VOLUME VII - SYSTEM EQUIPMENT

CHAPTER 2 - CONTACT RAIL AND PROTECTIVE COVERBOARD DESIGN CRITERIA

REVISION 1

Program Management Consultant

Submitted ___________________________ Date 4/16/2009

Project Manager, Soji Tinubu

Miami-Dade Transit
Engineering Review Board Members

Approval ___________________________ Date 4-16-09

Chief of Design & Engineering, Isabel Padrón

Date 4/16/09

Chief of Construction, Ron Steiner

Date 4/16/09

Chief of Safety, Eric Muntan

Date 4/16/09

Manager of Systems Engineering, Daniel Mondesir

Director Approval

Approval ___________________________ Date 4/30/09

Deputy Director, Albert A. Hernandez

Approval ___________________________ Date 6/1/19

MDT Director, Harpal Kapoor

VOLUME VII – SYSTEM EQUIPMENT
CH 2 – CONTACT RAIL AND PROTECTIVE COVERBOARD

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2.1 INTRODUCTION

2.1.1 SCOPE

The scope of the design criteria for the contact rail and protective coverboard includes:

A. The criteria for establishing the parameters and design methodology of the contact rail to satisfy the vehicle power requirements.

B. The criteria for establishing the parameters and design methodology of the contact rail protective coverboard to satisfy the operational and safety requirements.

C. The criteria for establishing structural performance requirements for contact rail and coverboard system.

2.1.2 POWER RAIL SYSTEM DESCRIPTION

The Contact Rail and Protective Coverboard Equipment include all equipment necessary to supply the 750 Vdc power from the wayside substations to the traction motors in each vehicle. Current collector shoes attached to each vehicle will normally maintain sliding contact with the Power Rail system. The running rails shall be used as negative return conductors for the traction power system. The entire Power Rail System, including the contact rails and associated cable connections, shall be capable of supporting the electrical currents and voltages to stay within the limit of maximum voltage drops as noted in Volume VII Systemwide Equipment, Chapter 1 Traction Power Equipment. The Power Rail System consists of the contact rail, the protective coverboard and all support hardware including such items as insulators, support brackets, anchor assemblies, etc.
2.1.3 DESIGN CRITERIA SCOPE

The contact rail, coverboard, and support insulators, individually and as a complete unit, shall be designed to meet the wind load requirements specified in Volume III - Guideway Design Criteria Chapter 3 – Structural Design Criteria for Aerial Guideway Section 3.05.6.10 as modified herein:

- The Importance Factor shall be taken as 1.00.
- The appropriate pressure coefficient including gust factor (GC) for use in defining the vertical and transverse loading requirements for the design of the Power Rail System shall be determined in accordance with ASCE/SEI 7-05, Minimum Design Loads for Buildings and Other Structures, Section 6.6. Full scale testing is required.

Acceptable performance as a result of wind testing shall be as follows:

- Under a 60 mph operational wind, the global deflection of any component of the Power Rail System shall not exceed 1/4 inch. All components shall be free of splitting, cracking or breaking, and shall immediately return to within 1/8 inch of its original shape and position when the load is removed.
- Under a design wind speed of 150 mph, all components shall be free of splitting, cracking or breaking, and shall immediately return to within 1/4 inch of its original shape and position when the load is removed.
- Under 120% of the design wind speed of 150 mph contact rail support insulators and pedestals shall be free of splitting, cracking or breaking.
The design of the contact rail, coverboard, support insulators, support insulator bolts and anchors, and pedestals system shall be designed such that the coverboard will breakaway from the contact rail prior to the failure of the contact rail support insulators, support insulator bolts and/or anchors, or the pedestal.

### 2.1.4 CODES, STANDARDS AND REGULATIONS

The currently adopted versions of codes, standards and regulations, as listed herein, 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 Electrical Safety Code (NESC)
- American National Standards Institute (ANSI)
- National Electrical Manufacturer's Association (NEMA)
- Institute of Electrical and Electronics Engineers (IEEE)
- Insulated Cable Engineers Association (ICEA)
- Occupational Safety and Health Act (OSHA)
- American Society for Testing and Materials (ASTM)
- Underwriter's Laboratories Inc. (UL)
- National Fire Protection Association (NFPA)
- Florida Building Code
- Volume III Guideway Criteria, Chapter 3 Structural Design Criteria
- Volume VII System Equipment, Chapter 1 Traction Power Equipment
- Metropolitan Dade County Fire Prevention and Safety Code
- Miami-Dade County Building Code
2.2 POSITIVE FEED SYSTEM

2.2.1 GENERAL

Electrical traction power for train operation will be supplied to the transit vehicle from the traction power substations through a contact rail installed parallel to the running rails. Current collector shoes attached to each vehicle will maintain sliding contact on the top surface of the contact rail to transmit electrical power to the traction motors in the vehicles. The Power Rail System will be operated as one electrically continuous conductor by operating with all dc main and feeder circuit breakers, gap tie circuit breakers and motorized disconnect switches closed. This mode of operation will prevent momentary loss of contact rail potential due to short duration outage at local traction power substations, and also, train loads will be shared between substations. This mode of operation will also increase the probability that the power regenerated by the vehicle braking system will be utilized.

2.2.2 CONTACT RAIL

The contact rail shall be bi-metallic contact rail, assembled from an 85 lb. ASCE running rail to which rolled or extruded aluminum sections are attached as needed to achieve the required conductivity. The rolled or extruded aluminum sections shall be forced to form and retain permanent contact by applied pressures from bolts or other equivalent methods. The contact surfaces between the two metals shall be thoroughly cleaned to insure maximum conductivity. Contact surfaces shall be tightly sealed to prevent ingress of polluting or corroding matter. The contact rail on main lines shall have an electrical resistance not greater than 0.002 ohm per thousand feet calculated at 68 degrees F and shall be capable of carrying 5,300 amperes dc continuously at a temperature rise not exceeding 104 degrees F above an average 86 degrees F ambient in still air. The contact rail in the yard
facilities shall have an electrical resistance not greater than 0.004 ohm per thousand feet calculated at 68 degrees F and shall be capable of carrying 3,000 amperes dc continuously at a temperature rise not exceeding 68 degrees F above an average 86 degrees F ambient in still air.

The contact rail sections which are bolted to the end approaches shall be precurved to match the curve radius for a sufficient distance to reduce lateral forces on the support insulators. The minimum length of precurved contact rail is 39 feet. The end approaches shall also be precurved over their entire length. All precurved contact rail and end approaches shall be appropriately marked to ensure proper field installation.

2.2.3 CONTACT RAIL INTERFACES

The design height of the contact rail, for the over-running collector shoes system, shall be 4 1/2 inches above the top of the running rail when the contact rail is seated upon insulators. The Designer shall note that special attention is required when assembling joints in the contact rail system that the rail end mismatch shall be no more than 1/64, is required as measured by a 3 foot straight edge on the top surface of the contact rail.

The base of the 85 lb ASCE contact rail will provide a stable arrangement for the unclamped rail under operating conditions. Vector forces from gravity and estimated peak short circuit currents of 200,000 amperes shall fall within the middle third of the base. The contact rail shall not retain permanent deformation from the stresses caused by the short circuit forces. The rail shall have sufficient section modulus so that it shall not deflect more than 0.001 of the span for a concentrated load of 250 pounds at mid span.
When designing contact rail layouts in special trackwork areas, the Designer shall configure the contact rail lengths and gaps such that each rail car has at least one shoe in contact with the contact rail system. The standard contact rail gap is 30 feet. Where this is not possible, the gap in the contact rail system shall be designed as per Case A in Figure 2-1 in Appendix A. With MDT approval, the minimum configuration, which qualifies as a bridgeable gap, may be used as shown in Case B. The allowance for thermal expansion can be adjusted based upon actual distances to the nearest contact rail anchors. The approach depicted in Figure 2-1 in Appendix A is also applicable to dip sections and end approaches with different ramp lengths. Deviations from the requirements of Figure 2-1 in Appendix A require MDT approval.

The minimum design offsets for locating contact rail in the switch section for tangential and modified #10 turnouts and tangential and modified #15 turnouts are listed in Figure 2-2 in Appendix A. The design offsets in Figure 2-2 in Appendix A are based upon the relationship of the contact rail to the rail car shoe as shown in Figure 2-3 in Appendix A. Figure 2-4 in Appendix A provides the factors that need to be considered when locating an end approach in the turnout area. For other turnout configurations, the Designer shall locate the end approaches using a similar methodology.

The Designer shall position the contact rail end approaches no closer to the Point of Switch than the distance needed to achieve a bridgeable gap as per Case A in Figure 2-1 in Appendix A or if Case A is not obtainable no closer than Case B in Figure 2-1 in Appendix A.
**Commentary:** Metrorail currently operates its rail vehicles in a married paired configuration using a train consists of 3 or more married pairs. In the future, it is envisioned that Metrorail will operate more frequent train service using shorter trains. Although a four-car train is 300 feet in length, each 75-foot long rail car is powered independently, and it is undesirable to have an unbridgeable gap in the contact rail which can cause excessive arcing and other related problems. A similar problem will occur if the length of the contact rail is too short. Although the gaps on each side of a short section of contact may be bridgeable, if the contact rail is too short, the rail car will lose power when traversing the contact rail. Maintaining continuous electrical power to a rail in crossovers, pocket tracks, and double crossovers is important, and breaks in the contact rail for walkways also need to be considered when designing contact rail in these areas.

### 2.2.4 PROTECTIVE COVERBOARD EQUIPMENT

The contact rail protective coverboard and support brackets shall be designed to protect personnel from accidental contact with the contact rail and other electrically energized parts of its assembly and to protect the contact rail from foreign objects either falling or being thrown onto it. The protective coverboard shall be a fire resistant, non-conductive material, and shall be designed in consideration of the harsh South Florida climate for a useful life expectancy of 25 years without refinishing or refurbishing the protective coating or finish.

The coverboard assembly shall be designed to limit deflection under its own weight to 1/8-inch between support brackets.
The coverboard assembly shall be designed to provide protection from electrical hazard when stepped on by a person weighing 250 pounds without splitting, cracking or breaking, and shall immediately return to within 1/8-inch of its original shape and position when the load is removed.

The coverboard shall be designed so that water will drain away from insulators.

The protective coverboard shall be supported at intervals by molded brackets attached directly to the bottom flange of the contact rail designed so as not to interfere with the contact rail/current collector shoe interface under both normal and abnormal conditions. Brackets shall be spaced at intervals as required to meet strength and deflection criteria but in no event at intervals greater than five feet.

At gaps, dip sections, and end approaches the protective coverboard shall be maintained at the standard height above the top of the running rail and shall not drop with the end approach. The protective coverboard shall extend a minimum of 12 inches beyond the tip of the end approach.

At expansion joints, a special section of protective coverboard shall be required to accommodate rail expansion and contraction of up to twice the movement range of the contact rail Expansion Joint Assembly with no gaps in the protective coverboard.

### 2.2.5 CONTACT RAIL SUPPORT INSULATORS

The contact rail shall be supported, intervals no greater than 10 feet, by post type insulators of wet process porcelain, fiberglass or other MDT approved
design using materials which provide the performance requirements of the contact rail, support insulator, and coverboard system.

When calculating thermal movements of the contact rail for locating insulators supports for end approaches and dipped sections the Designer shall address the bi-metallic composition of the contact rail. The design temperature range shall be from 25 degrees F to 146 degrees F.

Support insulators shall be designed to meet MDT and industry standards for arc resistance, dielectric strength, water absorption, flammability, flame resistance, heat distortion, impact, strength and electrical tracking.

The contact rail seat area of the support insulator shall consist of low friction materials to minimize weak areas due to contact rail movement.

2.2.6 CONTACT RAIL EXPANSION JOINTS

All sections of continuous contact rail, unless otherwise approved by MDT, shall be connected together by expansion joints. The design of the expansion joint assembly shall be submitted to MDT for approval. The preferred configuration consists of a short section of contact rail (Expansion Joint Center Section) beveled on both ends between two short sections of contact rail (Expansion Joint End Sections) which are beveled on the inner end adjacent to the Expansion Joint Center Section and the outer end will have a normal joint suitable for joining to the contact rail. See Figure 2-5 in Appendix A for additional information. The expansion joint assembly will contain the Expansion Joint End Sections and Expansion Joint Center Section but allow longitudinal movement of the Expansion Joint End Sections. Unless
otherwise approved by MDT, the total range of thermal movement of the expansion joint shall be 5 1/8 inches.

The bevel section and the expansion joint assembly shall be designed for the maximum thermal movement. At the extreme cold temperature, the opposite ends of the bevels shall provide a gap not greater than 1 inch, as the contact rail shoe transitions from the bevel of the Expansion Joint End Section to the bevel section of the Expansion Joint Center Section. The expansion joint assembly shall be designed to permit both End Sections to slide within the expansion joint assembly over the total range of thermal movement.

The Center Section shall be supported by an insulator and shall be anchored to the guideway by two single rod anchors consisting of an anchor plate and one rod located on each side of the Center Block. The maximum force required to initiate movement at both ends of the Expansion Joint Assembly shall be no greater than 20 percent of the service capacity of one single rod anchor.

A minimum of six jumper cables of equal length shall span the entire expansion joint assembly using the same attachment mechanism specified for feeder cables.

When calculating thermal movements of the contact rail in order to locate expansion joints and to determine the total movement needed to be addressed in the design of the expansion joint assembly, the Designer shall address the bi-metallic composition of the contact rail. The temperature range shall be from 25 degrees F to 146 degrees F.
(Commentary: The coefficient of expansion for steel is .0000065 inches per inch per degree F or .000078 inches per foot per degree F. The coefficient of expansion for aluminum is .0000133 inches per inch per degree F or .00016 inches per foot per degree F. Over a 500 foot distance and 121 degree F temperature range the amount of movement is 4.72 inches for steel and 9.68 inches for aluminum. The exact amount of movement for a bimetallic contact rail system is somewhere between these values and is a function of the cross sectional area of the rolled or extruded aluminum sections, the modulus of elasticity for aluminum and the same data for the 85# ASCE rail section. If the bimetallic contact rail system is similar to the Stage I system, the designer can assume that the thermal movements of the bimetallic contact rail system will be 25% more than the thermal movements of the base rail steel. The Stage I composite contact rail has 8.33 square inches of steel and 7 square inches of aluminum. Using a modulus of elasticity of 29 ksi for rail steel and 11.4 ksi for aluminum provides a composite coefficient of thermal expansion of .0000972 inches per foot per degree F. Combining this information with the total movement capacity of 5 1/8 inches in the expansion joint assembly yields an expansion joint spacing of 870 feet. (Thermal movement in inches = 435 feet * 121 degrees * .0000972 = 5.12 inches).

2.2.7 CONTACT RAIL ANCHORING
All sections of contact rail, unless otherwise approved by MDT, shall be anchored to the guideway to restrict the movement of the contact rail to movement caused solely by thermal forces and restraint. Unless otherwise approved by MDT, the maximum length of contact rail, which has end approaches on each end, shall be 870 feet. The maximum length of contact rail, which has expansion joints on one or both ends, shall be determined by the Designer based upon the thermal expansion characteristics of the contact rail.
rail and the ability of the expansion joint assembly to accommodate the thermal movements. The anchoring system shall be located equally distance from the adjacent expansion joints or end approaches. The anchoring system shall use two anchors. Each anchor shall have a center plate with two tie rods, one in each direction, bolted to the contact rail. The two anchors shall be located as close together as practical. All anchors shall be electrically isolated from the guideway structure.

2.2.8 CONTACT RAIL FEEDER and JUMPER CONNECTIONS

Connections to the contact rail for positive feeders shall be suitably designed, located and attached to the rail to provide permanent connection without excessive protrusion from the side of the rail. The permanent connection shall consist of a exothermically-welded copper clip designed such that the positive feeder can be bolted to the clip from either direction. Cable splices and terminations shall be insulated with 2 kV heat shrink tape insulation system and water proofing capability.

The Designer shall review and follow the Stage I configuration requirements provided in the commentary below except that the design shall confirm the number and size of the cables, size of the conduits given the updated insulation requirements. The exact number of cables in parallel for each positive feeder and negative returns shall be determined by analysis, based on the computer simulations, for each specific site.

All positive feeders or jumper cables connecting to the contact rail, at end approach, expansion joints or other locations shall be designed to be supported and insulated from the guideway structure, installed in non –
metallic raceways with appropriate provisions to prevent stressing and chafing of the cables from the movements of the contact rail system.

A minimum of two equal length jumper cables shall be used to connect short sections of contact rail typically used in special trackwork areas where the electrical load is less than the load on the mainline contact rail. A minimum of six equal length jumper cables shall be used to connect all sections of mainline contact rail. The jumper cables shall be connected and protected in the same manner as the feeder cables.

To the maximum extent possible, all exposed grounded metal surfaces on the guideway in close proximity to the feeders and 750 Vdc jumpers shall be insulated with a non conductive material. The intent is to mitigate damage that may occur if a broken or damaged positive or negative dc feeder comes in contact with a metallic element which may be intentionally connected to ground or is likely to be connected to ground via fasteners or by indirect but conductive paths. If the cabletray is metallic and intended to be also used as a walkway, only the sides and bottom shall be covered.

**Commentary:** The Stage I system generally applied the following approaches for feeder configuration. At locations with a four dc breaker configuration, each of the four contact rail positive feeder positions was designed for nine 750 MCM cables positive feeders from the TPSS to the pothead. Each Positive feeder has Four - 4 inch conduits with three of the conduits equipped with three feeder cables in each and one conduit being an empty spare. Therefore a typical Stage I, 4 breaker location consisted of sixteen 4 inch conduits for the positive and eight conduits for the negative. A typical Stage I installation would have 24
conduits of which 6 would be spare conduit. All cables were required to be run to a pothead style connection. For the positive voltage, each Pothead contained 3-750 MCM cables from the TPSS and 2-777 MCM jumper cables to the contact rail.

2.2.9 CONTACT RAIL LOCATIONS

Except at special trackwork, the locations of contact rail on the main line generally will be as follows:

A. Through stations - opposite side of the track from the platform

B. Aerial
   1. Closely spaced tracks (14.5 feet centers)-outside of the two tracks
   2. Widely spaced tracks - opposite side of the track from the walkway

C. At grade - outside of the two tracks
2.3 NEGATIVE RETURN SYSTEM

2.3.1 GENERAL

Both running rails of each mainline track will be used as negative conductors for the traction power system. The entire conductor system, including the positive contact rail, the negative running rails, and associated cable connections, will be capable of establishing and maintaining voltages within the limits of the maximum acceptable voltage drops. Within the interlocking area of the crossovers or pocket tracks, only one running rail will be used for negative return and the other running rail will be the signal rail. Single rail negative return conductors are also used in the yard storage tracks.

Running rails shall be insulated from the road bed and insulated track fasteners shall be used. Track ballast shall be clean, dry and well-drained and shall not contact the running rails.

2.3.2 RUNNING RAIL EQUIPMENT

The running rails for mainline operation shall be 115 pounds per yard RE section. The rails shall have a resistance of not more than 9.04 microohms per foot at 86 degrees F. The rails shall be welded in continuous lengths. At locations requiring insulated joints, the traction power direct current continuity of negative rails shall be maintained by use of impedance bonds and jumper cables. Sufficient cross bonds shall be provided to assure utilization of the four running rails in parallel. Cross bonding of the rails shall be coordinated with train control requirements but shall be spaced no greater than 1,500 feet.

2.3.3 CONTACT RAIL NEGATIVE RETURN CONNECTIONS

Commentary: In the Metrorail stage 1 design for the negative return cables, nine 750 MCM negative return cables are bolted to a copper
plate on the guideway near the outside running rail at a location between the nearest pair of impedance bonds. The 750 MCM center tap conductors of the two impedance bonds are brought to the copper plate and bolted in place. The other two 750 MCM conductors of each impedance bond are cad welded to the inside of each running rail. The same is done on the other track. All connections to the copper plate are bolted in place for removal if necessary.

For the extension design, connections to the running rail for negative return cables shall be suitably designed, and located. The exact number of cables in parallel for each positive feeder and negative returns shall be determined by analysis, based on the computer simulations, for each specific site.

The cables would be bolted to a copper plate near the outside running rail. The center tap conductor of the impedance bonds are then bolted to the same plate. The cables and mounting plates shall be isolated from the guideway deck.

All negative return cables shall be placed to the maximum extent possible inside non metallic conduits. Where the negative return cables are exposed, they shall be protected from damage due to rubbing along the guideway surface.
2.4 POWER RAIL SECTIONALIZATION

2.4.1 GENERAL

Sectionalization of the contact rail system shall be utilized to allow power to be removed from track zones for maintenance, emergency purposes, reliable fault detection and for possible future route expansion. These shall be achieved by providing gaps in the contact rail wherever crossovers, turnouts or pocket tracks and grade crossings for access roads (maintenance and emergency) are provided in the running rail. If gaps located at these points are not sufficient to permit reliable fault detection and protective relay operation, additional gaps (controlled isolation sections or CIS) shall be provided. Such gaps shall be coordinated with substation locations insofar as practical to reduce the requirements for remote gap tie stations.

The Designer shall make an effort to minimize the length of the power feeders from the TPSS to the power rails. It is assumed TPSS locations and special trackwork will be in close proximity to each other.

See Figures 2-6 and 2-7 in Appendix A, for example configurations of crossover electrification at special trackwork locations.

2.4.2 SECTIONALIZING METHODS

Contact rail sectionalizing shall be made by bridgeable gaps.

The bridgeable gap consists of one gap in the contact rail dimensioned so that the gap can be bridged by the front and rear collector shoes of the vehicle.
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APPENDIX A
FIGURE 2-1
FIGURE 2-2
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FIGURE 2-6
FIGURE 2-7