation - Construction Guidelines - Traction Power Pullboxes</td>
</tr>
<tr>
<td></td>
<td>4.06.4.3.C Systems-Facilities Interface Raceway - Materials of Construction - Application of Raceway - Cableway</td>
</tr>
<tr>
<td></td>
<td>4.06.5.2.A Systems-Facilities Interface Raceway - Raceway Identification Methods - Raceway Designations</td>
</tr>
<tr>
<td>ISSUE NO.</td>
<td>SECTIONS CHANGED</td>
</tr>
<tr>
<td>-----------</td>
<td>------------------</td>
</tr>
<tr>
<td>4.06.5.2.C</td>
<td>Systems-Facilities Interface Raceway - Raceway Identification Methods - Raceway Designations</td>
</tr>
<tr>
<td></td>
<td>Figures 4-1a - Single Guideway Structure, Grounding and Stray Current Diagram; 4-1b - Dual Track Guideway Structure, Grounding and Stray Current Diagram; 4-1c - Guideway Structure, Grounding and Stray Current Notes; 4-2 - Column Mounted Stray Current Test Box Rev. 1; 4-7 - Sections &amp; Details; 4-8 - Sections &amp; Details, Rev 1</td>
</tr>
<tr>
<td>Table of Contents</td>
<td>Page No.</td>
</tr>
<tr>
<td>-------------------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>4.01 GENERAL</td>
<td>1</td>
</tr>
<tr>
<td>4.01.1 PURPOSE</td>
<td>1</td>
</tr>
<tr>
<td>4.01.2 BASIC GOALS</td>
<td>1</td>
</tr>
<tr>
<td>4.01.3 SCOPE</td>
<td>1</td>
</tr>
<tr>
<td>4.01.4 INTERFACE DEFINITION AND CONTROL</td>
<td>2</td>
</tr>
<tr>
<td>4.01.5 CODES, STANDARDS AND REGULATIONS</td>
<td>3</td>
</tr>
<tr>
<td>4.01.6 RESERVED</td>
<td>4</td>
</tr>
<tr>
<td>4.02 ELECTRICAL SYSTEM</td>
<td>5</td>
</tr>
<tr>
<td>4.03 FACILITIES SUPERVISORY CONTROL, STATUS AND ALARM REQUIREMENTS</td>
<td>7</td>
</tr>
<tr>
<td>4.04 GROUNDING AND LIGHTNING PROTECTION</td>
<td>9</td>
</tr>
<tr>
<td>4.04.1 SCOPE</td>
<td>9</td>
</tr>
<tr>
<td>4.04.2 OBJECTIVE</td>
<td>10</td>
</tr>
<tr>
<td>4.04.3 ABNORMAL CONDITIONS</td>
<td>10</td>
</tr>
<tr>
<td>4.04.4 GROUNDING ELECTRODE SYSTEM</td>
<td>11</td>
</tr>
<tr>
<td>4.04.4.1 Main Line Facilities</td>
<td>11</td>
</tr>
<tr>
<td>4.04.5 TRACTION POWER GROUNDING</td>
<td>14</td>
</tr>
<tr>
<td>4.04.5.1 General</td>
<td>14</td>
</tr>
<tr>
<td>4.04.6 SECONDARY POWER DISTRIBUTION SYSTEM GROUNDING</td>
<td>17</td>
</tr>
<tr>
<td>4.04.6.1 General</td>
<td>17</td>
</tr>
<tr>
<td>4.04.7 GROUNDING NETWORKS</td>
<td>19</td>
</tr>
<tr>
<td>4.04.7.1 Signal Grounding Networks</td>
<td>19</td>
</tr>
<tr>
<td>4.04.7.2 Chassis Grounding Network</td>
<td>19</td>
</tr>
<tr>
<td>4.04.7.3 Guideway Grounding</td>
<td>20</td>
</tr>
<tr>
<td>4.04.7.4 Fences</td>
<td>22</td>
</tr>
<tr>
<td>4.04.8 LIGHTNING PROTECTION</td>
<td>23</td>
</tr>
<tr>
<td>4.05 CORROSION CONTROL</td>
<td>25</td>
</tr>
<tr>
<td>4.05.1 SCOPE</td>
<td>25</td>
</tr>
<tr>
<td>4.05.2 CONTROL OF ATMOSPHERIC CORROSION</td>
<td>25</td>
</tr>
<tr>
<td>4.05.2.1 Materials of Construction</td>
<td>26</td>
</tr>
<tr>
<td>4.05.2.2 Coatings</td>
<td>26</td>
</tr>
<tr>
<td>4.05.2.3 Electrical Equipment</td>
<td>28</td>
</tr>
<tr>
<td>4.05.2.4 General Construction</td>
<td>29</td>
</tr>
<tr>
<td>4.05.3 STRAY CURRENT CORROSION CONTROL</td>
<td>29</td>
</tr>
<tr>
<td>4.05.3.1 Stray Current Control</td>
<td>30</td>
</tr>
<tr>
<td>4.05.3.2 Utilities</td>
<td>33</td>
</tr>
<tr>
<td>4.05.4 CATHODIC PROTECTION</td>
<td>35</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
</tr>
<tr>
<td>---------</td>
<td>-----------------------------------------------------------------------</td>
</tr>
<tr>
<td>4.05.4.1</td>
<td>Introduction</td>
</tr>
<tr>
<td>4.05.4.2</td>
<td>Galvanic Anodes</td>
</tr>
<tr>
<td>4.05.4.3</td>
<td>Impressed Current System</td>
</tr>
<tr>
<td>4.05.5</td>
<td>TEST STATIONS</td>
</tr>
<tr>
<td>4.05.5.1</td>
<td>Test Boxes Installations</td>
</tr>
<tr>
<td>4.05.5.2</td>
<td>Ground Fault Monitoring Stations</td>
</tr>
<tr>
<td>4.05.6</td>
<td>CORROSION CONTROL OF MECHANICAL EQUIPMENT</td>
</tr>
<tr>
<td>4.05.7</td>
<td>MISCELLANEOUS ITEMS</td>
</tr>
<tr>
<td></td>
<td>4.05.7.1 Communication, Power and Control Cables</td>
</tr>
<tr>
<td>4.06</td>
<td>SYSTEMS-FACILITIES INTERFACE RACEWAY</td>
</tr>
<tr>
<td>4.06.1</td>
<td>SCOPE</td>
</tr>
<tr>
<td>4.06.2</td>
<td>PHYSICAL RELATIONSHIP</td>
</tr>
<tr>
<td>4.06.2.1</td>
<td>General</td>
</tr>
<tr>
<td>4.06.2.2</td>
<td>Guideways</td>
</tr>
<tr>
<td>4.06.2.3</td>
<td>Ancillary Spaces</td>
</tr>
<tr>
<td>4.06.2.4</td>
<td>Platform and Under-Platform Areas</td>
</tr>
<tr>
<td>4.06.2.5</td>
<td>Concourse Area</td>
</tr>
<tr>
<td>4.06.2.6</td>
<td>Station Attendant's Booth/Console</td>
</tr>
<tr>
<td>4.06.2.7</td>
<td>Traction Power Substation</td>
</tr>
<tr>
<td>4.06.2.8</td>
<td>Gap Tie Stations</td>
</tr>
<tr>
<td>4.06.2.9</td>
<td>Wayside Facilities</td>
</tr>
<tr>
<td>4.06.2.10</td>
<td>Raceway Transitional Areas</td>
</tr>
<tr>
<td>4.06.3</td>
<td>PHYSICAL INSTALLATION</td>
</tr>
<tr>
<td>4.06.3.1</td>
<td>General</td>
</tr>
<tr>
<td>4.06.3.2</td>
<td>Construction Guidelines</td>
</tr>
<tr>
<td>4.06.4</td>
<td>MATERIALS OF CONSTRUCTION</td>
</tr>
<tr>
<td>4.06.4.1</td>
<td>General</td>
</tr>
<tr>
<td>4.06.4.2</td>
<td>Material Nomenclature</td>
</tr>
<tr>
<td>4.06.4.3</td>
<td>Application of Raceway</td>
</tr>
<tr>
<td>4.06.5</td>
<td>RACEWAY IDENTIFICATION METHODS</td>
</tr>
<tr>
<td>4.06.5.1</td>
<td>General</td>
</tr>
<tr>
<td>4.06.5.2</td>
<td>Raceway Designations</td>
</tr>
<tr>
<td>4.06.5.3</td>
<td>Raceway Schedules</td>
</tr>
<tr>
<td>APPENDIX A</td>
<td></td>
</tr>
</tbody>
</table>
4.01  GENERAL

4.01.1  PURPOSE

These criteria describe the design requirements for the supply of electric power, grounding, lightning protection, stray current and corrosion control, and supervisory subsystems for all the facilities of the Metrorail Rapid Transit System Extension. Station related facilities are covered in other criteria. Supplementing these criteria are the MDT drawings of existing facilities.

4.01.2  BASIC GOALS

4.01.2.1 The design shall:

A. Provide for safe, economical, reliable and continuous operation of the entire system.

B. Promote uniformity and standardization in design and equipment compatible with existing installations and equipment, and compliant with all codes and applicable regulations.

C. Facilitate installation, operation and maintenance of the equipment.

4.01.3  SCOPE

4.01.3.1 The following shall be included in the guideway electrical system scope:

A. The electrical power and control requirements for the Metrorail electrical systems.

B. Supervisory requirements (controls, monitoring and alarms) for facilities equipment and interfacing of such facilities' supervisory requirements with the overall Supervisory, Control and Data Acquisition (SCADA)
system. Communications, Security, CCTV, fire alarms and intrusion
detection are covered under other design criteria sections.

C. The criteria for design of grounding and lightning protection for the
Metrorail extension equipment and facilities. These criteria apply to all
aerial, below grade, and at grade fixed facilities and equipment and to
rail, fences, and wayside equipment.

D. Requirements for corrosion control for the rapid transit facilities and for
monitoring, controlling and minimizing stray currents.

E. Raceway system for systemwide equipment along the guideway.

F. Systems/Facilities Interface Raceway requirements.

4.01.4 INTERFACE DEFINITION AND CONTROL
The facilities electrical subsystem interfaces with a number of other MDT
subsystems. In every case of subsystem to subsystem interface (for
example, Traction Power Substation/Passenger Station Interface) the
interface will be defined, controlled and changed only by the Designer, and
must be approved by MDT.

Section 4.06, Systems/Facilities Interface Raceway defines these interfaces
to a great extent. Electrical subsystem interfaces will be defined and
controlled during the design process by the Designer. For each phase of the
design process, the plans and specifications must be submitted to MDT for
review.
4.01.5 CODES, STANDARDS AND REGULATIONS

4.01.5.1 The current adopted version of codes, standards and regulations shall apply, and unless otherwise directed, all addenda, interim supplements, revisions and ordinances by the respective code body shall also apply. Where conflicts exist between these requirements, the more stringent requirement shall take precedence, unless otherwise directed by MDT.

- National Electrical Code (NEC)
- National Electric Safety Code (NESC)
- Ordinances of the City of Miami, Miami-Dade County and other Authorities Having Jurisdiction (AHDs)
- American National Standards Institute (ANSI)
- National Electric Manufacturers Association (NEMA)
- Institute of Electrical and Electronic Engineers (IEEE)
- Insulated Cable Engineers Association (ICEA)
- The Occupational Safety and Health Act (OSHA)
- Florida Building Code (FBC)
- Lightning Protection Code (NFPA No. 780)
- National Association of Corrosion Engineers (NACE International)
- Standard for Fixed Guideway Transit and Passenger Rail Systems (NFPA 130)
- National Fire Alarm Code (NFPA No. 72)
- Life Safety Code (NFPA 101)
- American Society for Testing and Materials (ASTM)
- Certified Ballast Manufacturers Association (CBM)
- Underwriters’ Laboratories, Inc. (UL)
- Miami-Dade County Fire Prevention and Safety Code
• National Electrical Testing Association (NETA)
• Federal Transportation Administration Safety and Security Standards
• American Disabilities Act (ADA)

4.01.6 RESERVED
4.02 ELECTRICAL SYSTEMS

Electrical Systems which are not applicable to Guideways are covered in other design criteria within this compendium.
Facilities Supervisory Control, Status and Alarm requirements which are not applicable to Guideways are covered in other criteria within this compendium.
4.04 GROUNDING AND LIGHTNING PROTECTION

4.04.1 SCOPE

4.04.1.1 This section identifies the requirements for the design of the grounding and lightning protection systems throughout the Metrorail extension areas.

4.04.1.2 Facilities covered by these grounding and lightning protection criteria include the following:

A. Passenger stations including Electrical Equipment Rooms, Train Control and Communications Rooms, concourses, pedestrian overpasses, parking lots, parking structures and other areas in the station confines;
B. Traction Power Substations;
C. Gap Tie Stations;
D. Roadway and Bridge Structures;
E. Guideways.

4.04.1.3 The following equipment items, although not housed in a facility indicated above, are also covered by these criteria:

A. Wayside train control equipment, signal lines and raceways;
B. Traction power equipment (Blue Light Stations with ETS buttons);
C. Wayside telephone equipment, telephones, pull boxes, raceways and other miscellaneous communication equipment;
D. Rails and switch machines;
E. Wayside raceway and facilities.
F. Corrosion Control Test Stations.
G. Motor Operated Switches
H. Bumping Posts
I. Derailer (if applicable)
Contact Rail, Cover board, Insulators, Cables, Etc are covered in Volume VII, Chapter 2, Contact Rail and Cover Board Design Criteria.

4.04.2 OBJECTIVE

4.04.2.1 The grounding and lightning protection systems shall be designed:

A. To protect persons, equipment, facilities and systems against the hazards posed by voltages that occur in the system under all operating and fault conditions;

B. To provide a path to ground for discharge of lightning strokes;

C. To reduce electromagnetic interference;

D. To reduce corrosion from stray currents;

E. To provide a low impedance path to ground to facilitate the operation of over current protection devices on ground faults.

F. To mitigate any induced voltages from overhead power lines.

4.04.3 ABNORMAL CONDITIONS

4.04.3.1 The design of grounding systems in various facilities shall consider the following hazardous conditions:

A. Primary and secondary distribution systems ground fault.

B. Switching surges.

C. Electrical equipment faults.

D. Direct lightning stroke on any of the facilities.

E. Contact rail ground fault.

F. Fallen power lines across the tracks, structures, wayside equipment, and security & metallic ornamental fencing.

G. Touch potential (accessible to patrons) voltage between the passenger vehicle and any nearby grounded metal surfaces, also to include the
potential difference between the running rails and any grounded metal surface on the guideway, such as the cable tray.

4.04.4 GROUNDING ELECTRODE SYSTEM

4.04.4.1 Main Line Facilities

A. The grounding electrode system for Passenger Stations, Traction Power Substations and Gap Tie Stations shall consist of a network of electrically interconnected ground rods, counterpoise, ground grids and grounding risers designed to obtain a maximum of five ohms resistance to ground and to minimize step and touch potentials to the level indicated in IEEE-80 throughout the facility during both normal and abnormal conditions. The system shall also be capable of dissipating fault currents to ground for that period of time required for the operation of the protective devices within the power system. The design of the grounding electrode system shall be in accordance with NEC Section 250 and IEEE standards utilizing the values of soil resistivity for the specific site. Resistivity will be determined by the Section Designer with a minimum of two (2) tests per site to be conducted by the Designer.

B. Ground rods shall be 3/4 inch diameter copper-clad steel and at least 10 feet long. Ground rods shall be installed in accordance with NEC Section 250.

C. Bare stranded copper ground wire shall be buried without kinks and with approximately 20 percent slack to form the grounding electrode configuration (counterpoise and ground grid). Buried ground conductors shall be installed a minimum of three feet below the final (finished) grade unless the buried ground conductors are installed beneath concrete.
slabs and/or structural footings. The ground conductors shall be installed in trenches six inches below final excavation for two feet outside the boundaries of the structure, measuring from outside face of the exterior walls. In addition, in the event that shallow spread footings (structural foundations) are utilized, buried ground conductors shall be installed in trenches six inches below the bottom of the footing excavation when within five feet or below of said footings. All buried bare stranded or insulated copper ground wire connections at each crossover points or taps shall be exothermically welded and coated with brush applied protective mastic.

D. Counterpoise shall consist of a buried bare stranded copper ground wire interconnected with driven ground rods surrounding the perimeter of the facility to which grounding risers and lightning down conductors shall be connected.

E. Ground grid shall be placed beneath the unit substations and where required. The ground grid shall consist of horizontal bare stranded copper ground wire, interconnected with the counterpoise to form a square mesh. The square mesh shall be spaced at minimum intervals of 10 feet. Driven ground rods shall be connected to the grid in the peripheral ground network as determined by the design to provide the required resistance, typically 5 ohms or less.

F. Grounding risers shall be insulated copper wire in nonmetallic conduit connecting equipment to the grounding electrode system with an allowance of 10 percent slack. The conductor shall be sized to avoid fusing under the maximum fault current for that equipment. Grounding
riser shall be exothermically welded to the grounding electrode system at a node where a ground rod is located. The grounding electrode conductor shall be sized in accordance with N.E.C. Section 250 for electrical equipment.

The structural steel rebars in the Electrical Equipment Room, the Train Control and Communication Room, the Traction Power Substation and the Gap Tie Station floor shall be tack welded at the four corners of each room and at approximately six feet intervals to form a square grid. The structural steel rebar grids shall be connected to the facility grounding electrode system at two diagonally opposite corners, using No. 4/0 AWG insulated copper wire in a nonmetallic conduit.

H. Elevators shall be grounded in accordance with the requirements of applicable elevator codes and the National Electrical Code.

I. At a convenient point close to a wall within electrical manholes, a 10 foot long ground rod shall be driven (before the manhole is poured) so that the top of the rod is approximately four inches above the manhole floor. When precast concrete manholes are used, the top of the rod may be below the floor and a No. 4/0 AWG copper conductor shall be extended from the rod into the manhole through a watertight penetration in the wall or floor.

J. Metallic utility pipe lines (including water lines) shall be bonded to the ground grid network at the point nearest to where the pipes enter and leave the facility and shall be electrically continuous inside the facilities. The pipe bond shall be on the building side of the insulating joint.
There shall be no connection between electrical equipment and any utility line (including water) for the purpose of grounding the equipment. All metallic incoming utility piping shall be provided with dielectric sections immediately inside the building wall to electrically isolate the ground grid from the external piping system.

K. Ground bonds above ground surface shall be made with non-reversible compression ground clamps or with exothermic welds. Exothermic welds are the preferred method. When bonding copper grounding wire to dissimilar metal, the mechanical connection surface areas shall have a no-ox grease application. When outdoors, direct buried or in a highly humid, corrosive atmosphere, all compression and/or exothermic weld connections, taps, and crossover points shall be covered by waterproof brush applied mastic coating.

4.04.5 TRACTION POWER GROUNDING

4.04.5.1 General

A. To reduce the stray currents that can cause corrosion to underground metal pipes and structures, the dc traction power system and the running rails will be isolated from ground. The secondary side of the traction power rectifier transformers and rectifiers output connections to the cathode breakers and isolating disconnect switches shall not be grounded. The running rails shall be fixed in place with insulating rail fixation devices which, under normal design conditions, will provide a high resistance to ground. The track switches and all special track work shall include insulating members and parts such that the insulation of the rails from any grounded metal surfaces, any isolated structural steel and
the concrete guideway deck shall not be degraded. The following acceptable criteria are as follows:

1. Single Track (2 rails Direct Fixation Track) - 500 ohms/1000 feet.
2. Grade Crossings (2 rails Direct Fixation Track) - 500 ohms/1000 feet.
3. Special Track Work (2 rails Direct Fixation Track) - 500 ohms/1000 feet.
4. Yard Tracks (2 rails Ballasted Track) – 100 ohms/1000 feet.

At time of construction and acceptance of new track sections, the acceptable measured values shall be twice the above values.

B. Prior to the rail to ground testing the Corrosion Engineer shall make a visual inspection of the area to ensure the area is ready for testing. All discrepancies shall be repaired prior to testing. Rail to ground testing shall be accomplished using two calibrated multimeters such as the Fluke 177 True RMS Multimeter or equivalent and as approved by the Corrosion Engineer. A charged 12 volt battery with appropriate test lead shall be used. The test procedure shall be approved by the Corrosion Engineer.

C. All embedded tracks, if any, shall be installed using a rail boot. During the installation of the rail boot the corrosion engineer will visual inspect the boot and perform rail-to-ground tests after installation to verify that no damage to the rail boot has occurred during the installation process.

D. Reserved
E. Enclosures of traction power transformers and ac switchgear shall be grounded to the Traction Power ground electrode system through two separate risers for each piece of equipment.

F. The rectified dc traction power output, feeders, contact rails and running rails shall be insulated from ground.

G. All metallic equipment enclosures, except rectifier assemblies and dc switchgear, shall be grounded. The rectifier and dc switchgear enclosures shall be completely isolated from ground as indicated below. A distance of five feet or more shall be maintained between the grounded surfaces and the ungrounded rectifier and dc switchgear enclosures.

H. An insulated floor surface covering (epoxy, or other equivalent insulating material) shall be provided around and under all ungrounded enclosures in the Traction Power Substations and Gap Tie Stations and shall extend five feet beyond the enclosures on all sides. Walls which are within five feet of ungrounded cabinets shall be covered with insulating material to a height of six feet.

I. As defined in within the Volume VII System Equipment, Chapter 1, Traction Power Design Criteria, the rectifier assemblies and the dc switchgear enclosures shall be insulated from the transformer case, from each other and from any other grounded metal. An insulation failure between the live bus and the rectifier enclosure shall be detected by means of a ground relay device 64/64G which will trip and lock out the ac feeder breaker and main dc breaker for the faulted rectifier assembly.
The relay shall also provide a visible warning at the substation with alarm indication transmitted to Central Control. In the event that floor surface covering insulation fails from the enclosure to ground, a visible warning shall be given at the substation, with alarm indication transmitted to Central Control. Similarly, an insulation failure between the positive bus and the dc switchgear enclosure shall be detected by means of a ground relay, device 164/164G, which will trip and lock out both dc main breakers and all dc feeder breakers and also provide a visible warning at the substation with alarm indication transmitted to Central Control. In the event that floor surface covering insulation fails from the enclosure to ground, a visible warning shall be given at the substation, with alarm indication transmitted to Central Control.

4.04.6 SECONDARY POWER DISTRIBUTION SYSTEM GROUNDING

4.04.6.1 General

A. For the ac power distribution system, all electrical system neutrals, raceways, and electrical equipment frames shall be completely and effectively grounded as required by NEC Article 250 and as described hereinafter.

B. At the passenger stations, each of the two unit substations "A" and "B" shall be grounded to the facility grounding electrode system through two separate risers and the transformer neutrals shall be connected to one of the risers with a removable jumper.

C. All raceways shall contain an electrically continuous green colored insulated grounding conductor. The conductor shall be connected to all
ground buses, metallic pull and junction boxes, and equipment enclosures.

D. All metallic conduits shall be electrically continuous and grounded utilizing ground bushings at each end connected but not limited to ground buses and plates, equipment enclosures, and receptacle ground terminals except as noted for Traction Power equipment.

E. Conduits containing branch circuits shall have a green colored insulated equipment grounding conductor run inside the same conduit as the branch circuit conductors. Grounding conductors shall be properly sized.

F. Motor frames shall have an insulated equipment grounding conductor carried inside the same conduit as the phase conductors.

G. Receptacles shall be grounded to their outlet boxes by means of a grounding conductor from the green terminal on the receptacle to a grounding screw and the continuous insulated grounding conductor.

H. Lighting fixtures not attached directly to the raceway system (flexible conduit or chain hangers are considered not to be direct attachment) shall be grounded by means of green-colored insulated conductor of the same size as the power conductors supplying the fixture. This grounding conductor shall be in the flexible conduit or shall be an integral portion of the flexible cord supplying the fixture. Ground continuity shall be maintained across sections of flexible conduit by means of an insulated grounding conductor terminated at each end by
means of approved grounding connectors attached to fixed portions of the raceway system, continuous grounding conductor and equipment.

I. Dry type transformers (480-208Y/120 volt) used for secondary power shall have their neutrals grounded to a single riser from the ground grid.

4.04.7 GROUNDING NETWORKS

4.04.7.1 Signal Grounding Networks

The Train Control and Communications Rooms shall be provided with two wall mounted signal ground plates; one for Train Control and one for communications.

The Traction Power Substations and Gap-Tie Stations shall be provided with one signal ground plate. The signal ground plate shall be connected to the facility grounding electrode system at a node where a ground rod is located by means of a 500 kcmil AWG insulated copper conductor in a nonmetallic conduit riser. All equipment equipped with signal grounding terminals shall have those terminals bonded to this ground plate.

4.04.7.2 Chassis Grounding Network

The Train Control and Communications Rooms shall be provided with two chassis ground plates; one for Train Control equipment and one for Communications equipment. Each wall of the Electrical Equipment Rooms, Traction Power Substations and Gap-Tie Stations shall be provided with a chassis ground plate. The enclosure of each piece of electrical equipment, device and panel board shall be bonded to the chassis grounding network. All metallic conduits, tubing, the supports and all normally non current carrying metal parts, including structural steel support members shall be electrically
continuous and shall be connected to the facility grounding network. The chassis grounding network shall be connected to the facility grounding electrode system.

4.04.7.3 Guideway Grounding

Guideway grounding shall be designed to the following criteria;

A. Guideway structural steel shall not be part of the Metrorail grounding system. The Guideway structural steel shall be protected and isolated from the ground system whenever possible. Any special conditions or exceptions must be approved by MDT. The guideway structural steel shall have stubs or conductors installed for measurements of stray currents and voltages. See Figures 4-1 through 4-7 within Appendix A for details.

B. Each metallic box or housing for wayside telephone, blue light station, signal light, pull box, and junction box which are connected to only nonmetallic conduits, shall be grounded to the nearest grounding system by means of a green-colored insulated conductor run with the branch circuit or control wires. The green-insulated ground wire shall be electrically continuous and bonded to the ground bus. All sections of metallic hand rail and cable tray on aerial guideway, and manhole ground rod on at-grade guideway shall also be bonded to the ground bus.

C. Systems less than 600 volts shall be grounded using the metallic conduit as follows:

1. On aerial guideway: Metallic conduits shall be electrically continuous and bonded to the guideway’s 4/0 ground conductor.
2. On at-grade guideway: Metallic conduits shall be electrically continuous, provided with a grounding bushing and bonded to the manhole ground rod.

D. Each pull box for systems over 600 volts (except dc traction power) shall be separately connected to the nearest grounding source with a No. 4/0 bare copper ground wire. Sections of metallic conduit not terminating in pull boxes or other enclosures shall be provided with a grounding bushing at one end and bonded to the nearest grounding source. Metallic conduit terminating in manholes shall be provided with a grounding bushing at both ends and bonded to the manhole ground rod.

E. All metal walkways, cable ways (inbound cableway and outbound cableway), metallic handrails, and metallic conduits on the aerial structures shall be made electrically continuous and grounded. Each section of the cableways shall be bonded to the adjacent one with a No. 4/0 AWG bare copper ground conductor. At every support column that contains a grounding conductor, the cableway shall be connected to the grounding conductor at the nearest point. The grounding conductor shall be a No. 4/0 AWG insulated copper ground wire in one inch PVC conduit embedded in the girder support columns. In the vicinity of each traction power substation located under an aerial guideway and each passenger station, the grounding conductor shall be connected directly to the ground grid system of the above-mentioned facilities. All other grounding conductors shall be connected to one or more ground rods. If more than one ground rod is installed in an array configuration, the ground rods shall be interconnected with a No. 4/0 AWG conductor.
F. Conductors installed within support columns shall be epoxy sealed to prevent water intrusion, vandalism and/or theft.

G. Grounding conductors shall not exceed 200 feet in length before connection to a ground rod.

H. Guideway and column structural steel shall be electrically isolated with no exposed metal and no connection to the grounding system.

The reinforcing steel of girder shall be bonded together at both ends of each girder section. At each end of the girder, the reinforcing steel shall be brought out and bonded to the cableway by means of 4/0 AWG copper conductor, thus maintaining the continuity of the guideway structure.

I. The aerial grounding system shall be designed with the same materials and techniques specified in Section 4.04.4.1 and as shown in Figure 4-1 and 4-2 in Appendix A.

4.04.7.4 Fences

All metal fences shall be grounded. At each gate, a buried bare stranded copper ground wire shall be installed to connect the fence to the gate.

Fences for electrical substations shall be bonded to the substation ground grid system at intervals not exceeding 20 feet. A minimum of four bonded connections shall be provided. All mechanical connection shall be made using a high grade stainless steel or a brass alloy material. This includes all associated hardware.
4.04.8 LIGHTNING PROTECTION

4.04.8.1 Adequate lightning protection shall be provided for all new work. Lightning protection systems and equipment shall be designed to provide protection for persons, equipment, facilities and electrical systems against the hazards posed by lightning related currents and voltages.

Lightning protection systems shall be required for at-grade and aerial passenger stations and parking structures that are outside the zone of protection provided by nearby structures.

Lightning protection shall also be required for the aerial guideway sections at all locations that are outside the zone of protection provided by nearby structures.

The design of the lightning protection system and the placement of air terminals and conductors shall meet the requirements of the Lightning Protection Code, NFPA No. 780 and the Master Labeled Lightning Protection System, UL 96A.

The lightning down conductors shall be connected to the facility grounding electrode system (ground grid) via the outside counterpoise. Roof conductors shall be bare copper stranded wire. Down conductors shall be No. 4/0 AWG (insulated for guideways, bare for stations) copper stranded wire in properly sized nonmetallic conduit. Typically, the air terminals will have 1/2 inch minimum diameter and be made of solid copper. Air terminals shall extend at least 10 inches above the object being protected, but not more than 24 inches, and shall be provided at all corners and 20 feet on centers along the
roof perimeter. The Designer shall investigate alternative, code compliant aesthetically oriented solutions and review them with MDT.

Parking structures exceeding 50 feet in width shall have a 1/4 inch by one inch copper bar embedded in the concrete roof slab where center roof cable runs would normally be placed. The copper bar shall be installed with the top face exposed flush with the top of concrete and be connected to the perimeter conductors at each end. Additional copper bars shall be installed and connected between center run copper bars and perimeter conductors at intervals not exceeding 150 feet. Air terminals along the roof perimeter and down conductors shall be installed as described in the preceding paragraph.

The location, elevation and spacing of air terminals on the aerial guideway section shall be designed to provide adequate protection taking into consideration the zone of protection provided by the adjacent structures.

The positioning of air terminals and the routing of roof and down conductors shall consider the appearance of the facility and lightning protection requirements. Air terminals shall be located on the roof parapet or at the edge of roof as applicable. The protection offered by structural features shall be used to full advantage in designing the lightning protection system.
4.05 CORROSION CONTROL

4.05.1 SCOPE

4.05.1.1 This section defines requirements for corrosion control systems for the facilities of the Metrorail Extension. Personnel engaged in the testing and supervision of corrosion control for the system shall have the following minimum qualifications: NACE International Certified as a Corrosion Technologist. The corrosion person shall have a minimum of five years experience in the testing of mass transit facilities and equipment and other corrosion control knowledge. All equipment used for corrosion control testing shall have a current calibration sticker.

4.05.1.2 The corrosion control systems within the facilities include:
   A. Control of Atmospheric Corrosion;
   B. Stray Current Corrosion Control;
   C. Cathodic Protection;
   D. Test Stations;
   E. Corrosion Control of Mechanical Equipment;
   F. Water Distribution Systems and Sanitary Sewer Systems
   G. Electrical Distribution Systems.
   I. Other Utilities and Miscellaneous Items.

4.05.2 CONTROL OF ATMOSPHERIC CORROSION

All exposed above grade structures shall be protected from corrosion because of the South Florida coastal marine environment. Protection shall be achieved by proper material selection and suitable coatings to minimize maintenance, maximize material life and preserve function and appearance of
the materials exposed to the high humidity, salt contamination, high temperature, direct sunlight (UV exposure) and high annual rainfall.

4.05.2.1 Materials of Construction

A. Concrete Structures

See Structural Design Criteria - Station - Volume II, Chapter 3 and Structural Design Criteria - Guideway - Volume III, Chapter 3. If Epoxy Coated rebar or other epoxy coated structural materials are used, the corrosion engineer will make a visual inspection of the epoxy coating prior to concrete pour to ensure that there are no areas that are damaged or not coated with epoxy. This inspection is required for field pours and for pre-cast concrete operations.

B. Structural Steel


C. Exposed cast iron structures shall be coated to preserve appearance. Aluminum structures shall be anodized and have a seal coat on the anodizing. Anodizing film thickness shall be 0.8 mil minimum. Stainless steel structures shall be either type 316 stainless or equivalent in corrosion resistance to type 316 stainless. Copper base alloys shall be used only in protected enclosures. Zinc containing copper base alloys shall not be used.

4.05.2.2 Coatings

Inorganic - base, zinc - rich protective coatings or equivalent shall be used for protection of carbon steel. Manufacturers of protective and appearance thin
film coatings or paints shall furnish performance test data prior to acceptance of the coating. Tests shall be conducted in accordance with ASTM or Federal Test Method 141a Specifications. Typical performance criteria shall be as follows:

A. The coating, when applied, shall cure to a uniform smooth surface, free of runs, sags, bubbling, dusting, streaks, wrinkling, pinholing, haze, cratering, orange-peel, blushing, floating, mottling or other surface defects.

B. Adhesion, ASTM D2197
   Adhesion strength should be not less than 2.0 kilograms.

C. Impact Resistance, ASTM D2794
   Impact resistance should be not less than 10 inch pounds.

D. Abrasion Resistance, ASTM D658
   The abrasion coefficient should be not less than 200.

E. Weathering, ASTM D1014
   Test panels should be exposed for six months at a site in Miami or test data near Miami certified. Panels should be exposed at a 45 degree angle, facing south.
   1) Gloss Retention, ASTM D523 (appearance coatings) – Gloss deterioration should be no less than 10 points when measured with a 60 degree gloss-meter.
   2) Color Retention, ASTM D1535 (appearance coatings) - Color should not change after six months.
3) Chalking Resistance, ASTM D659 (appearance coatings) - Coatings should have a rating not lower than eight when tested according to ASTM D659.

4) General Appearance - Coatings should show no evidence of corrosion beyond 1/64 - inch from the scribe (ASTM D1654) and no evidence of blistering (ASTM 714), checking (ASTM 660), cracking (ASTM 661) or flaking (ASTM 772).

F. Water Immersion Test, ASTM D870
   Coatings should show no change in appearance after being subjected to this test.

G. Salt Spray Test, ASTM B117
   Coatings subjected to a five percent sodium chloride fog at 95¼F for 500 hours should show no disbondment and no more than 0.10 inch blistering from the scribe.

If any of the above tests have already been conducted for a certain coating, there is no need to repeat the particular tests. Proof that the test was conducted and the certified test results will suffice.

4.05.2.3 Electrical Equipment
   Electrical equipment such as control panels, switchgear, etc., shall be enclosed in cabinets provided with heaters or in air conditioned cabinets or located in air conditioned environments. Electrical motors shall be totally enclosed or heated when not in use to prevent condensation. Junction boxes
containing terminal strips shall be weatherproof. All steel raceways, including cableways, shall be zinc coated. Use of FRE conduits is recommended where feasible. Schedule 80 PVC is also acceptable where use of PVC is permitted and conduit is encased in concrete. PVC is not permitted for use with traction power feeder or return cables, only FRE is permitted for traction power dc cable applications. Where underground metal conduits are required, they shall have an outer coating of polyvinyl chloride or epoxy. All hardware shall be zinc coated or stainless steel.

4.05.2.4 General Construction
Assemblies with more than one type of metal, except for the bimetallic (steel-aluminum composite) contact rail, shall not be used unless the metals can be isolated with non-conducting gaskets. Crevices shall be avoided. Crevices areas shall be properly sealed with suitable caulking compound or continuous weld beads.

For galvanizing of steel members and steel structures, see the Structural Design Criteria of this volume.

4.05.3 STRAY CURRENT CORROSION CONTROL
Measures shall be taken to minimize stray currents and to provide means for monitoring any such currents in affected structures and utilities' facilities in the proximity of the Transit System facilities. Stray current control measures will be designed and specified by the extension Designer.
For examples of stray current control measures to be implemented, see Figure 4-1 through 4-7 in Appendix A.
4.05.3.1 Stray Current Control

The following measures shall be taken for stray current control:

A. Minimizing Stray Currents

The following measures shall be taken to minimize stray currents:

1) The dc traction power system of the Metrorail Extension shall be ungrounded in accordance with Section 4.04, Grounding and Lightning Protection Criteria. See also; Design Criteria, Volume VII, System Equipment, Chapters 1 – Traction Power Installation, Chapter 2, Contact Rail and Coverboard, and Chapter 3, Traction Power Equipment.

2) All running rails and special track work within the Transit System shall be supported on insulated rail supports in accordance with Section 4.04, Grounding and Lightning Protection Criteria. A “1” inch clearance between the bottom of the running rails and top of the ballast shall be maintained to mitigate stray currents.

3) Electrical Resistance and Impedance Test.

This test shall be conducted as per the track specification for direct fixation.

4) The construction of aerial structures shall provide electrical isolation between the superstructure and substructure in accordance with Volume III- Guideways, Chapter 3, Structural Design Criteria. All structural steel shall be isolated from the grounding system. Where structures are to be attached to the guideway, insulated anchors shall be used to provide electrical isolation. All metal equipment
mounted to the guideway shall also have insulating pads to avoid contact of the grounded metallic structures to the guideway.

The Plinth pads shall be designed to use non-conductive reinforcements. See Figure 4-1 through 4-7 in Appendix A for examples and details of the plinth pad and guideway materials and construction.

No grounded metal structures shall come in direct contact with the guideway surface or the guideway’s structural steel.

5) Operation of an isolated traction power system results in some potential difference between rail and ground. In order to minimize this rail to ground voltage and to protect the transit personnel and patrons, the following precautions shall be taken:
   a) Inbound and Outbound running rails shall be cross bonded as indicated in Section 4.06, Systems-Facilities Interface Raceway Criteria. Cross bonding shall be done at no greater than every 1500 feet of track length. Locations of cross bonds shall be coordinated with the train control design to avoid affecting the train control signals within the running rails.
   b) Station platform shall be insulated and all non-insulated metallic grounded items shall be out of the normal reach of a passenger while touching a vehicle body.

B. Monitoring Stray Currents
The following measures shall be taken to provide means of monitoring stray currents:

1) Recording voltmeters shall be installed at each traction power substation to monitor track-to-earth potentials.

2) Metallic elements of all new, relocated, or replaced utilities or pipes associated with construction of the Transit System shall be made electrically continuous. Test wires shall be installed for future testing. This does not apply to guideway drains and station roof drains above ground.

3) Permanent steel piles shall be bonded to achieve electrical continuity and test wires shall be installed for future testing.

Test stations shall be installed so that stray currents may be measured before and after the Transit System is in operation. See Section 4.05.5 and Figures 4-1 through 4-7 in Appendix A for a description of the test box installation and connections. The test boxes shall be used for monitoring stray currents in the piers, the guideway structure and the grounding system.

C. Controlling Stray Currents

If excessive stray currents are measured during final acceptance testing or initial operation of the System Extensions, action must be taken to identify the source. The corrective measures required to eliminate the source will be determined, and necessary corrective action will be taken to correct the reason(s) for the stray current condition. Excessive stray currents are those which, as shown by engineering studies, have
significant detrimental effects on utilities or the MDT System facilities. Corrective measures may include cleaning of insulators, replacement of faulty insulated rail supports, or removal of debris and any accidental grounds paths in the dc traction power system.

No stray current mitigation bonds shall be installed unless no other reasonable corrective measures are available. Mitigation bond installations must be pre-approved by MDT.

4.05.3.2 Utilities

Metallic utilities pipes and reinforced concrete pipes (except those for flammable fuel, electric and communications lines, and others specifically excluded by their owners) crossing or within the Transit System right-of-way shall have corrosion monitoring facilities as described below.

A. Water Lines

Sections of new metallic water lines constructed within the Transit System right-of-way shall be bonded together for electrical continuity and have test wires attached for future testing. Where new metallic water lines cross under a Transit System structure, a test station shall be provided on each structure.

Sections of casings shall also be bonded together where new metallic lines are installed inside a metallic casing. The casing and the water line shall be monitored separately. The metallic casing shall be insulated from the metallic water pipe by providing casing insulators and insulating casing seals. Individual test leads shall be attached to the pipe and to the casing and brought to separate test stations.
When a split metallic casing is installed around an existing metallic water line because of construction of the Transit System, the casing and the existing line shall both be bonded and isolated electrically. Individual test leads shall be attached to the pipe and to the casing and brought to separate test stations.

B. Sewer Pipes
New reinforced concrete and metallic pipes for storm, combined, and sanitary sewers located within the Transit Yard Facility shall be bonded. A test station shall be installed to facilitate future work.

C. Fire Protection Lines and Water Service Lines
Transit System fire protection lines and water service lines constructed of steel and installed in earth shall be coated and provided with cathodic protection. No special external corrosion control measures shall be provided for cast or ductile iron piping except for electrical insulating sleeves to isolate from building wall and dielectric insulation inside the station.

D. Sprinkler System Inspection
The Designer will specify that any sprinkler system installed adjacent to the tracks are to be adjusted and inspected to prevent water spray over track insulating materials, or water run off saturating the track area. Water saturation will lower the rail-to-ground resistance for that area of track.

E. Protective Coatings
All insulating fittings shall be coated to assure the continued effectiveness of the insulating joint. Buried dielectric insulating joints shall be encapsulated in hot-applied coal tar pipeline enamel or equivalent. Dielectric insulating joints which will be exposed to the atmosphere within buildings or vaults shall be coated with a coal tar epoxy. Buried steel pipes shall have a hot-applied coal tar enamel protective coating system.

F. Bonding of Reinforcement
Within each guideway segment, the metal reinforcing bars of the structure shall be made electrically continuous, but isolated from the grounding system. See Figures 4-1 through 4-7 in Appendix A for details.

4.05.4 CATHODIC PROTECTION

4.05.4.1 Introduction
All buried steel pressure piping, including hydraulic elevator cylinders and storage tanks shall be cathodically protected to prevent corrosion. Cathodic protection shall be provided by galvanic anodes or an impressed current system.

4.05.4.2 Galvanic Anodes
Galvanic anodes shall be used on short piping sections or in areas where interference with other structures might result from the use of impressed current systems.

4.05.4.3 Impressed Current System
A. General
Impressed current systems shall consist of ac to dc transformers, rectifiers, chromium bearing silicon iron anodes placed in suitable soil, and wiring to connect the rectifiers to the structures and the anodes.

Rectifiers shall be selected following completion of construction of structures concerned. Current requirements shall be determined on the site after anodes and wiring has been installed.

B. Insulation

To restrict current flow to structures requiring protection, the structures shall be isolated from other underground metals, such as reinforcing steel, by physical separation, or by suitable dielectric insulation.

Care must be taken to prevent insulated protected structures which are electrically isolated from contacting unprotected metallic structures. Dielectric materials shall be carefully installed, and shall be inspected after installation to ensure their effectiveness. In general, dielectric materials shall be installed so as to be accessible after backfilling. If this is not practical, test wires shall be extended at or above grade terminal to facilitate testing. When piping enters a building, the piping shall be isolated from reinforcing steel, masonry, concrete, etc., by a non-conducting sleeve of plastic, or a metal sleeve with an insulating modular seal. A flange or union shall be located immediately inside the building for the installation of dielectric materials. These points shall be accessible for inspection and repair. Where it is necessary to interconnect dissimilar metals underground, dielectric insulation shall be installed at the connecting point. All buried insulating fittings shall be
coated. Coating of above grade insulating fittings shall be done with coal tar epoxy, so as not to short circuit the insulator.

C. Bonding
If a buried structure, such as a pipeline, is to be cathodically protected, it shall be electrically continuous. Some types of piping have mechanical joints with high resistance, or no metallic contact between joints. Insulated copper cables or steel straps shall be welded or brazed across any joints in ferrous piping systems which may otherwise have poor electrical conductance. Bonds may also be required between adjacent or crossing piping systems to allow protection of several systems from the same current source. Drain bonds shall be installed on any structure which may be subject to interference effects.

D. Casings
Casings are often used to mechanically protect buried pipelines from high external loading. In general, they should not be used unless absolutely necessary or specified by local authorities. If extra mechanical strength is actually needed, it is recommended to use higher strength steel or heavier wall coated and cathodically protected pipe, designed to withstand anticipated external loads without any casing.

When casings must be used, install bare unless coating is specified by utility owner or MDT, with pipeline casing insulators and end seals to electrically insulate the casing from coated carrier pipe. Sections of casings shall be bonded together. Provide permanent test leads on casing and carrier pipe. Test casing to carrier pipe resistance before and after carrier pipe is welded into the rest of the line.
E. Coordination of Cathodic Protection Design
The design of cathodic protection systems for Transit System facilities
will be coordinated with local utility owners by the Designer.

F. Foreign Structures
When foreign structures are adjacent to protected structures within the
Transit right-of-way, test wires shall be attached to both structures to
facilitate testing. Details and location of test stations on foreign
structures shall be approved by that structure's owner or his corrosion
engineer.

4.05.5 TEST STATIONS
Test boxes shall be installed at test station locations to facilitate inspection of
the system.

4.05.5.1 Test Boxes Installations
See Figure 4-1 through 4-7 in Appendix A for examples of the test box
installation and connections for the guideway test box and for the pier test
box.

- The guideway test box shall contain a wire or stub which is
electrically bonded only to the isolated guideway structural
steel.

- The pier test box shall contain a wire bonded to the pier
structural steel. The insulated wire shall be coiled and stored
within the box.
• The pier test box shall also contain the grounding conductor with a jumper bar which can be opened to make stray current measurement tests within the grounding conductor. Note that the pier test wire stored within the test box shall have no connection to the grounding conductor.

4.05.5.2 Reserved

4.05.6 CORROSION CONTROL OF MECHANICAL EQUIPMENT
In addition to corrosion control requirements of this section, see also Chapter 5, Mechanical Design Criteria of this volume.

4.05.7 MISCELLANEOUS ITEMS
4.05.7.1 Communication, Power and Control Cables
Traction power, train control, communication and other system cabling shall conform to the respective system design criteria section(s) which address cabling for these systems.

To mitigate cable damage caused by temperature cycling, all cabling installed outside of buildings in cable trays, troughs, conduits and/or duct banks shall be suitable for direct burial or duct installations in all wet and dry locations. Insulations shall be heat, moisture and chemical resistant, mechanically rugged zero halogenated compound type.

When tested in accordance with ICEA and UL requirements, the low smoke, non halogenated, flame resistant thermoplastic polyolefin (TPPO) jacket shall meet or exceeds the guaranteed values of ICEA, ASTM and NEC requirements. Lead sheathed cables shall not be used.
At the discretion of the Designer and warranted by the design, cabling with shielding can be specified.

Refer to the respective subsystem design criteria for more specific cable requirements for each subsystem.

4.05.7.2 Non-metallic Materials

Where metallic and non-metallic materials are completely acceptable alternatives for the same service, preference shall be given to use of the nonmetallic material.

In specific cases where metallic conduit must be used for direct earth burial application, it shall be galvanized steel. Galvanized steel conduits embedded in concrete shall be electrically continuous.

Where non-metallic conduits are used, both underground and above ground, they must be protected by a minimum of 3 inches of concrete covering. Concrete protection of above ground non-metallic conduits extending up the Metrorail piers shall extend to 8 feet above grade.
4.06 SYSTEMS-FACILITIES INTERFACE RACEWAY

4.06.1 SCOPE

This section identifies the raceway requirements including size, material, quantity, location, and contractor responsibility for all the 'Systems-Facilities Interface Raceways throughout the Metrorail extension. Interface raceway systems are to be designed in compliance with the latest issue of the National Electrical Code, except where otherwise noted. Interface raceway shall be consistent with the existing Metrorail design. Where variations are necessary, they should be identified and brought to the attention of MDT, along with the Designer’s recommendation, as early as possible for a prompt resolution.

This document addresses the Systems Facilities Interface Raceway requirements for the following:

- Train Control
- Emergency Power
- Blue Light Stations with Emergency Trip Buttons (ETS)
- Traction Power Installation
- Telephone Subsystems
- Radio Subsystems
- Closed Circuit Television Subsystem
- Fare Collection
- Intercommunication Subsystem
- Public Address Subsystem
- Fire Alarm System
- SCADA Subsystem
- Fiber Optic Cable Transmission Subsystem
- Power Feeders (480/277V, 208/120V)
- Primary Power (13.2 KV)
- Variable Message Sign System
- Access Control and Intrusion subsystems
- Other miscellaneous MDT subsystems

4.06.2 PHYSICAL RELATIONSHIP

4.06.2.1 General

This subsection describes in general the physical and functional relationships between different areas throughout the Metrorail extension. This information used in conjunction with the existing MDT Drawings and other applicable system design criteria should enable the Section Designer to design the raceway according to the requirements of all the applicable systems. Raceway requirements discussed here are in addition to the many raceway requirements which are an inherent part of station electrical power, communication and control cable raceway design.

Each station will have many Systems-Facilities Interface raceway requirements which are related to indication and control device wiring routed from the Input/Output modules of the PLC based SCADA system to equipment throughout the station. These general locations are to be identified and specified during the design process.

The Train Control & Communications (TC&C) Room housing the Metrorail Communications Network, Train Control, CCTV, SCADA and other systems contain a variety of equipment and cable termination facilities which require a large number of cables entering and leaving various areas within the station. While each station will have a unique physical arrangement, the Section
Designers are advised to utilize the cableways communications systems compartment or place several convenient-to-the-devices junction boxes within the station much in the same manner suggested in paragraph 4.06.2.3.A.3.

For cables and conductors routed within the Rapid Transit System susceptible to interference, galvanized rigid steel raceway or properly shielded cables shall be specified to adequately shield those signals. It is expected that the majority of sensitive cabling will be between the Train Control and Communications Room and other locations. As a normal part of the design process, it can be expected the raceway distribution will change and evolve to it final design during the design and review phases. Systems most likely to have their own raceway distribution are described in paragraph 4.06.2.3.

Conduits or other types of raceways entering areas described below need to be routed to their destination by the most direct means with a minimum of conduit bends or transitions (see paragraph 4.06.2.3). In specified cases where conduits penetrate initial construction (i.e., foundation, floor slab, ballast, sub-ballast, pads) into areas in which finishing is designed for future construction by a separate contractor, the conduit layout must be sufficiently clear as to purpose and destination to preclude conduit mismatches.

Station columns shall be used to route communications and other miscellaneous systems conduits from the platform to the cableway "communications" section. On columns where there are drain pipes, only one conduit shall be installed adjacent to the drain pipe. The conduit shall be used for the lightning protection down conductor from the roof. To the maximum
extent possible, conduits in public areas shall be concealed and aesthetics shall be taken into consideration.

For Stage 1, the maximum available conduit space in station columns where there is no drain pipe is 4-1/2 inches diameter in the center of the column.

For the extension design, the Designer shall confirm conduit space is available within the center of the support columns. Separate conduits shall be provided for platform and concourse lighting (normal and emergency), platform receptacles and miscellaneous systems, as described above. Conduits may be spread around the reinforcing steel bars in accordance with structural requirements.

Installation of spare conduits throughout the station for future use is encouraged. For systems related equipment installations within the station which are not clearly defined at the time, or in cases of planning for future installations, a general rule is to provide one conduit to the location for power and a separate conduit for communications cables or control wiring.

This document and MDT Drawings of the existing system and other documents related to various systemwide contracts will indicate physical relationships between equipment requiring conduit as well as other conduit interfaces. Even though the rationale may not always be readily evident, the prescribed relationships should be maintained. In cases where the relationship and interfaces cannot be confirmed by the designer, timely clarification from MDT should be sought to avoid design and/or construction errors.
The remainder of subsection 4.06.2 is intended to highlight major raceway requirements throughout the transit system. Any conflicts between this document and existing MDT documents or standards should be brought to the attention of MDT by the Designer, along with the Designer’s recommendation, for resolution by MDT.

4.06.2.2 Guideways

A. Aerial Single Guideway Two-Track Configuration: In the aerial single guideway two-track configuration, two 21 inch wide by 6 inch deep cableways shall be provided. They shall be located on top of the deck and at the center of the guideway on tangent and flat curves and shall extend longitudinally the full length of the guideway. The northbound and southbound track cableways shall be divided into two compartments with metal barriers separating the compartments. The compartments are for routing cables for the following systems:

A. Train Control
B. Communications.

The cableway configuration shall be as indicated in the MDT drawings of the existing system. Two two inch conduits shall be installed under the girder flange adjacent to the cableway as indicated for Gap Tie Station power and ETS power and control.

Pull boxes shall be installed at accessible locations for ease of maintenance of the ETS power and control system cables from below the guideway.
B. Aerial Separate Guideway Single-Track Configuration. In the aerial separate guideway single-track configuration, a 27 inch wide by 6 inch deep cableway with cover and structural steel support bracket attached to the guideway girder flange shall be provided and located adjacent to the running rail on the side opposite from the contact rail. This configuration occurs at the guideways adjacent to and into passenger stations and special track work areas. The cableway shall be divided into three compartments with metal barriers for routing cables for the following systems:

A. Train Control
B. Communications
C. Power to Gap Tie stations and ETS power and control.

C. Special Aerial Guideway Sections
At special aerial guideway sections such as cross-overs, pocket-tracks, and turn-backs, cableway transitions shall be made to locate the cableway under the special.

D. At-Grade Guideway Configurations
Underground, concrete-encased duct banks shall be provided for cable runs required for train control, communication, traction power and 480 volt power feeder.

Transition from aerial cableways to underground duct banks shall be made via column mounted conduits routed into manholes at both ends of the at-grade sections.
4.06.2.3 Ancillary Spaces

A. Train Control and Communications Room:

1) The Train Control and Communications Room will be the focal point for the equipment, wire and cable support for station system communications (MDT Communications Network), Train Control, Supervisory Control and Data Acquisition (SCADA), CCTV, PA, Fire & Intrusion, and other systems including the UPS and the feeders (208/120V) from the Electrical Equipment Room to the Train Control and Communications Room to support the systems.

The Train Control and Communications Room will house the equipment cabinets for these systems.

Raceways terminating within this room must be stubbed-up, routed or terminated. All raceways must be labeled. Spare raceways must contain a pull rope and be sealed. Raceway design shall be validated during the station and line section design and review process.

2) Typical raceway destinations from the TC & C Room will include but not limited to:

- Wayside Blue Light Stations with Emergency Trip Buttons (for indications to PLC)
- Parking Structures
- Traction Power Substation
- Gap Tie Stations
- Electrical Equipment Room
- Mechanical Equipment Room
• Platform Areas
• Concourse Areas
• Station Attendant's Booth
• Station Supervisor/ Dispatcher Booth
• Fire Alarm System Devices
• Telephone and Communication Equipment and Devices
• Wayside Duct Banks (at-grade)
• Wayside Cableways and conduits (aerial)
• UPS Battery Room
• Next train out and start signs for terminal stations
• ADA compliant signage and audio messages
• Grounding Equipment
• Security Devices
• Revenue Room & Employee Lounge

3) The Train Control and Communications Room will contain an electrical panel dedicated to supplying power to CCTV cameras located at various areas within the station. When these power loads are concentrated in certain sections of a station, the cableway miscellaneous systems compartment and/or larger conduits may be specified from the Train Control and Communications Room to a readily accessible, convenient-to-the-loads junction box. Smaller branch circuit empty conduits shall then be extended from this junction box to the specific loads. Drawings submitted by the Designer will be reviewed and commented on by MDT during the design and review phases. In all station designs, the same method shall be used for control circuit conduits routed to the Electrical Equipment Room.
4) For CCTV cameras and other low voltage equipment, use of a composite cable for both low voltage power (NEC Class II) and signal within the same cable is acceptable. Where other than low voltage is utilized, separate conduits and cables shall be provided for the signal and power.

B. Electrical Equipment Room

1) Systems-Facilities conduits are required from the Electrical Equipment Room to the Train Control and Communications Room Panel to supply 3 phase 120/208V power to the UPS and electronic equipment within the Train Control and Communications room.

2) Conduits in duct bank are required from the Electrical Equipment Room to the Traction Power Substation for the following:

- 480/277V, three phase, four wire power feeder to supply all the auxiliary power requirements in the Traction Power Substation facility.

- 13.2KV primary feeders to the unit substations in the Electrical Equipment Room from the Traction Power Substation primary distribution switchgear.

3) Conduits are required from the Supervisory Control Interface Terminal Cabinet (SCITC) located in the Electrical Equipment Room to the PLC Input/Output interfaces at the SCADA system...
cabinets within the TC&C room for remote control, monitoring and/or alarms.

4.06.2.4 Platform and Under-Platform Areas
As noted in paragraph 4.06.2.1 several raceway distribution systems shall be used within the station leading to several systems equipment and devices.

Two 2'-3" x 6" deep cableways shall be located in the under-platform areas of the passenger stations from which empty conduits shall be run to equipment and devices on the station platforms and on the guideway to provide for communication, train control, supervisory control, CCTV, P.A. Subsystem, Fire and Intrusion Status, Alarm cables and other miscellaneous cables.

Passenger station facility related conduits for lighting, receptacles and miscellaneous power shall not be run through or from the cableways to the devices.

4.06.2.5 Concourse Area
As indicated in paragraph 4.06.2.1, several empty spare raceway distribution subsystems may be designed within the concourse area leading to several subsystems equipment and devices such as CCTV, P.A., VMS subsystems, Fire and Intrusion Status and Alarms, telephones etc. Station design submittals will be reviewed by MDT so that raceway design may evolve over the design process. See MDT drawings of existing systems and stations for reference.

Fare collection system raceways shall extend from a power panel in the TC&C Room to the fare collection area(s) within the station for power and
communications circuits. Raceways for fare collection equipment control shall be served by raceways from the Station Attendant’s Booth (if installed) to the fare gates and fare vendors. The number of fare collection equipment units and raceway configuration will be determined by the Designer. Raceway capacity shall be provided for future fare collection equipment as defined during the station design phase and shall be made compatible with the under floor raceway configuration. Refer to Volume VII, Chapter 4, Fare Collection System Integration and Volume II, Chapter 1, Station Architectural, Section 1.10 of the Design Criteria Compendium.

4.06.2.6 Station Attendant's Booth/Console
Where station attendant's booth or console will be provided, raceways shall be provided from the Station Attendant's Booth or console location to the Train Control and Communications Room, Electrical Equipment Room, fare gates, CCTV subsystem, P.A. subsystem, elevator/machine room, escalator machine space, transfer machines, mechanical equipment room and change dispensers. Adequate raceways shall be provided to support the equipment typically installed within an attendant's booth, giving MDT the option of installing either an attendant’s booth or simply a console with lesser capabilities at the time of station construction. This configuration will provide MDT with the capabilities of upgrading to an attendant’s booth at a later time, if needed.

4.06.2.7 Traction Power Substation
Systems-Facilities raceways are required from the Traction Power Substation to the adjoining underground duct bank or to the aerial guideway for the following applications, depending upon the location of the Traction Power Substation.
Based on the Metrorail Stage 1 design, the following is a list of conduits typically required. For the extensions, the actual quantities and sizes are design dependant and are to be determined by the Designer.

For example, where the Traction Power Substation is located away from the guideway:

- Four 2" conduits for the SCADA system
- Three 2" conduits for communications.
- Two 2" conduits for emergency trip circuits.
- Sixteen (dependant upon design) 4" conduits for traction power positive feeder cables.
- Eight (dependant upon design) 4" conduits for traction power negative return cables from impedance bonds to negative bus box.
- Two 2" conduits - spare.

Where the Traction Power Substation is located below the aerial guideway:

- Two 2'-3" x 6" deep cableways from the Traction Power Substation to the cableways atop the aerial guideway structure.
- Sixteen (dependant upon design) 4" conduits for traction power positive feeder cables.
- Eight (dependant upon design) 4" conduits for traction power negative return cables from impedance bonds to negative bus box.
See Volume VII, Systemwide Equipment, Chapter 1, Traction Power Equipment, Chapter 2 Contact Rail and Protective Coverboard, and Chapter 3, Traction Power Installation Hardware for additional electrical power related conduit criteria. See also MDT drawings of existing systems and stations for reference.

4.06.2.8 Gap Tie Stations

Systems-Facilities raceways are required from the Gap Tie Station to the adjoining underground duct bank or to the aerial guideway for the following applications, dependant upon the location of the Gap Tie Station. The following is a list of conduits typically required. The actual quantities and sizes are design dependant and are to be determined by the Designer.

Where the Gap Tie Station is located away from the guideway:

- Two 2" conduits for the SCADA system
- Three 2" conduits for communications.
- One 2" conduit for relaying.
- Two 2" conduits for emergency trip circuits.
- One 2" conduit for auxiliary power feeder.
- Two 2" conduits - spare.
- Sixteen (dependant upon design) 4" conduits for traction power positive feeder connection to contact rail from Gap Tie Station for a crossover. Twenty (dependant upon design) 4" conduits for traction power positive feeder connection to contact rail of a Gap Tie Station for a pocket track.

Where the Gap Tie Station is located below the aerial guideway:
• Two 2'-3" x 6" deep cableways from the Gap Tie Station to the cableways under the aerial guideway structure for 35'-10" (Verify distances are coordinated with latest structure drawings) to configuration or two 1'-9" x 6" deep cableways from the Gap Tie Station to the cableways and 2-2" conduits for emergency trip circuits and 480 volt power feeder under the aerial guideway structure for 14'-0" (Verify distances are coordinated with latest structure drawings) to configuration.

• Sixteen (dependant upon design) 4" conduits for traction power positive feeder connection to contact rail from Gap Tie Station for an aerial crossover.

• Twenty (dependant upon design) 4" conduits for traction power positive feeder connection to contact rail from Gap Tie Station for an aerial pocket track.

For additional power related conduit criteria, See:

• Volume VII, Systemwide Equipment, Chapter 1, Traction Power Equipment,

• Chapter 2 Contact Rail and Protective Coverboard with figures depicting rail electrification and feeder arrangements for special trackwork areas, and

• Chapter 3, Traction Power Installation Hardware.

See also MDT drawings of existing systems and stations for reference.
4.06.2.9 Wayside Facilities

A. Wayside raceway design involves a variety of sizes and relationships to other wayside facilities. The pull box, conduit body, trough, manhole or handhole is the key to the successful installation of system cables. Hence, close coordination between the Systems and Facilities design is required. However, the following general guidance shall be used as applicable in the design of underground duct banks or aerial raceways:

1) Distances between at-grade manholes, handholes or pull boxes shall be evaluated based on such factors as; accessibility, conductor size, number and length which will affect pull tension, continuous conductor length requirements versus splice requirements, etc.

2) Other pull boxes, handholes and manholes shall be generally spaced 450 feet maximum on centers except where required for connection to the wayside equipment and devices.

3) Selected wayside duct bank details, pull boxes, manholes and handholes locations shall be submitted within the plans and specifications package as part of the design submittal and review process.

B. The cableways on the aerial guideway structure and manholes or handholes on the at-grade guideways shall be designed and submitted within the plans and specifications package as part of the design submittal and review process. The following are some typical requirements of wayside equipment and conduit installation from the
cableway for aerial structures, and from manholes or handholes for at-grade sections, to the wayside equipment:

1) Blue Light Station/Emergency Trip Stations

- Two 2" conduits for emergency trip control circuit and Location indication light. (Blue light.)
- One 3/4" conduit for emergency communication to central control facility. (In Yard, Yard Control Tower)
- One 3/4" conduit for a telephone jack connection for communication by the maintenance people.

All of the above three conduits shall be routed from the emergency trip station.

2) Train Control Circuits

Stub-ups from the manholes/handholes (for at-grade guideways) or from the cableways (for aerial guideways) shall be run to the outer edges and/or to the center of the trackways. Exact positions of the conduit stub-ups depend upon the nature of the trackway and wayside devices at each specific location.

3) Cross-Bond Connections

Provisions shall be made in the aerial guideway structure for a metal trough or four 4" conduit runs from one track across to the other at impedance bond locations. For at-grade sections, conduits shall be run underground from one track across to the other.
4.06.2.10 Raceway Transitional Areas

A. General
Raceway transitional areas are those areas in which physical provisions must be made to facilitate the routing of cables from wayside duct banks or cableways to the station raceway system or from the wayside raceway system to the Traction Power Substation, Gap Tie Station, wayside equipment or Central Control Facility. Also, physical provisions are required when two types of wayside raceway configurations must be joined together such as at-grade duct banks with aerial cableway system.

B. Aerial to At-Grade Transitions
Conduits entering the at-grade manhole and the cables entering the pull box from the aerial cableways shall be aligned in a manner consistent with conduit and cable bending criteria. Also, transitions in pull boxes and manholes shall separate the power (120/208 - 277/480 volt) and Train Control and Communications cables by means of metal barriers. NEC and other applicable codes for power and communications cable installation within conduits are to be followed.

C. Guideway to Passenger Station Transitions
Cableways on the aerial structure running into a station area shall enter the Train Control and Communications Room at four separate locations using cableway fittings.

D. Aerial Transitions at Special Trackwork Sections
Cableways running surface-mounted on the aerial structure shall be transitioned through cutouts in the girder slab at both ends of the special
trackwork section and shall be run suspended along the full length of the special trackwork section.

4.06.3 PHYSICAL INSTALLATION

4.06.3.1 General

This subsection outlines acceptable methods of raceway design and installation. Conduits shall be sized not to exceed fill ratio as specified by NEC. In general, conduits shall be 3/4 inch or larger. ½ inch conduit is acceptable for small diameter low voltage communication and CCTV cables.

4.06.3.2 Construction Guidelines

A. Visibility Provisions for Station Areas

1) Public Areas

Raceways shall be concealed from public view. Where allowance must be made for future floor-mounted equipment, under floor raceways with flush-with-the-floor covers shall be employed. Also, flush mounted junction boxes with supporting conduit maybe used for certain communication equipment. On parking structures, conduits joining lighting fixtures to a double tee shall be run exposed; conduits in between double tees shall be run concealed in the beams. Some passenger station equipment design installation standards (e.g., Fare Collection Equipment) will provide more specific guidance. However, the basic design objective shall be to minimize both the visual impact of exposed raceways in public areas and tripping hazards that would exist with stub-ups for future equipment in public or non-public areas.

2) Non-Public Areas
In general, all raceways in the Electrical Equipment Rooms, Mechanical Equipment Rooms, service areas, Train Control and Communications Rooms, Traction Power Substations, and Gap Tie Stations shall be installed exposed mounted on the walls or supported from the ceiling.

3) Conduit Emergence
Embedded nonmetallic conduits shall be converted to galvanized PVC-coated rigid steel (GRS) before emerging from their protective cover. As noted in the preceding paragraphs, in some cases concealed conduits should be terminated in flush mounted junction or outlet boxes rather than providing for the complete emergence of a conduit.

B. Conduit Bending
Conduit bending shall be in accordance with the National Electrical Code minimum bending radius, with the following exceptions:

1) Unless otherwise noted, a conduit run shall have no more than the equivalent of three 90 degree bends (270 degrees total) between an outlet or service point and pull box, manhole, handhole or outlet box.

2) All traction power feeder conduits shall have a minimum bending radius of 36 inches for four inch conduit and 18 inches for two inch conduit.

3) All wayside cableways entering the Train Control and Communications Rooms, Traction Power Substations, Gap Tie
Stations, manholes, pull boxes, etc., including vertical and horizontal fittings, shall have a minimum bending radius of 24 inches. All wayside concrete embedded conduits entering the Train Control and Communications Rooms or any wayside facility building, shall have a minimum bending radius of 36 inches. Where space limitations preclude the minimum radii, conduits shall terminate in a bushed pull box having a minimum length equal to eight times the conduit diameter.

4) Special care and considerations shall be given to fiber optic cable handling and installations. Industry standards and manufacturer’s recommendations shall be followed.

HDPE innerduct shall be installed within the raceways and conduits before the fiber optic cable is installed.

A fiber cable management system shall be provided to protect the fiber cables, jumpers and patch cables.

C. Traction Power Pull-Boxes

Traction power pull-boxes shall be provided. Where the curvature of the conduit bends exceeds 270 degrees between the conduit termination point in the substation or Gap Tie Station and the conduit termination point at the running rails or contact rail, or when the maximum value per cable pulling tension and sidewall pressure exceeds manufacturers recommendations.

D. Drainage
Duct banks, conduits and cableways require adequate drainage to prevent entrapment of water. Cableway bottoms shall be equipped with adequate drain holes with screening to prevent insect intrusion. Duct banks shall be designed with a slope towards a manhole, handhole or pull box from which provisions shall be made for drainage. Duct bank invert elevations shall be indicated on the drawings. Where continuous drainage from a pull box or manhole is not cost effective, provisions shall be made to enable the use of a permanent or portable sump pump for efficiently pumping out the water.

4.06.4 MATERIALS OF CONSTRUCTION

4.06.4.1 General
All materials, in general, shall be listed, inspected and approved by the Underwriter’s Laboratories and shall bear the UL label where labeling service is available.

4.06.4.2 Material Nomenclature
The following nomenclature shall be used on contract drawings to identify conduit materials:

- PVC - Schedule 80 polyvinyl chloride conduit
- GRS - Galvanized rigid steel conduit
- PVC.GRS - PVC - coated galvanized rigid steel conduit
- FRE – Fiberglass Reinforced Epoxy conduits

The material and extent of use of each material shall be shown on the contract drawings.

4.06.4.3 Application of Raceway
A. Schedule 80 PVC Conduit (PVC)
Schedule 80 PVC conduit shall be used non-encased in certain underground and ground floor slabs and for all concrete encased conduits except as noted. The concrete envelope shall provide a 3 inch minimum outer protective cover on the top, bottom and side of the duct bank.

B. Galvanized Rigid Steel Conduit (GRS)
Metallic conduits shall be avoided whenever possible. Where the design does require metallic conduits, GRS conduit shall be used. GRS conduit shall be used as the transition from concrete encased PVC conduits to above grade, exposed conduits. The transition to GRS shall be made before the conduit emerges from the encasement.

As an alternative to concrete encased non-metallic conduit, PVC coated Galvanized Rigid Steel conduit may be used whenever a train control or communication conduit (two inches or less) is used underground, directly buried within the guideway boundaries.

C. Cableway
Cableways shall be used on all aerial guideway structures as the main raceway support system for train control, communications, and supervisory control.

All surface-mounted cableways, except those in the under-platform areas of passenger stations, and those under special trackwork guideways, i.e., pocket track, cross-overs and turnback tracks, shall be provided with nonskid, embossed pattern type surface covers which will be used as a walkway.
MDT prefers the use of non-metallic materials on the guideway especially in areas of the Traction Power feeders.

The Designer shall investigate the use of non-metallic cableways and present the results to MDT with a recommendation. MDT will provide direction on the cableway.

If metal cableways are used, they shall be rigid steel, hot dip galvanized after fabrication and compartmentalized with metal barriers.

4.06.5 RACEWAY IDENTIFICATION METHODS

4.06.5.1 General

This subsection describes the raceway identification requirements for all the Systems-Facilities Interface Raceways. The identification methods outlined here shall be on the basis of function rather than the physical location.

4.06.5.2 Raceway Designations

A. The purpose for which a raceway has been included shall be denoted through the use of one of the notations below. These notations shall be used as a prefix for raceways (conduits, cableways, etc.), which serve as a feeder or homerun raceway. These raceways shall be numbered and included in the raceway schedule as described below.

For purposes of these criteria, a feeder or homerun raceway is any raceway which has at least one end terminated within the Train Control and Communications Room, Electrical Equipment Room, Traction Power Substation, Gap Tie Station, Central Control facility or other
physical locations in a given facility design. Systemwide raceways which are not homerun raceways shall be identified in the plan drawings with the raceway symbol spaced along the line. Notations for raceway designations are:

<table>
<thead>
<tr>
<th>Raceway Type</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Feeder (480/277 or 208/120V)</td>
<td>F</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>M</td>
</tr>
<tr>
<td>Communication</td>
<td>C</td>
</tr>
<tr>
<td>Fare Collection</td>
<td>FC</td>
</tr>
<tr>
<td>Fire Alarm</td>
<td>FA</td>
</tr>
<tr>
<td>Intrusion Alarm (Security)</td>
<td>IA</td>
</tr>
<tr>
<td>Primary Power (13.2KV)</td>
<td>PP</td>
</tr>
<tr>
<td>Public Address Subsystem</td>
<td>PA</td>
</tr>
<tr>
<td>Uninterruptible Power Supply</td>
<td>UPS</td>
</tr>
<tr>
<td>Traction Power Positive Feeder</td>
<td>TPP</td>
</tr>
<tr>
<td>Traction Power Negative Feeder</td>
<td>TPN</td>
</tr>
<tr>
<td>Cable Transmission Subsystem (Obsolete)</td>
<td>CTS</td>
</tr>
<tr>
<td>Metrorail Communications Network</td>
<td>MCN</td>
</tr>
<tr>
<td>Train Control</td>
<td>TC</td>
</tr>
<tr>
<td>Closed Circuit Television Subsystem</td>
<td>CCTV</td>
</tr>
<tr>
<td>Supervisory Control Subsystem (SCADA)</td>
<td>SC</td>
</tr>
</tbody>
</table>

*Superseded by Metrorail Communications Network - MCN (Do not use –)*
Emergency Trip Station  ETS
Door Lock Control  DLC
Fare Gate Control  FGC
Data Transmission Subsystem (Obsolete)  DTS (*Do not use – Superseded by SCADA/PLC system*)

B. A second letter shall be added to the communication raceways (e.g., CA) not used as homerun raceways.

PABX  CP
Patron Assist Telephone  CA
Public Pay Telephone  CX
Emergency Telephones  CE
Elevator Intercom  EI

C. These designations shall be used throughout the system. The suffixes IN and OUT shall be used to denote conduits serving the duct bank inbound towards a passenger station and outbound away from a passenger station, respectively.

4.06.5.3 Raceway Schedules

Individual raceway schedules shall be prepared for each of the subsystems indicated in paragraph 4.06.5.2.A. Raceway schedule shall include the following information:

- Raceway Designation
• Raceway From
• Raceway To
• Raceway Size
• Raceway Type

An additional column shall be provided in the raceway schedule against each raceway to enter the cable description information that will be provided later.
APPENDIX A
Soundwall/handrail attachment See Detail 5 No electrical connections to structural steel.

Lightning protection as required—both sides

#4/0 Insulated softdrawn copper conductor longitudinally run for grounding & lightning protection No connection to structural steel

Contact Rail Lighting Arrester #4/0 grounding conductor

See Detail 6 for return rail lightning connection

#4/0 Insulated softdrawn copper conductor longitudinally run for grounding & lightning protection No connection to structural steel

Electrically isolate cableway and handrail attachments to the guideway from guideway structural steel. (See Detail 4 & 5)

Steel collector bar within superstructure at expansion joint

Contact Rail Lightning Arrester #4/0 grounding conductor

See Detail 6 for return rail lightning connection

Flexible joint for conduit

Flush mounted fiberglass test box (See Figure 4-2)

#4/0 Insulated softdrawn copper conductor

#4/0 Insulated softdrawn copper conductor

Lightning protection as required—both sides

Grounding and stray current details as shown are typical at every guideway column.

General Notes:
Information provided here is diagramatic and is intended to show basic system design. System designer shall provide systems that comply with applicable requirements.

Not to Scale

SUPERCEDED SEE FIGURES 4-1a THROUGH 4-1c, Rev. 1
Soundwall/handrail attachment
See Detail 5
No electrical connections to structural steel.

#4/0 Insulated softdrawn copper conductor
longitudinally run for grounding & guideway lightning protection
No connection to structural steel

Contact Rail
Lightning Arrestor
See Detail 7 for positive feeder lightning connection.

#4/0 grounding conductor
See Detail 6 for return rail lightning connection

Electrically isolate cableway and handrail attachments to the guideway from guideway structural steel. (See Detail 4 & 5)

Steel collector bar within superstructure at expansion joint

Flexible joints for conduit

Electrically isolate superstructure from columns

Flush mounted fiberglass test box (See Figure 4-2)

Removable jumper bar

#4/0 Insulated softdrawn copper conductors

1" Non-metallic conduits with epoxy filled ends

Insulated copper test wire coiled in box with no connection to down conductor

Ground rod array A (Note 1)

Ground rod array B (Note 1)

Elevation

See Notes (Figure 4-1c)

Not to Scale
Notes:

1. Ground rod array A and ground rod array B are independent ground systems. Separation of ground rod arrays to be determined by the system designer in accordance with applicable codes, during final design. The ground rod systems must be sufficiently spaced apart from one another to minimize the transference of voltage from one system to another during conduction periods - defined as the “zone of influence”. The system designer shall calculate the zone of influence and transference voltage, utilizing factors such as the soil resistivity between ground rods, the level of current assumed flowing into the grounding systems and the resistivity of the grounding systems.

2. Information provided here is diagramatic and is intended to show basic system design. System designer shall provide systems that comply with applicable requirements.

3. The calculation and design of the ground systems shall include the requirements from NFPA-780, whereby the lightning protection down conductors and ground rod system are made as short and straight line as possible. Therefore, the traction power surge protection grounding systems would be separated from the lightning protection grounding systems to the fullest extend possible, but within reason from a cost point of view and with a constraint that it must remain within the MDT ROW boundaries.

4. Down conductor from lightning rods and other metallic elements on guideway deck.

5. Down conductor(s) from positive feeder and negative return lightning arrestors. See Figure 4-8 for connection details.

6. Grounding and stray current details as shown are typical at every guideway column.
#4/0 ground conductor continuous from Metrorail Guideway

Non-metallic conduit with weathertight bushings
Seal with epoxy

Flush mounted fiberglass weatherproof test box with hinged cover (cover not shown)

Non-conductive fiberglass stud, washer & nut for test wire storage

Column test wire No. 8 insulated copper wire from vertical column rebar no contact to ground system

Resistive shunt not required
Use copper jumper bar
Phenolic back panel

#4/0 ground conductor continuous ground rod

Non-metallic conduit with weathertight bushings Seal with epoxy

Brass studs mounted on the back panel for conductor termination & jumper mountings

Compression lug termination of #4/0 conductors

Install ground conductor lugs over studs then mount jumper & firmly tighten all in place using brass nut with flatwasher providing a good electrical bond

Coat with “No-Ox” type protectant

Not all test box details are shown

Not to scale
#4/0 ground conductor continuous from Metrorail Guideway

Non-metallic conduit with weathertight bushings

Seal with epoxy

Flush mounted fiberglass weatherproof test box with hinged cover (cover not shown)

Non-conductive fiberglass stud, washer & nut for test wire storage

Column test wire No. 8 insulated copper wire from vertical column rebar no contact to ground system

Resistive shunt not required

Use copper jumper bar

Phenolic back panel

#4/0 ground conductor continuous to ground rod

Non-metallic conduit with weathertight bushings

Seal with epoxy

Gold Test Nut (Goldnut) (Note 1)

Brass studs mounted on the back panel for conductor termination & jumper mountings

Compression lug termination of #4/0 conductors

Install ground conductor lugs over studs, then mount jumper & firmly tighten all in place using brass nut with flatwasher providing a good electrical bond

Coat with “No-Ox” type protectant

1” Insulated Test Link Assembly (Note 1)

Notes:

Not all test box details are shown

Not to scale
Standard Guideway Superstructure & Piers

Multi-Span Continuous

Simple Span

Superstructure
Test Boxes

C Pier

Expansion Joint

Superstructure

Test Boxes

C Pier

Expansion Joint

Not All Details are Shown
Note:
Tack Weld all Top Transverse Reinforcing Steel to One Longitudinal Reinforcing Steel Bar. Location of Stub-Up and Test Box to be Determined by Designer to Avoid Tripping Hazard.
Figure No: 4-5

Sections & Details

Section A

- Test Stub in Non-Metallic Box
- Joint
- Weld a Stub-Up Reinforcement Piece to the Test Box
- Longitudinal Reinforcing Bar
- Transverse Reinforcing Bar

No Electrical Continuity Across Segments

Superstructure Test Box & Bonding Detail

Section B

Detail 2

- Use Only Non-Conductive Reinforcement Bars in Plinth Pad

Detail 2 - Plinth Pad Reinforcement Bars
Use Non-Conductive Inserts for Handrail & Noisewall Attachment to Top Slab Minimum 2" Clearance to Reinforcing Steel

Detail 5 - Non-Conductive Inserts

Cabletray

Use Non-Conductive Anchors and/or Bushings

2" Min. Clearance Anchor to Reinforcing Steel

Detail 4 - Cabletray Attachment Example

750 mcm Conductors Return Rail to Negative Return Bus

Detail 6 - Return Rail Lightning Arrestors

SUPERCEDED
SEE FIGURES 4-8
Detail 6 - Return Rail Lightning Arrestors

- 750 kcmil Conductors Return Rail to Negative Return Bus
- Negative Return Bus on Guideway
- Lightning Arrestor
- #4/0 Conductor to Lightning Down Conductor (Note 1)

Detail 7 - Positive Feeder Lightning Arrestor Installation Detail

Note:
1. The ground conductors from the lightning arrestors protecting the positive feeders and negative return are typically connected to a single ground conductor before entering its own conduit down to the ground array.