**TABLE OF CONTENTS**

**4.0 UTILITIES....6**
4.1 PRE-CONSTRUCTION....6
4.1.1 Approval Process....7
4.2 CONFLICTING UTILITY DESIGN CRITERIA....8
4.2.1 Gas Lines....8
4.2.2 Sanitary Sewer....8
4.2.3 Storm Sewers....9
4.2.4 Electrical Power Facilities....9
4.2.5 Telephone Communications Facilities....9
4.2.6 Water 9
4.2.7 Street Lights and Traffic Signals....10
4.2.8 Parking Meters....11
4.2.9 Private Vaults....11
4.2.10 Overhead Utility Lines....11
**5.0 STRUCTURAL....14**
5.1 GENERAL....14
5.2 APPLICABLE CODES AND STANDARDS....14
5.3 LOADS AND FORCES....14
5.3.1 Dead Loads....15
5.3.2 Live Loads....15
5.3.3 Other Loads and Forces....15
5.4 SOILS 16
5.5 REINFORCED AND PRE-STRESSED CONCRETE....16
5.6 STRUCTURAL STEEL....16
5.7 FOUNDATIONS....16
**9.0 MAINTENANCE AND STORAGE FACILITY....18**
9.1 GENERAL....18
9.2 APPLICABLE CODES AND STANDARDS....18
9.3 MATERIALS....19
9.3.1 Exterior....19
9.3.2 Interior 19
9.4 FUNCTIONAL REQUIREMENTS....19
9.4.1 Streetcar Shop Functional Requirements....20
9.5 SITE 21

9.5.1 Selection ..... 21
9.5.2 Planning ..... 21
9.6 ELECTRICAL SERVICES ..... 21
9.7 INTERIOR LIGHTING ..... 22
9.8 ACOUSTICS ..... 23
9.9 MAINTENANCE ..... 23
9.10 MECHANICAL SYSTEMS ..... 23
9.11 SECURITY ..... 23
9.12 CORROSION CONTROL AND SAFETY GROUNDING ..... 23
9.13 FIRE PROTECTION SYSTEM ..... 24
9.14 CENTRAL MAINTENANCE, OPERATIONS AND ADMINISTRATIVE AREAS ..... 24
9.15 STREETCAR WASH FACILITIES ..... 24
9.15.1 Exterior Streetcar Wash Facility ..... 24
9.15.2 Interior Cleaning Area ..... 24
9.16 STORAGE ..... 25
9.16.1 Yard 25
9.16.2 Outside Storage Areas ..... 25
9.17 AUTOMOBILE PARKING AND ON-SITE ROADS ..... 25
9.18 ACCESS FOR THE MOBILITY IMPAIRED ..... 25
9.19 YARD LIGHTING ..... 25
9.20 REFUSE/RECYCLING COLLECTION ..... 26
9.21 LANDSCAPING ..... 26
**10.0 TRACTION POWER SUPPLY & DISTRIBUTION ..... 28**
10.1 GENERAL ..... 28
10.1.1 Definitions ..... 28
10.1.2 System Description ..... 28
10.1.3 System Load Flow Simulation ..... 28
10.1.4 Design Parameters ..... 29
10.1.5 Design Environment ..... 29
10.1.6 Codes and Standards ..... 29
10.1.7 Integration into Systems and Operating Plan ..... 30
10.2 TRACTION POWER SUBSTATIONS ..... 30
10.2.1 Substation Description ..... 30
10.2.2 Substation Structure or Enclosure ..... 30
10.2.3 Substation Foundation ..... 31
10.2.4 Substation Spacing and Location ..... 31
10.2.5 Substation Equipment Rating ..... 32

10.2.6 Substation Incoming Service ..... 32
10.2.7 AC Switchgear ..... 32
10.2.8 Rectifier Transformer ..... 32
10.2.9 Rectifier ..... 32
10.2.10 DC Switchgear Assembly ..... 33
10.2.11 Negative Return ..... 33
10.2.12 Protective Devices ..... 33
10.2.13 Emergency Trip Stations ..... 33
10.2.14 Local and Remote Control and Annunciation ..... 33
10.2.15 Auxiliary Power ..... 34
10.2.16 Busbars and Bus Connectors ..... 34
10.2.17 Miscellaneous Equipment ..... 34
10.2.18 Equipment Arrangement ..... 34
10.2.19 Substation Grounding ..... 34
10.2.20 Underground Distribution Feeders ..... 35
10.2.21 Metals and Finishes ..... 35
10.2.22 Site Improvements ..... 35
10.2.23 Noise Levels ..... 35
10.2.24 Control and Indications ..... 35
10.3 DC FEEDER SYSTEM ..... 36
10.3.1 Feed/Return Cable ..... 36
10.3.2 Cable Ducts and Raceways ..... 36
10.3.3 Lightning Arresters and Surge Arresters ..... 36
10.4 OVERHEAD CONTACT SYSTEM (OCS) ..... 37
10.4.1 General ..... 37
10.4.2 Design Requirements ..... 38
10.4.3 Product Requirements ..... 42
10.5 NEGATIVE RETURN PATH AND STRAY CURRENT CONTROL ..... 43
**15.0 STRAY CURRENT AND CORROSION CONTROL ..... 46**
15.1 PURPOSE ..... 46
15.2 STANDARDS AND CODES ..... 46
15.3 SCOPE ..... 47
15.3.1 General ..... 47
15.3.2 Stray Current Corrosion Control ..... 47
15.3.3 Soil Corrosion Control ..... 47
15.3.4 Atmospheric Corrosion Control ..... 48
15.3.5 Grounding ..... 48
15.4 INTERFACES ..... 48
15.5 APPLICABILITY OF CRITERIA ..... 48

15.6 EXPANSION CAPABILITY ..... 48
15.7 SPECIAL DESIGN PROVISIONS ..... 48
15.8 STRAY CURRENT CORROSION PREVENTION ..... 49
15.8.1 Purpose ..... 49
15.8.2 Scope 49
15.9 STRAY CURRENT CORROSION PREVENTION SYSTEMS ..... 49
15.9.1 Traction Power Substations (TPSS) ..... 49
15.9.2 Electrical Bonding ..... 51
15.9.3 Drainage Facilities ..... 52
15.9.4 Test Facilities ..... 52
15.9.5 Quality Control ..... 52
15.10 SOIL CORROSION CONTROL OF BURIED STRUCTURES ..... 52
15.10.1 General ..... 52
15.10.2 Scope ..... 53
15.11 SOIL CORROSION PREVENTION SYSTEMS ..... 53
15.11.1 General ..... 53
15.11.2 Materials and Structures ..... 53
15.11.3 Coatings ..... 55
15.11.4 Electrical Insulation ..... 55
15.11.5 Electrical Continuity ..... 56
15.11.6 Cathodic Protection ..... 56
15.11.7 Test Facilities/Testing ..... 56
15.11.8 Water Treatment ..... 57
15.12 ATMOSPHERIC CORROSION PREVENTION ..... 57
15.12.1 General ..... 57
15.12.2 Scope ..... 57
15.13 ATMOSPHERIC CORROSION PREVENTION SYSTEMS ..... 58
15.13.1 Materials ..... 58
15.13.2 Coatings ..... 58
15.14 GROUNDING ..... 59
15.14.1 Purpose ..... 59
15.14.2 Scope ..... 59
15.15 DESIGN AND COORDINATION OF GROUNDING SYSTEMS ..... 59
15.15.1 Aerial OCS Structures ..... 59
15.15.2 Traction Power Substations ..... 60

**THIS PAGE INTENTIONALLY LEFT BLANK**

# 4.0 UTILITIES

Design criteria for utilities shall be based on KCMO Utility Relocation Guidelines, and shall govern the planning and design of maintenance, support, restoration, abandonment, reconstruction, removal and construction of utilities encountered or affected by construction of the streetcar system.

Utilities design criteria shall be coordinated with, and in compliance with, the requirements of the municipalities, utility owners, and the applicable codes, regulations, and policies as established by, but not limited to, the Kansas City Missouri Building Code, the City of Kansas City Missouri, Missouri Water Services Department, and Jackson County Unified Development Code. The following is a list of both public and private utility companies to be affected by the construction of the streetcar project.

Public utility agencies:

- Jackson County Storm Water Commission
- City of Kansas City Missouri Water Services Department (KCMO WSD)
- Missouri Department of Natural Resources- Division of Environmental Quality

Private utility agencies:

- Kansas City Power & Light (KCP&L)
- Aquila
- Missouri Gas Energy (MGE, natural gas)
- Comcast
- SureWest
- AT & T
- Time Warner
- Birch Telecom

## 4.1 Pre-Construction

The objective of pre-construction activities is to ensure that pertinent utility information is obtained, properly incorporated into the design process, and shown on engineering plans. Information to be acquired includes owner, type, size, material, location, and existing right-of-way (ROW) of all existing and proposed utility facilities affected by the streetcar construction, and the disposition of existing and proposed facilities within the project limits.

The streetcar trackway will likely be in conflict with underground and above ground utilities at many locations along the proposed route. During planning and early engineering phases, designers shall seek to place the trackway to avoid impacting existing utilities as much as practical. However, not all impacts can be avoided, and once a conflict is identified, the designer and KCMO shall decide a course of action to mitigate the impact to the utility. Impacts include the influence of stray current on metallic utilities, conflicts with streetcar-related facilities,

such as OCS poles, and changes in access to the utility due to the trackway. Mitigation strategies shall be developed according to the KCMO Utility Relocation Guidelines.

The following information shall be clearly and correctly identified on the final construction drawings:

- Utilities that are to be protected in place, supported and maintained during construction and continued in service following construction of the streetcar system.
- Utilities temporarily relocated and maintained, then restored upon completion of the streetcar system.
- Utilities permanently relocated beyond the immediate limits of streetcar construction.
- Utilities that have been abandoned, or are to be abandoned and removed.
- Utilities that are to be abandoned in place.
- Utilities that are to be removed.
- Existing utility ROW and properties to be acquired for their relocation, if any.

Existing utility service shall not be interrupted and, if temporarily relocated, shall be restored upon completion of work to the original condition or better. Replacements for existing sewers or water mains shall be designed to provide service equal to that offered by the existing installations. Designers must bring any proposal for betterment to the attention of KCMO at an early stage of the design. No betterments shall be included unless specifically approved by the utility owner or public agency and KCMO prior to final design.

### 4.1.1 Approval Process

The horizontal and vertical alignments, ROW and construction easements of the streetcar system and affected roadways, and the necessary property lines adjacent to the ROW will be indicated in the final construction documents. As the design is developed, the affected utility companies will be furnished with preliminary plans and specifications.

Design drawings prepared by the utility companies shall be reviewed and approved by KCMO and the design consultant. All utility relocation plans shall be reviewed by the design consultant prior to final submittal to KCMO for final permitting. The review shall consider space reservations for utility work to be completed during final streetcar system work.

The utility company design drawings shall be consistent with any work authorization estimates and compatible with the work of other utility agencies. Pertinent utility elevations and locations shall be checked by field survey and potholing (subsurface utility engineering, or SUE). Plans being developed by others in adjoining areas shall be checked to ensure that the overall utilities systems will be comparable to those existing before start of construction and that they will be compatible with the streetcar system.

New construction and the support, maintenance, restoration, rearrangement, and relocation of utilities shall be in strict conformance with the latest technical specification and practices of the governing utilities or public agencies.

Standard specifications and standard utility drawings for the various utilities shall be incorporated into the contract documents as required. In the event that there are no standards, final design shall be in accordance with the current design criteria and engineering practices for

the particular utility agency involved. Satisfactory completion of the work and its acceptance shall be signified through sign off by the responsible utility or agency.

Utility coordination meetings are encouraged and may be requested by utility owners to exchange information and resolve potential conflicts with the design engineer and KCMO.

## 4.2 Conflicting Utility Design Criteria

### 4.2.1 Gas Lines

Permanently relocated gas lines shall be designed, installed, and tested in accordance with the current standards used by the utility owner (MGE for this project), and will follow:

- "Minimum Federal Safety Standards for Gas Lines, Title 49 Codes of Federal Regulations, Part 192."
- "ASME Guide for Gas Transmission and Distribution Piping Systems" of the American Society of Mechanical Engineers' Gas Piping Standards Committee.

Construction of temporary and/or permanent gas mains and replacement of mains will be evaluated by the utility owner company and KCMO on a case-by-case basis. The design consultant will consider and recommend the most efficient of options for the project. Gas lines that are to be supported and protected in place shall be identified by the utility owner.

Pipe installed within the limits of the streetcar guideway shall be designed to support the dead loads imposed by earth, sub-base, embedded track section, and vehicular loads when the pipe is operated under a range of pressure from maximum internal to zero. General specifications of the pipe parallel to the guideway should be 5 feet outside the edge of the guideway where possible. Pipe crossing the guideway shall have 42” of cover and be designed to support the loads imposed by earth, sub-base, embedded track section, and vehicular loads when the pipe is operated under a range of pressure from maximum internal to zero. Pipe crossing the guideway shall be sleeved to a distance of 10 feet from the track centerline when possible.

Steel carrier pipe shall be protectively coated and provided with a cathodic protection system in conformance with the corrosion control requirements of the "Minimum Federal Safety Standards for Gas Lines, Title 49 Code of Federal Regulations, Part 192, Subpart I” and the current standards of the utility owner.

All cathodic protection test points shall be a minimum of 5 feet outside the edge of the guideway. Pipe that is crossing the guideway should have cathodic protection test points on both sides of the guideway, with a minimum of 5 feet outside the edge of the guideway as directed by the utility owner and KCMO.

A mandatory preconstruction field meeting will be required prior to the start of any major gas line relocation project; attendees should include, but are not limited to, KCMO Inspector, the construction contractor, the traffic control manager, and the utilities manager for the streetcar project.

### 4.2.2 Sanitary Sewer

Relocations, replacements, or extensions of existing sanitary sewer systems serving other than the streetcar facilities shall comply with all federal, state and local standards; shall be approved by the City of Kansas City Mo. Water Services Department; shall be designed to the criteria of

the governing municipality or agency as well as criteria set forth by the Kansas City, Mo. Water Services Department; and shall conform to the following Kansas City Metropolitan Chapter of the American Public Works Association requirements:

- General specifications of the pipe parallel to the guideway should remain 10 feet outside the edge of the guideway when possible. Pipe parallel to the streetcar guideway shall be evaluated by KCMO WSD as to its condition and ability to remain in place or be relocated on a case-by-case basis. Pipe crossing or installed parallel to the guideway shall be designed to support the loads imposed by earth, sub-base, embedded track section, and vehicular loads.
- All cathodic protection test points (when required), manholes, and access points shall be a minimum of 5 feet outside the edge of the guideway. For sewer pipes crossing the guideway that require cathodic protection, test points shall be located on both sides of the guideway, with a minimum of 5 feet horizontal clearance from the outside the edge of the guideway.
- Sanitary sewer service to adjoining properties shall be maintained at all times by supporting in place, by providing alternate, temporary facilities, or by diverting to other points.
- Construction of permanent relocations, and temporarily relocated and restored sewer lines requiring support and maintenance in place shall be the responsibility of the contractor.

### 4.2.3 Storm Sewers

Existing storm sewer pipes parallel to the guideway shall be evaluated by KCMO as to their condition and ability to remain in place or be relocated on a case-by-case basis. Existing manholes shall be evaluated for conflicts with the streetcar guideway and relocated as necessary to provide access to existing pipes.

### 4.2.4 Electrical Power Facilities

All design work, maintenance, and relocation efforts, of underground and above-ground electric lines throughout the streetcar corridor shall be in strict conformance with current practices of the power company, the requirements of the Electrical Code of the responsible jurisdictions and agencies and the National Electric Safety Code (NESC).

### 4.2.5 Telephone Communications Facilities

Relocation design and support of existing telephone communication lines during construction of the streetcar shall be in strict conformance with the current practices of the telecommunications industry and under the terms of their franchise agreement with KCMO.

Declaration and identification of Prior Rights, equipment easements, private easements and public easements shall be the responsibility of the utility owner.

In the event of a required relocation, the relocating utility shall notify other utilities of the proposed new alignment to explore opportunities for a joint trench effort.

### 4.2.6 Water

Relocations and rearrangements of existing water mains impacted by streetcar construction shall comply with applicable Federal, State, and local standards and the standards of ANSI, AWWA and regulations of the Kansas City Metropolitan Chapter of the American Public Works Association Section 2900 standards; and shall be designed to the criteria of the Kansas City

Metropolitan Chapter of the American Public Works Association Section 2900 standards, and Missouri Department of Natural Resources- Division of Environmental Quality.

### 4.2.7 Street Lights and Traffic Signals

All relocations (temporary or permanent) and maintenance of municipal street lights and traffic signal equipment shall be in accordance with the requirements of the governing owner agency and/or municipality. The combined resultant of both the existing lighting elements to remain and any proposed replacement lighting elements will be evaluated to meet or exceed City of Kansas City, Mo/Jackson County Lighting Design Criteria.

The street and traffic lights are usually either served by cables located in ducts, municipally owned, or wires on poles of the owner utility company.

Existing lighting in conflict with proposed improvements will be removed and new lighting installed. All other lighting will be protected in place. The contractor shall maintain street lights and traffic signal equipment during construction. The contractor shall provide temporary traffic signals which may be required as a result of streetcar system construction operations in accordance with Chapter 14, Traffic, and the consent of the utility owner.

It is anticipated that the existing underground power distribution for the existing roadway lighting will remain intact. In locations where new lighting is proposed, new underground power distribution for lighting will be proposed and new points of service established with the power service company. The power distribution system for lighting will remain independent of the OCS designed for streetcar propulsion.

All traffic signal modifications and new installations will conform to KCMO design standards, National Electrical Safety Code (NESC), and the *Manual on Uniform Traffic Control Devices* (MUTCD). A minimum 4-foot clearance will be required between any traffic signal face and the overhead streetcar conductor, in order to meet NESC and OSHA safety requirements. It is recommended that new traffic signal installations use a pole and mast arm configuration as opposed to span wire wherever possible for consistency with existing traffic signals and City standards.

Traffic signal system design will include the following:

1) Existing signal equipment will be re-used and incorporated into new designs wherever possible, with new equipment only used where required as a result of the streetcar impacts.

2) Traffic signals will be a pole and mast arm configuration, generally consisting of a pole-mounted signal head and a single signal head on the mast arm, supplemented by a far-left signal head where necessary to meet MUTCD cone of vision requirements.

3) At existing traffic signals and All Way Stop Controller (AWSC) locations, existing poles, mast arms, and underground infrastructure will be incorporated into the design of new traffic signals where feasible and cost-effective. The design team will evaluate each affected pole and mast arm during the design process.

4) At existing traffic signal and AWSC locations, existing electrical points of service will be considered and incorporated into the traffic signal design. New electrical points of service and equipment will only be designed if existing conditions warrant the new service.

5) Height of existing pedestrian lighting on some signal poles will need to be adjusted to accommodate pole-mounted signal heads and pedestrian indications in accordance with MUTCD requirements.

6) Fiber optic conduit and cable will only be installed as directed by KCMO.

7) Existing pull boxes will be utilized where feasible; however, replacement and upsizing of pull boxes will occur at the direction of KCMO.

8) New traffic signal conductors will be pulled through existing conduits where feasible. Existing metal conduits will be replaced with PVC conduits as part of traffic signal modifications.

### 4.2.8 Parking Meters

The governing owner agency/municipality will remove and restore existing meter heads including coin vaults. The contractor will remove, store, and reinstall posts after completion of streetcar construction.

Where stand alone parking vending machines are encountered, KCMO will address removal and reinstalling of equipment. Work by the owner agency/municipality will be at no cost to the contractor unless otherwise indicated in the Contract Documents.

### 4.2.9 Private Vaults

Remodeling, abandonment or other work involving existing private vaults extending from adjoining buildings into public space shall be in strict accordance with rules, regulations and practices of governing municipality which shall include currently applicable Building Codes, Electrical Codes, Plumbing Codes, and the NESC.

### 4.2.10 Overhead Utility Lines

Abandonment, relocation, restoration, maintenance, and extension of existing overhead utility lines, poles, and appurtenances, including service lines to adjoining properties, will be performed by the utility owners in accordance with laws and regulations of the appropriate jurisdiction, utility owners' standards, the NESC, and the appropriate owner utility company or their approved contractor.

Poles supporting overhead facilities may be owned by one party and shared with or rented to others under mutual agreement. Utilities in this joint use arrangement are:

- Electric Cables
- Telephone Cables
- Cable Television
- Railroad Communication Lines
- Police, Fire Alarm and other Government Lines
- Street Lights and Traffic Signals

The designers shall coordinate their efforts with those of the owners to assure that KCMO plans include designs mutually acceptable to the owners and KCMO.

Plans shall denote the general type of service provided by overhead lines in accordance with the symbols of Utility Standard Drawing.

Certain jurisdictions may restrict the use of overhead lines in some areas. The designer shall reflect these requirements in the project design.

Clearances shall be in accordance with the standards adopted by the utilities involved. Those specified in the NESC shall be considered the minimum requirements with respect to the streetcar OCS and structures.

The designer shall evaluate the need for relocation of existing overhead high-voltage electric lines, including transmission lines, due to hazards from the streetcar's OCS system, streetcar route control, or streetcar operations. Findings and recommendations shall be developed and submitted to the appropriate utility agency for consideration and inclusion in the project's files and construction documents.

**This page intentionally left blank**

# 5.0 STRUCTURAL

## 5.1 General

This chapter defines the preliminary structural design criteria and standards for the streetcar line. Structures anticipated include bridges, viaducts, and other miscellaneous structures.

## 5.2 Applicable Codes and Standards

The following codes, manuals and specifications shall be applicable to the design of structures (all publications listed shall be the latest edition unless noted otherwise):

- American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications (hereinafter referred to the AASHTO LRFD Specifications);
- AASHTO Guide Specifications for Design and Construction of Segmental Concrete Bridges;
- AASHTO Guide Specifications for Structural Design of Sound Barriers;
- Missouri Department of Transportation (MoDOT) Bridge Design Manual;
- AREMA Manual for Railway Engineering (hereinafter referred to as the AREMA Manual);
- International Code Council (ICC);
- International Building Code (IBC);
- American Concrete Institute (ACI) ACI 318 Building Code Requirements for Reinforced Concrete (hereinafter referred to as ACI 318);
- American Institute of Steel Construction (AISC) Specification for Structural Steel Buildings (hereinafter referred to as the AISC Specifications);
- Concrete Reinforcing Steel Institute (CRSI) Manual of Standard Practice (hereinafter referred to as the CRSI Manual);
- City of Kansas City Mo. Public Works Design Criteria & Construction Specifications.

## 5.3 Loads and Forces

The load rating method for each structure shall be as follows:

- Delaware Street over I-35/I-70 – Load Factor Rating
- Main Street over I-670 – Allowable Stress Rating
- Main Street Viaduct over the Kansas City Terminal Railway – Load Factor Design

Each bridge shall be load rated at two levels, inventory and operating levels. The general expression for determining the load rating factor of the structure shall be:

$$RF = \frac{\mathrm{C} - (\mathrm{A})\ \mathrm{x}\ \mathrm{D}}{\mathrm{A}(2)\ \mathrm{x}\ \mathrm{L}\ \mathrm{x}\ (1 + \mathrm{l})}$$

Where:

RF = the rating factor for live load to be multiplied by the weight of the rating vehicle in tons to give the rating of the structure

C = The capacity of the member

D = The dead load effect on the member

L = The live load effect on the member

L = The impact factor to be used with the live load effect

A(1) = The factor for dead loads

A(2) = The factor for live loads

### 5.3.1 Dead Loads

The dead load along bridges shall consist of the existing dead load of the basic structure plus an additional superimposed dead load due to a 3.5-inch infill pavement and rail in elastomeric grout. The minimum unit weight of infill pavement shall be the weight of concrete, 150 lb. per cu ft. and the weight of rail which shall be 112 lb. tram rail (112 lb. per yd.)

### 5.3.2 Live Loads

- Structures subject to streetcar loading shall be designed for the vehicle loading for the selected modern streetcar. The total live loading is based on vehicle weight plus maximum passenger crush load.
- Structures subject to highway loading shall be designed for HL-93 truck loads.
- The dynamic load allowance shall be in accordance with the AASHTO LFRD Standard Specifications for highway bridges (30 percent maximum) applied to the streetcar and MoDOT rating vehicles.
- The distribution of live loads shall be the number of traffic lanes to be loaded and corresponding distribution factors shall be in accordance with the AASHTO LFRD Standard Specifications for Highway Bridges. As well, a reduction in load intensity for additional lanes loaded shall follow the same criteria.

### 5.3.3 Other Loads and Forces

Other loads and forces (i.e., wind, thermal, longitudinal, centrifugal, shrinkage, etc.) on structures shall be as follows:

- Structures subject to streetcar or highway loading: AASHTO LRFD Specifications;

- Structures subject to railroad loading: AREMA Manual;
- Other structures: International Building Code.

## 5.4 Soils

The soils in the Kansas City area vary widely. Soil and geologic data for the preliminary design of structures shall be site specific data.

## 5.5 Reinforced and Pre-Stressed Concrete

The rating of pre-stressed concrete members at both Inventory and Operating level shall be established using strength requirements of the AASHTO LFRD Standard Specifications. In addition, at Inventory level, the rating must consider the allowable stresses at service load as specified in the AASHTO Standard Specifications.

The compressive strength of existing concrete members shall be taken from the original bridge design Plans.

## 5.6 Structural Steel

Structural steel structures shall be designed in accordance with the requirements of the following:

- Structures subject to streetcar loading: AASHTO and AISC;
- Structures subject to railroad loading: AREMA Manual;
- Structures subject to highway loading: AASHTO and Mo Standards;
- Buildings and other structures: IBC and AISC Specifications.

## 5.7 Foundations

Foundations for structures shall be designed in accordance with the site specific soil and geological data as well as requirements of the following:

- Structures subject to streetcar loading: AASHTO LRFD Specifications;
- Structures subject to railroad loading: AREMA Manual;
- Structures subject to highway loading: AASHTO LRFD Specifications and MoDOT Standards.

**This page intentionally left blank**

# 9.0 MAINTENANCE AND STORAGE FACILITY

## 9.1 General

The Maintenance and Storage Facility (MSF) will perform daily and routine inspections, maintenance, on-car repairs, and interior/exterior cleaning of the streetcars. The facility will also serve as a storage and component change-out location and house administrative and operations staff needed to support the streetcar system.

Component rebuild, truck overhaul, body repairs, machine shop work, and sheet metal work will be performed at this location. Major car overhaul and body painting will be accomplished by contracting those services out to other facilities. Wheel truing may be performed at the MSF or be contracted out to other facilities.

The Maintenance and Storage Facility (MSF) must be designed to achieve a LEED for New Construction certification of Gold or higher.

The Maintenance and Storage Facility (MSF) must allow for fleet expansion and development potential.

## 9.2 Applicable Codes and Standards

Design requirements for the shop and yard shall comply with all federal, state, and local laws, regulations, rules, requirements, and the preservation of natural resources as well as all laws, ordinances, rules, regulations and lawful orders of any public entity bearing on the performance of the work. Listed below are the principal applicable codes – their latest editions must be consulted for design:

- International Fire Code (IFC)
- International Building Code (IBC)
- International Energy Conservation Code, and any supplements International Mechanical Code
- International Code Council Performance Code
- Missouri State Plumbing Code
- National Electrical Code (NFPA-70)
- Telecommunications Industry Association/Electronic Industries Alliance (TIA/EIA)
- Underwriters Laboratory (UL)
- Telecommunications Distribution Methods Manual (TDMM)
- Building Industry Consulting Services International (BICSI)ASME A18.1 Safety Code for Platform Lifts and Stairway Chairlifts
- Kansas City, Missouri Building Construction Code - Administrative Provisions
- Federal OSHA requirements
- National Electric Safety Code (NESC)
- Uniform Plumbing Code (UPC)

- American National Standard Code for Elevators
- American National Standards Institute, Inc.
- Americans with Disabilities Act (ADA)
- USGBC/LEED
- US Department of Transportation Transit Security Design Considerations, Final Report November 2004
- Kansas City Zoning and Development Code Guide

## 9.3 Materials

### 9.3.1 Exterior

The exterior materials to be used on the facility are to be selected based on durability, appearance and compliance with KCMO requirements for the development. The goal is to establish a facility that will provide 30 to 50 years of a low maintenance, pleasing appearance and fit in KCMO's plans for the local area.

Where exposed to direct sunlight, energy efficient glass is to be used. Exterior wall and roof areas are to be insulated to meet current energy codes. Roof materials shall be selected based on long-term durability and appearance.

### 9.3.2 Interior

The emphasis on material selection for the interior of the facility is on durability and low maintenance.

Finishes should be as follows:

- Sealed concrete floors in shop areas and storage rooms;
- Wall areas in shops shall have a minimum 8 foot high concrete or concrete block wainscoting. Alternatively, if a pre-engineered building is selected, provide a minimum 8' high plywood wainscoting;
- Office areas shall be 3 5/8 inch metal studs and 5/8 inch gypsum-board construction with sound batt insulation. Ceilings shall be acoustical ceiling tile with regress trim for 70% of the facility; the remainder shall be gypsum wallboard. Offices shall be carpeted. Sound insulation shall be provided between adjacent office spaces;

Toilet/shower areas shall have ceramic tile floor and wall finishes to 6 feet above finished floor.

## 9.4 Functional Requirements

The MSF shall house the following functions:

- Streetcar storage and streetcar parts storage;
- Operator report and break area;
- Operator and maintenance training;
- Streetcar service and inspection;

- Streetcar interior and exterior cleaning;
- Streetcar air-conditioning, current collector and resistor unit repair;
- Facilities maintenance;
- System-wide parts storage;
- Streetcar operations administration;
- Streetcar maintenance administration;
- Local Central Control;
- Electronic component repair;
- Communications equipment repair, storage and inspection;
- Storage of streetcar maintenance-of-way (MOW) materials.

### 9.4.1 Streetcar Shop Functional Requirements

The following general streetcar maintenance functional requirements have been established for the shop, and shall dictate the types of service and repair facilities to be provided:

- Service, remove and replace car pantograph assemblies
- Service, remove and replace car HVAC units
- Exchange of trucks
- Exchange of defective components with new or rebuilt parts
- Streetcar modifications
- Repair of miscellaneous system equipment and components
- Running repair
- Periodic maintenance
- Air-conditioning unit secondary maintenance and overhaul
- Safety inspections
- Interior and exterior cleaning
- Sand box filling
- Loading/off-loading equipment to/from rail bound equipment, if applicable
- Wheel and component replacement on axles
- Minor paint and body repair
- Tire replacement on wheels

## 9.5 Site

### 9.5.1 Selection

Site selection criteria include the following:

- Site Size: The MSF site shall be of sufficient size to permit the construction of the facilities necessary to support the initial and ultimate revenue service, fleet sizes, and maintenance functions for the planned streetcar system.
- Site Location: The selected sites shall be located to provide convenient access to the main line with a minimum of deadhead mileage. The site selection process shall include consideration of land use, zoning, adjacent properties, land acquisition, adaptability, configuration, clearing/grading, drainage, existing utilities, and construction costs.
- Environmental Impact: The selected sites shall comply with all environmental requirements minimizing the negative impact on adjoining land. Considerations shall include air and noise pollution, traffic, aesthetics, social, economic, and safety.
- Site Configuration: Configuration of the Yards and Shops shall permit a functionally efficient layout to provide vehicle storage and work flow that minimizes streetcar and personnel movement requirements. The site should be level in order to store and maintain streetcars without the danger of a car rolling down any grades on the site or toward the main line. The site should accommodate positioning of the shop and yard trackwork in such a manner to preclude entrapment of cars from access to the storage yard, shop, or mainline.

### 9.5.2 Planning

The MSF layout shall include:

- Open Yard
  a. Streetcar storage;
  b. Streetcar exterior wash area
  c. Automobile parking, service and access roads
  d. Outside storage area for MOW and traction power equipment
  e. Fire protection system
  f. Yard Lighting
  g. Security fences and gates
  h. Refuse collection locations
  i. Landscaping
- Streetcar Maintenance of Equipment Shop
- Operations Administration Offices

## 9.6 Electrical Services

A separate Traction Power (TPSS) substation shall be provided for the shop with shop tracks electrically isolated from the yard and mainline tracks. KCP&L will provide service to the new TPSS via an underground primary service located as close as possible to the TPSS. Overhead

wire in the yard and over the individual shop car positions shall be sectionalized to allow the shutdown of power to the individual car positions in the shop and tracks in the yard without affecting the remainder of the shop or yard. Individual, lockable, manual disconnects shall be provided for each section isolation switch to remove traction power when required for maintenance. The shop substation will be solidly grounded to the building ground network for safety purposes.

A separate yard substation will be provided, with yard trackage electrically isolated from Maintenance Facility. Refer to the Traction Power Supply and Distribution Chapter.

One hundred twenty volt (120V) single-phase, and 208V 3-phase service shall be provided to operate small HVAC, machinery, office equipment and communication equipment all up to ½ hp. Incandescent and fluorescent lighting shall be 120 V AC for normal lighting and 125 V DC for emergency egress lights. Fluorescent lighting may be 277 V AC. All motors and machinery 3/4 hp and over shall be supplied at 480V, 3-phase.

The TPSS and other transformers shall be screened from view.

An alternate power source shall be provided for the MSF. Required egress lighting, access, data, fire alarm, security, and similarly required systems will be provided with an alternate (backup) power source to support the requirements for such systems.

A Lightning Risk Assessment should be conducted to evaluate the facility's protection against a strike.

## 9.7 Interior Lighting

General light levels shall be as follows:

- Shop Areas 50-70 fc
- Pit Areas 100 fc
- Storage Areas 30 fc
- Office Areas 30-50 fc
- Lobby, Break, Restrooms, Lockers, Stairs, and Corridors 5-10 fc

Lighting for specific task areas is to be located and designed to meet task requirements.

Shop areas shall utilize high bay type fluorescent fixtures.

Energy-saving lighting systems and fixtures shall be used where possible and shall comply with LEED criteria.

Natural light from skylights, windows, and clerestory windows (including those in maintenance bays) shall be maximized to reduce dependence on light fixtures during daylight hours.

Pits shall have lights along both sides aimed upward for under-car lighting with a lens on the bottom for floor lighting.

Emergency egress lighting will be provided per NFPA 101, Life Safety Code requirements.

## 9.8 Acoustics

In planning the new facility, noise- and vibration-generating equipment such as air compressors and pumps shall be located away from office areas and/or acoustically isolated. HVAC mechanical units shall be located and specified so that noise and vibration transmission is minimized. In addition, walls, ceilings, and floors in these spaces shall be insulated to further reduce noise transmission to other parts of the facility.

## 9.9 Maintenance

In planning the new facility, proposed maintenance procedures shall be reviewed and staff operations personnel shall be consulted to ensure that the new facility provides an efficient work environment. Janitorial closest and other maintenance rooms shall be located convenient for users. Floor drains, hose bibs, etc. shall be located for convenience of use.

## 9.10 Mechanical systems

Shop areas shall be heated and cooled. The HVAC system shall be designed in zones. Maintenance pits shall have a section of wall-mounted hot water radiant heat. Pit areas shall have exhaust air ducts at side walls. Shop compressed air shall be available in all pits at convenient intervals to operate tools.

Electronics storage areas shall have a split system A/C to mitigate against excessive humidity levels.

Office, administration, support, and Central Control areas shall have forced air heating, ventilating, and air conditioning systems. The HVAC system shall be designed in zones appropriate for use and exposure to heating and cooling demands. The shop substation electrical room shall be air conditioned and vented with exhaust fans.

## 9.11 Security

Operations facility security shall be achieved by fencing the periphery of the yard, lighting, and video surveillance. The fences shall be in accordance with zoning requirements between 6 and 10 feet in height. Card readers will be on all exterior doors with intrusion door alarm switches. Electronic locksets will be on all exterior and interior doors, with proximity card readers. Gates shall be provided at all yard track and road accesses and shall provide for minimum interference to streetcar movement. Exterior cameras shall be commercial grade and mounted to monitor exterior building entry points. The control room shall be equipped to monitor the video images concurrently. Security lighting shall be placed as necessary to supplement the normal area outside work lighting.

## 9.12 Corrosion Control and Safety Grounding

The maintenance facility shall have an equipotential grounding system for all conductive surfaces exposed to human contact. This shall be accomplished through use of a building perimeter ground. The perimeter ground shall be bonded to ground rods and bonded to the metal structure of the building and reinforcement bars of the concrete. The reinforcing steel of the main shop floor shall be bonded into a grid pattern and all shop conductive surfaces shall be bonded to the grid. The shop trackwork shall be continuous and bonded to the grid. The shop grid and perimeter ground shall be bonded to the shop substation negative return. Insulated rail

joints shall be located in the ends of the concrete aprons, which will define the extent of the shop grounding system and DC electrical system.

In order to minimize the effects of DC stray currents, ferrous pipe shall be coated with an electrical insulating material and tested prior to burial. Some underground services (such as natural gas) may be better served by use of plastic pipe where the code allows. Joints in piping will require bonding in some locations and insulated joints in others. Refer to Chapter 15, Stray Current and Corrosion Control, of these Criteria.

## 9.13 Fire Protection System

Fire protection utilities such as hydrants, sprinklers in the building, and extinguishers shall be provided in accordance with local Fire and Rescue requirements in effect at the time of construction of the facility. The hydrants shall be located so as not to block the movement of streetcars when fire hoses are being used.

A fire sprinkler system shall be provided throughout the building in compliance with jurisdictional requirements. The system shall be of the dry type in areas prone to freezing and a wet system elsewhere. Chemical fire protection for areas such as electrical rooms, communications rooms, flammable storage, etc., may be necessary depending on local jurisdictional requirements. The system shall be held tight to the structure to avoid clearance problems.

## 9.14 Central Maintenance, Operations and Administrative Areas

Space shall be provided for the management of the maintenance shops, operations facilities, and administration. The space should be planned to house an adequate number of staff to operate and maintain the system, and provide coordination with KCATA, KCMO, and other agencies that interface with the streetcar system. A space planning needs analysis shall be conducted in the conceptual phase of the building design program.

## 9.15 Streetcar Wash Facilities

### 9.15.1 Exterior Streetcar Wash Facility

A car position exterior to the building shall be provided for washing the exterior of the streetcars. The car position shall accommodate single streetcars only. Infrastructure shall be provided to capture wash water and direct it to the sanitary sewer or be reclaimed to minimize fresh water use. A roof over the wash area may be necessary to assure that storm water does not enter the sanitary sewer.

### 9.15.2 Interior Cleaning Area

Cleaning of the interior of the streetcars will take place in the yard. This track shall also be used to perform daily and scheduled extraordinary interior cleaning of the streetcars.

## 9.16 Storage

### 9.16.1 Yard

Sufficient storage tracks or space for storage tracks shall be provided to accommodate the ultimate fleet size to be stored and maintained. The storage yard shall be arranged to provide space for all streetcars to be stored on level tangent track. Area around train storage should be level to facilitate safety of workers moving around the cars.

Track centers shall be 12 ft - 0 in minimum where no access aisle is required between tracks and 14 ft - 0 in minimum where a paved access aisle is required. OCS and lighting poles may be located between tracks with 14 ft - 0 in track centers when no access aisle is required.

The layout of the storage yard shall enable movement of streetcars to and from the shop, other yard facilities, and the mainline with the smallest possible number of reverse movements and crossovers, consistent with site space limitations. This shall be accomplished by avoiding the use of stub-end tracks and by proper relationship of yard track orientation to the mainline.

Storage yard tracks shall be ballast type track with a pavement (asphalt or concrete) cap of approximately 4 inches over a geo-tex fabric (like that used in Tampa and in parts of Portland's yard). At a minimum paving all walkways would be necessary, but in order to make the yard useful, paving all tracks is recommended. This is required in order to improve other vehicle access, reduce tripping and falling hazards, and mitigate dust.

### 9.16.2 Outside Storage Areas

Outside storage space is recommended for the storage of the following types of equipment and structures: OCS poles and large OCS hardware, lighting poles, rail, ties, special trackwork (such as switches, switch stands, frogs, etc.), other track materials (such as insulated joints, etc.), and reels of OCS wire. Locations of these types of storage areas shall be coordinated with the City of Kansas City Missouri (KCMO).

## 9.17 Automobile Parking and On-site Roads

Automobile parking shall be provided for visitors and employees to a level adequate to satisfy City requirements. Access for truck deliveries shall be provided.

Service roads and/or aisles shall be provided around the shop and to outside storage areas within the yard.

## 9.18 Access for the Mobility Impaired

The facility shall be designed to meet applicable federal, state and local codes for accommodating access for the mobility impaired in effect at the time of facility design.

## 9.19 Yard Lighting

The yard shall be illuminated to provide a safe working environment for ultimate 24 hour operation of the facility. Yard lighting shall be provided to a level of 2 fc average, 4:1 average to minimum and 9:1 maximum to minimum for the entire site. Lighting shall be shielded so as not to spill on to neighboring properties. Light shall also conform to applicable LEED criteria.

## 9.20 Refuse/Recycling Collection

Refuse/recycling collection bins, dumpsters, etc. shall be provided at several locations convenient to work areas as well as to collection vehicles. Space allocation limitations associated with the shop and yard site may require the transfer of waste and recycled materials from local collection points to a central location.

Certain containers shall be designated for recycling purposes, such as those used for metal waste, and for office waste paper, cardboard, glass, etc.

## 9.21 Landscaping

Landscaping shall be minimal but meet local land use requirements. The amount and type shall be consistent with the local development requirements for the site. Low maintenance ground cover material (gravel, bark dust, etc.) shall be provided on areas of the site not used for structures, track, or access roads and walkways. Water harvesting shall be implemented when appropriate and in coordination with LEED-BD+C guidelines.

**This page intentionally left blank**

# 10.0 TRACTION POWER SUPPLY & DISTRIBUTION

## 10.1 General

This chapter establishes the design criteria for the Traction Electrification System (TES), which includes traction power substations, the DC feeder system, and the Overhead Contact System (OCS).

### 10.1.1 Definitions

Traction power substations (TPSS) are located along the system route and connected to the local power utility company. They include all equipment necessary to transform and rectify AC three-phase voltage to DC electrification voltage.

The DC feeder system (DCFS) includes the ducts, cable and/or overhead connectors from the substations to the trackside disconnect switches and the track rails.

The OCS distributes power supplied from the TPSS to the vehicles. It includes contact wires and their physical support.

### 10.1.2 System Description

The TES configuration shall be of the multiple feed types with DC electrical continuity between substations.

The streetcar vehicle will collect power from the contact wire by means of a pantograph and will complete the negative return path of the power to the substation via running rails. During regenerative braking, power will be placed back into the system via the vehicle pantograph to the OCS.

Mainline and yard tracks will be isolated from ground. The Shop tracks will be solidly grounded.

The traction power supply system shall maintain the distribution system voltage above the minimum allowable value. The OCS shall be designed to allow the streetcar to operate with all pantographs in contact with the conductors up to the maximum allowable speed without excessive oscillations of the system and without pantograph bouncing or arcing.

Traction power and distribution system equipment shall be designed taking into account the effects of the harmonic content of the traction load, the highly fluctuating pattern of traction current, and system faults.

The TES shall be designed for a minimum functional life expectancy of 30 years before major overhaul or complete replacement becomes necessary; assuming that approved maintenance policies are followed.

### 10.1.3 System Load Flow Simulation

The design of the Traction Electrification System shall be based on a computer-aided load flow simulation. The trains shall be simulated to operate on the system for the following schedules:

- Ultimate design capacity assuming the heaviest projected schedule under normal and contingency conditions. The addition of future line extensions shall be considered in the design.

- Minimum Signal System design headway under normal operation and contingency conditions.

- Single-outage condition will be the contingency condition for load flow simulation. Defined as one TPSS out of service at any time.

### 10.1.4 Design Parameters

System Voltages

| | |
|---|---|
| Substation 1% Load Voltage | 795 VDC |
| Maximum System Voltage | 950 VDC |
| Substation Voltage at 100% Load (Full Load) | 750 VDC |
| Regulation | 6% |
| Minimum System Voltage | 525 VDC |

Rail-to-Ground Voltages

| | |
|---|---|
| Maximum Rail-to-Ground Voltage | 50 VDC |

### 10.1.5 Design Environment

The traction power distribution system will be designed to operate continuously and satisfactorily under the environmental conditions described in Chapter 1, General.

### 10.1.6 Codes and Standards

All design work and material selection shall conform to or exceed the requirements of the latest editions of standards and codes issued by the following organizations:

- Association of American Railroads (AAR)
- American Railway Engineering and Maintenance-of-Way Association (AREMA)
- American National Standards Institute (ANSI)
- American Society for Testing & Materials (ASTM)
- Institute of Electrical & Electronics Engineers (IEEE)
- National Electrical Manufacturers Association (NEMA)
- Insulated Cable Engineers Association (ICEA)

- American Society of Mechanical Engineers (ASME)
- Underwriters Laboratories (UL)
- National Fire Protection Association (NFPA)
- National Electrical Testing Association (NETA)
- National Electrical Code (NEC), where applicable
- Applicable State, Local, and County Codes
- National Electrical Safety Code (NESC)
- International Code Council/American National Standards Institute (ICC/ANSI) A117.1.1-03
- Federal Transit Administration Regulation 49 CFR Part 37

### 10.1.7 Integration into Systems and Operating Plan

The traction electrification design shall be coordinated with streetcar civil design, other systems design (vehicles, signals, communication) and the Operating Plan.

## 10.2 Traction Power Substations

### 10.2.1 Substation Description

The TPSS design shall include the following elements: substation housings, AC switchgear, transformer/rectifier units, DC switchgear assemblies, negative return system, protective systems, annunciation, intrusion detection systems and Fire Alarm System, telephone system, auxiliary power supply systems, busbars, grounding systems, ventilation and air conditioning systems, batteries and chargers, lightning arresters, metering equipment and auxiliary power for non traction loads where required.

Substations will be standardized in size and configuration where possible to minimize maintenance, inventory of parts, and to allow for full compatibility and interchangeability of equipment between substations.

### 10.2.2 Substation Structure or Enclosure

The substation equipment shall be housed either in buildings, electrical equipment rooms, or in weatherproof factory-built packaged substation structures.

A paved or concrete sidewalk or ramp at ground level shall be provided outside the substation to allow removal and replacement of heavy equipment.

Steps shall be provided for access to substations.

Substations shall have adequate area to accommodate all the electrical equipment and ancillary components.

Ceiling heights, structural openings, and door openings shall permit entry and removal of the largest components installed in the structure.

Two exit doors with panic hardware, one at each end of the substation, shall be provided.

Insulation of walls, ceilings and floors sufficient to prevent condensation, dust especially from the roof, shall be provided. Insulation may be fiberglass batting in the walls and solid insulation on the roof.

Portions of the substation building floor shall be coated with ¼ inch epoxy material and walls with ¼ inch insulated sheeting to insulate and electrically isolate the dc switchgear from any grounded objects.

Adequate space heating shall be provided to prevent condensation in electrical equipment. Minimum permissible inside temperature is 40° F.

Adequate air conditioning and ventilation shall be provided to prevent damage to the equipment. Maximum permissible inside temperature shall be 90° F.

Lighting levels shall be designed for 50 to 70 foot-candles, average. Emergency lighting shall be provided with 2 foot-candles minimum at floor level for 1.5 hours. Exterior luminaires shall be provided and be photo-electric controlled.

Provide a distribution panelboard for installations that feed other buildings, rooms or a passenger station platform. Provide an ac panelboard for the substation auxiliary equipment, lighting, convenience receptacles, and HVAC.

#### 10.2.2.1 Substation Structural Requirements

Design enclosure in accordance with AISC 303 and 325 and the IBC to withstand live roof loading, wind loading, wind loading, and seismic loading based on service conditions in the Specifications.

### 10.2.3 Substation Foundation

The substation foundation will conform to established civil and structural engineering practices, ASTM and ACI standards as well as other applicable standards and local codes. The foundation design will be coordinated with the electrical design for the incoming and outgoing conduit interfaces. The substation foundation will be capable of withstanding the live and dead loads of the substation equipment during fault conditions as well as normal operation and maintenance procedures.

### 10.2.4 Substation Spacing and Location

Locations shall be based on the System Load Flow Study. Substations shall be located such that the following requirements are met:

- Distribution system DC voltages do not drop below the minimum level required
- Temperatures of distribution system conductors do not exceed the allowable maximum
- Rail voltages do not exceed the maximum permissible values
- Short circuit detection and protection can be accomplished

Locations shall be sensitive to real estate and other cost considerations.

### 10.2.5 Substation Equipment Rating

The continuous rating of substation equipment such as the traction transformer, rectifier, circuit breakers, and cables shall be based on the System Load Flow Study.

Each mainline substation shall be capable of supplying the extra heavy-duty traction power service in accordance with NEMA RI-9.

### 10.2.6 Substation Incoming Service

Incoming primary ac power to the Traction Power Substations will be supplied by the local serving utility. If possible, adjacent traction substations should be supplied from separate utility substations or from different buses of the same utility substation.

### 10.2.7 AC Switchgear

The AC switchgear assembly shall be rated for the utility supplied voltage.

The assembly shall provide the means to deliver, control, and measure the substation power requirements.

The assembly shall be housed in dead-front enclosures containing AC draw-out vacuum circuit breaker, solid state relaying/protective devices, metering equipment, and auxiliary power supply. Drawout switchgear shall be provided to allow removal and testing of the AC circuit breaker when withdrawn from its cubicle.

### 10.2.8 Rectifier Transformer

The rectifier transformer shall be copper wound vacuum pressure impregnated dry-type (VPI), self-cooled Class AA, with the primary voltage to be consistent with utility supply and equipped with five taps, two above and two below nominal voltage with 2.5% between each tap. Provisions shall be included for future addition of fans for increasing the output above the specified base.

The transformer/rectifier shall have overall regulation not greater than 6 percent ± 0.5 percent between 1 percent rated load and 100 percent rated load.

The transformer shall be rated extra heavy traction based on NEMA RI-9.

### 10.2.9 Rectifier

The rectifier shall be of uncontrolled design and naturally convection-cooled. Provisions shall be included for future addition of fans for increasing the output above the specified base.

Each rectifier shall be a complete operative assembly consisting of the rectifier elements, heat sinks, internal buses, connections, fuses, and all other necessary components and accessories.

Rectifier shall consist of full wave bridges providing 6 phase 12-pulse ANSI 31 circuit rectification.

Rectifier for shop substations may be 3 phase 6-pulse rectification.

Rectifier shall be provided with an interphase transformer for 12-pulse ANSI 31 circuit rectification.

### 10.2.10 DC Switchgear Assembly

The DC switchgear assembly shall form a lineup of dead-front metal enclosures.

The DC circuit breakers shall be draw-out, single-pole units.

Main DC disconnecting means shall be provided in each line up. Disconnecting means may be by a circuit breaker or a no-load break switch. The positive and negative switches shall be interlocked to prevent opening or closing of both unless the AC main circuit breaker is open.

Rail grounding devices shall be provided with grounding clamp device.

### 10.2.11 Negative Return

The negative return shall include negative disconnect switches, negative busbar, terminations for negative return cables and other associated equipment.

### 10.2.12 Protective Devices

Based on the magnitude of load, overload, and short circuit currents, a comprehensive protective scheme shall be designed to protect the substation equipment, the feeders, and the OCS, as well as provide back up for the transit vehicle protective devices.

Protective relays shall be high quality solid state utility-type draw-out devices enclosed in rustproof, dust-proof, high-impact cases with test switches.

Protective relays shall be self-resetting and shall have seal-in, hand-resetting targets indicating relay operation.

Relays shall be arranged to be visible, accessible for maintenance, and logically grouped, with devices of related functions located in proximity to each other.

Transfer tripping of substations adjacent to the section where a fault is detected shall be provided.

Annunciation with acknowledge and reset functions shall be provided.

### 10.2.13 Emergency Trip Stations

Each substation shall be equipped with traction electrification emergency trip stations (ETS).

Actuation of the ETS shall trip the incoming AC breaker and DC feeder breakers at the substation.

### 10.2.14 Local and Remote Control and Annunciation

Substations shall be equipped with a local control and annunciation system and provision for a remote control and annunciation system through future SCADA.

Alarm functions shall include at minimum: unauthorized entry, fire and smoke alarms.

### 10.2.15 Auxiliary Power

Each TPSS shall be furnished with a battery charger/eliminator and DC distribution panelboard, which shall be sized to supply all substation control power loads.

Batteries shall be Ni-Cad.

Secondary AC power may be supplied to both the substation facility loads and other loads at the building site. All transformers within the TPSS shall be VPI. Separate AC panelboards shall be provided for substation facility loads and other loads.

The voltage for auxiliary equipment shall be 120/240V, 1-phase, 208Y/120V, 3-phase or 480Y/277V 3-phase and shall be the same throughout the project.

### 10.2.16 Busbars and Bus Connectors

Busbars and bus connections shall be designed to withstand the thermal and mechanical stresses occurring during the specified load cycle and the rated short circuit currents, without damage to the bus, bus supports, or enclosure.

Busbars shall be rigid, high electrically conductive copper.

Busbars shall be adequately insulated and braced with high-strength insulators.

Bus connections shall be bolted and furnished with silver-plated surfaces. Each joint shall have conductivity at least equal to that of the busbar. A minimum of two bolts shall be provided for each bus connection with four bolts for larger busbar joints.

### 10.2.17 Miscellaneous Equipment

Each TPSS will be equipped with appropriate safety equipment such as a fire extinguisher; a blue light station; as well as a tool cabinet furnished with a set of special tools necessary to maintain the equipment.

### 10.2.18 Equipment Arrangement

Spacing and positioning of each item of equipment shall permit maintenance, removal, and replacement of any unit without the necessity of moving other units.

The arrangements of the equipment shall permit doors to be opened, panels to be removed, and breakers to be withdrawn without interference to other units.

Equipment shall be arranged to preserve the maximum amount of space for future growth.

### 10.2.19 Substation Grounding

Each traction power substation shall be provided with a ground mat.

The ground mats shall be constructed of bare copper or “Copperweld” conductors and ground rods exothermically welded together. Pressure connected joints will be considered for special applications.

Grounding connections shall carry the rated short circuit current. Minimum size of grounding conductors shall be 4/0.

Ground mat conductors shall be totally encased in native soil. If possible, a layer of coarse, clean, crushed gravel, free of fines and debris, shall be placed over the soil. A surface layer over the gravel may be asphalt, masonry, or concrete.

The ground mat shall be designed to protect personnel from step and touch potentials, which may arise under substation fault conditions, and to meet the requirements of the IEEE Standard 80. The mat shall be used to solidly ground traction power transformer enclosures, auxiliary power transformer neutrals, building and doorframes, ac switchgear enclosure, and low voltage panels. The ground mat shall be extended 5 feet beyond equipment enclosures and/or metallic fences if provided.

The DC switchgear enclosure, including the rectifier and negative cubicles shall be connected to the substation ground through a high resistance ground relay.

The utility ground conductor shall be grounded to the TPSS station ground mat.
Grounding grid shall be connected to TPSS bus by four individual connections.

Ground electrode resistance shall be 5 ohms or less.

### 10.2.20 Underground Distribution Feeders

Underground distribution feeder cables shall be insulated to 2 kV minimum and sized according to the System Load Flow Study.

### 10.2.21 Metals and Finishes

Exteriors shall be heavy 11 gauge galvanized or galvanneal metal. Interior equipment shall be 11 gauge steel. Equipment and exteriors of buildings shall be coated using polyester triglycidyl isocyanurate.

### 10.2.22 Site Improvements

KCMO will specify the requirements for site layout, building access, pedestrian and maintenance vehicle access, site utility, conduit and cable interface requirements and any site enhancement requirements.

### 10.2.23 Noise Levels

The substation sound level will meet the requirements of codes and standards of local ordinances and industrial norms for equipment of this type.

### 10.2.24 Control and Indications

The TPSS will contain an enclosed self-ventilating local control panel to centralize the local and remote control and indication functions. The control panel will be LED panel type or LCD type, which can include the controls on touch screen. The local control panel will house the annunciator, metering equipment, control switches, and provisions for interfacing with a future SCADA System.

## 10.3 DC FEEDER SYSTEM

The DC feeder subsystem shall include all feeder conductors, jumpers, cable ducts and raceways, and associated hardware that feed the dc power to the OCS, and the return current conductors, rail, and connections to the negative bus in the substation.

### 10.3.1 Feed/Return Cable

DC feed and return cables shall be sized for the anticipated RMS loads. Each circuit shall consist of a number of 250 kcmil copper cables. Cable insulation shall be rated 2 kV minimum. Cable shall be Ethylene Propylene Rubber (EPR) insulated, non-shielded.

### 10.3.2 Cable Ducts and Raceways

Cable ducts and raceways for DC circuits shall consist of one or more PVC conduits, sized for the cables to be installed, protected by a poured concrete duct bank, as appropriate.

Conduit stub-ups, and stub-outs from concrete, shall be galvanized steel, if exposed. PVC is acceptable if the stub-ups and stub-outs are enclosed.

DC positive and DC negative traction power cables shall be shall be fireproofed in all manholes, handholes and switchgear.

### 10.3.3 Lightning Arresters and Surge Arresters

Over-voltage protection for the traction power system shall be provided by lightning arresters and surge arresters.

Arresters shall be rated to withstand the maximum system voltage regeneration and anticipated voltages induced from paralleling high-voltage transmission lines.

Arresters shall be capable of discharging the energy resulting from lightning strikes or other excessive surges.

At a minimum, lightning arresters or surge arresters shall be installed at feeder terminations located adjacent to each substation, each tie station, substation feeder switches and 1,000 feet either side of the substation and in areas of reduced clearances, such as overhead bridges and tunnel portals. Surge arresters shall also be installed approximately 1.000-feet on each side of a feed point and midway between substations.

Surge arresters will be installed in all substations on each outgoing feeder external to switchgear preferably in an adjacent area and between the negative bus and the ground.

Surge arresters will be installed in all substations on the primary of the rectifier-transformer in the rectifier transformer compartment with a shield protecting the transformer windings.

# 10.4 OVERHEAD CONTACT SYSTEM (OCS)

## 10.4.1 General

The overhead contact system includes the contact wire system and the physical support system. Technical, operational, maintenance, local climatic and economic considerations will be the basis of design of the OCS as well as environmental conditions discussed in Chapter 1, General.

The contact wire system consists of the contact wire; in-span fittings; jumpers; conductor terminations and associated hardware from which the vehicle draws power by means of the physical contact of the pantograph on the contact wire. Design of the contact wire system will be interfaced with the vehicle dynamic performance characteristics in order to develop a system in which the pantograph maintains contact with the contact wire for proper current collection under all operating conditions; see Chapter 8, Vehicle.

The physical support system consists of foundations; poles or masts; guys; insulators; brackets; cantilevers; and other assemblies and components necessary to support the contact wire system in accordance with the requirement that contact will be maintained during all operating conditions. The support system will be double insulated throughout the OCS.

The feeder system consists of the feeder conductors; jumpers; switches; and associated hardware that connect the TPSS DC positive feeders to the contact wire.

The traction power distribution system will be electrically continuous from substation to substation. At the TPSS, the OCS continuity can be sectionalized to provide isolation of each electrical section. An arrangement providing continuity and flexibility for sectionalization of the OCS while any track is out of service will be incorporated in the design. Sectionalization at switches or other special trackwork locations as well as in the yard can be required to provide flexibility in operations and maintenance.

In locations where it is required to have an insulated separation in the contact wire, such as at special trackwork, jumpers, switches, or breakers will be employed to maintain electrical continuity. Where jumpers are used, they will be sized to provide the same ampacity as the contact system.

### 10.4.1.1 OCS Configuration

For all mainline at-grade and aerial structures, the OCS will consist of a fixed termination (variable tension) single contact wire system, consisting of a contact wire supported by means of cantilevers, cross spans, head spans, and pull-off arrangements. The system will be supported by poles located curbside outside the track areas for the mixed traffic alignment sections or between the tracks in two track areas for the semi-exclusive alignment sections. The use of building mounted anchor points will be encouraged when possible. In multi-track areas, a head span configuration may be employed.

If the OCS requires parallel feeders they will be run underground. Choice of center or side poles will be determined on a site specific basis. Street lights may also be supported from OCS structures.

The yards and shop area will also contain a single wire fixed termination system. Depending on yard layout, the contact wire in the yard will be supported by a single or back to back pole

mounted cantilever arms, cross spans or head spans. Contact wire supports in the shop will be attached to the building structure.

#### 10.4.1.2 Design Coordination

The OCS will be designed in accordance with the criteria in Chapter 2, Track Alignment and Trackwork; and Chapter 8, Vehicle.

### 10.4.2 Design Requirements

#### 10.4.2.1 Contact Wire Height

The nominal contact wire height will be in accordance with the requirements listed in Table 11.1 below. Note that minimum is the minimum height allowed under worst case conditions of temperature, sag, tension, construction tolerances and maintenance tolerances.

**Table 11.1 - Contact Wire Heights**

| Route Description | Type of OCS | Minimum Contact Wire Height | Normal Wire Height |
|---|---|---|---|
| Low Clearance Areas (i.e. tunnels) | Fixed Termination Single Contact Wire | 13' 6" | 14' 6" |
| Yard | Fixed Termination Single Contact Wire | 16' 0" | 19'0" |
| Segregated Right of Way | Fixed Termination Single Contact Wire | 15' 0" | 19' 0" |
| Railway Grade Crossing | Fixed Termination Single Contact Wire | 22' 0" | 22' 0" |
| Mixed use, with road vehicles | Fixed Termination Single Contact Wire | 18' 0" | 19' 0" |

The contact wire height at supports will take into consideration the effect of wire sag, due to temperature rise or to ice loading, and installation tolerance, including track construction and maintenance tolerances. At critical locations, restricted clearance over bridges, or fixed track points, grade crossing, embedded or direct fixation trackwork, no allowance will be made in the OSC design for track lift. At non-critical ballasted section locations, the OCS design will allow for a future track lift of up to 3 inches.

#### 10.4.2.2 Contact Wire Gradient

The pantograph shall track smoothly under the contact wire at all times. Where the contact wire height needs to be changed, the change shall not cause bouncing and arcing of the pantograph. Table 11.2 provides recommendations for the maximum wire gradient versus the streetcar speed ranges. To allow for an installation tolerance, the design wire gradient shall not exceed 90% of those listed here:

**Table 11.2 - Maximum Wire Gradient versus Vehicle Speed**

| Vehicle Speed Range (mph) | Maximum Gradient (%) |
|---|---|
| 1 - 15 | 2.3 |
| 15 - 30 | 1.3 |
| 30 - 35 | 0.8 |

Note: The maximum change of contact wire gradient shall be equal to one-half the maximum gradient, from one span to the next.

#### 10.4.2.3 Loading

Structural loading will be based on NESC Rule Sections 25 and 26, combined wind and ice loading, "medium" or “light” loading district, based on engineering judgment.

#### 10.4.2.4 Span Lengths and Staggers

The span lengths will be designed to provide for security (prevention of de-wiring) and to maintain good current collection.

The contact wire will be displaced from track centerline on both tangent and curved track. Stagger is the deliberate lateral displacement of the contact wire at each support to the left or right of the elevated track centerline. On tangent track, the wire is staggered primarily to achieve uniform wear of the pantograph collector strip. On curved track, the offset displacement achieves the tangent/cord construction necessary for the "straight-wire" OCS to negotiate the curve.

The designer will consider the effects of environment, track geometry, vehicle and pantograph sway, and installation and maintenance tolerances. Vehicle roll into the wind will be taken equal to 50% of the maximum dynamic roll value, in accordance with AREMA Manual Chapter 33, Part 4. To minimize the possibility of harmonic oscillation in the OCS not more than five equal spans will be located successively. A span which is at least 10% shorter will be inserted to minimize the possibility of any sympathetic oscillation. Structure spacing for the OCS shall be as great as possible consistent with maximum midspan offset criteria and maximum working load at registration points.

#### 10.4.2.5 Clearances

Clearances will be maintained between live conductors, including pantographs, and any grounded fixed structures in accordance with the AREA Manual, Chapter 33, Part 2 as follows:

| | Static | Passing |
|---|---|---|

| | | |
|---|---|---|
| Normal Minimum | 6" | 4" |
| Absolute Minimum | 5" | 3” |

Static clearance is the clearance between the OCS and any grounded structure when not subject to pantograph pressure. Passing clearance is the clearance between the OCS or pantograph and an overhead structure under actual operating conditions with the vehicle moving.

For vehicle related clearances, full allowance will be included for dynamic displacement of the vehicle under operating conditions, including tolerances for installation and maintenance in the track and OCS. Refer to Chapter 2, Track Alignment and Trackwork, and Chapter 8, Vehicle, for additional information.

#### 10.4.2.6 Factor of Safety

The OCS will be designed in accordance with the factors outlined in the NESC Section 26 under the loading conditions specified.

#### 10.4.2.7 Basic Design

The design of the OCS shall be based on engineering studies. Basic design, as expressed below, is to provide a set of detailed parameters for application in site specific design of the OCS for the project.

***OCS Parameter Study***

The OCS parameter study shall include calculations that take into account all factors that contribute to horizontal and vertical displacement of the contact wire with respect to the pantograph. This study is required for different contact wire heights as shall be applied to the project.

The study shall include calculations for the following:

- Maximum structure (registration points) spacing as a function of track curvature
- Conductor blow-off
- Permissible midspan static offset for contact wire spans over tangent tracks
- Permissible midspan static offset for contact wire spans over curved tracks
- Pantograph security analyses for selected contact wire heights

The results of each study shall be given in basic design charts and graphs included in the project drawings.

***Required Considerations for Each Study***

- Climatic condition: wind and temperature
- Conductor dimensions and tensions
- Conductor stagger
- Stagger effect
- Pole deflection due to live loads such as wind and conductor tension change

- OCS erection tolerances
- Vehicle roll and lateral displacement, or 50% maximum roll into 'operating' wind
- Pantograph Collector overall width
- Pantograph sway
- Track maintenance tolerances
- 'Wind' and 'no-wind' operating conditions

***Conductor Tensions***

Conductor tensions shall be selected to provide a practical and economical configuration of the OCS suitable for the environmental conditions, the electrical requirements, normal and emergency operations and ease of maintenance. Maximum conductor tensions shall comply with NESC Rules 261H and referenced Rules 250 and 251. The OCS is to be considered as NESC Grade C construction for these purposes.

***Contact Wire Vertical Loads***

Vertical loads for 5-foot increments of span length shall be calculated for selected operating and non-operating conditions.

***Contact Wire Radial Loads***

On tangent track, contact wire radial loads due to maximum tension for 5-foot increments of span lengths shall be calculated with maximum staggers. On curved track, contact wire radial loads shall be calculated for every degree of angle deviation, in one degree increments, between 1 and 15 degrees. Radial angles greater than 15 degrees are not acceptable.

***Contact Wire Staggers***

Maximum stagger calculations shall be prepared using 50% of all allowances made for pantograph security calculations. Maximum stagger shall be determined by subtracting the 50% allowance total from the half width of the pantograph carbons. Maximum stagger values shall be calculated for curved track and tangent track for both normal contact wire height, and for maximum contact wire height.

***Pantograph Clearance Envelope***

A pantograph clearance envelope shall be developed for application on all tracks, for the worst track conditions and full vehicle roll plus a 3-inch mechanical clearance. No equipment, except OCS steady arms attached to the contact wire, shall intrude into the pantograph clearance envelope.

***Sectionalizing Requirements***

OCS sectioning at power feed locations shall be done using insulated overlaps. All other operational sectioning shall be done using insulated overlaps or, where not possible, section insulator assemblies.

***OCS Route Design***

A route design is to be prepared to determine at a low level of detail, the arrangements of each tension length of OCS to be built or altered. Each tension length shall be planned to be as long as practical in accordance with the results of sectioning requirements and the lengths of contact wire on a drum. Splicing of new construction contact wire should be avoided.

The route design shall take into consideration fixed locations for insulated overlaps, station crossovers, low clearance buildings and bridges, and any infrastructure features preventing the placement of wiring terminations.

Live conductors shall not be installed above passenger platforms or buildings. A clearance study, showing plan and profile of OCS shall be made for each overhead bridge and structure. The study shall bring out the minimum clearance between OCS and the structure under worst conditions.

The result of the OCS route design shall be documented on a Master Overlap Chart.

### 10.4.3 Product Requirements

#### 10.4.3.1 OCS Conductors

The contact wire will be solid grooved hard-drawn copper 350 KCMIL, conforming to ASTM Specification B47. The conductor size should be confirmed by the power simulation study. The effect of temperature change on all conductors will be taken into consideration when designing for conductor tension. In addition cross section area loss will be taken in to account when performing calculations. Tension calculations should take into account a 30% loss and current carrying calculation should take a 15% loss into account.

#### 10.4.3.2 Poles and Foundations

Round or round tapered poles as specified with KCMO's Department of Transportation will be used everywhere along the alignment. In some areas existing OCS poles may be reused subject to verification of the ability of the poles to carry the applied loads. Unless dictated by special conditions, poles will be mounted by means of embedded anchor bolts. In areas where conditions require other than cast-in-place concrete foundations, each location must be evaluated and a foundation designed that meets the site specific requirements as well as the Design Criteria and approved by KCMO. Each foundation will have a ground connection installed and all poles will be grounded to the foundation reinforcement bars. Ground resistance shall not exceed 10 Ohms. The pole base plate, foundation reinforcing bars, anchor bolts and ground rod will be electrically connected. Poles will be sized in accordance with NESC Sections 25 and 26 for "medium" districts.

Anchor bolt patterns will be selected to provide a one-on-one relation between pole and foundation, based on matching strength.

Pole live load deflection plus foundation rotation during train operation will be no more than 2 inches at contact wire height. Pole deflection at the top of the pole under NESC medium loading conditions will be no more than 2.5 percent of pole length. Overload factors will not be applied in the calculation of pole deflection Cross track pole width, live load deflection and foundation rotation will not be greater than 18.5 inches.

The design and construction of the pole foundations and guy anchor foundations will conform to established civil and structural engineering practices, ASTM and ACI standards, and other applicable codes. The foundations will be reinforced concrete or steel tubular piles and will be capable of withstanding the design load imposed during installation, operation and maintenance.

#### 10.4.3.3 OCS Support Systems

Depending on location and type of system, various types of supports are required for the OCS. In all cases, the supports will be double insulated. All supports for the OCS will be designed to comply with Article 225, Electric Railway Construction of the NESC.

#### 10.4.3.4 Cantilevers

Cantilevers shall be used for parts of the alignment requiring single OCS poles or where the use of cross spans is not viable. The bracket used to attach the arm to the pole will be fitted with hinge pins.

#### 10.4.3.5 Head Spans

Head span supports, consisting of a lower steady span wire and an upper headspan wire, will be used where more than two contact wires need to be supported or where the track separation is more than 30 feet. Head spans will be designed to allow for temperature induced along-track movement of the OCS conductors.

#### 10.4.3.6 Cross-spans

In areas where wide support systems are required and there is no need for along track movement, such as in the yard and downtown areas, cross-spans will be employed. The majority of the OCS will consist of cross-spans.

#### 10.4.3.7 Bridge Attachments

Bridges along the streetcar alignment will be able to support poles and pole loading. Typically OCS over bridges will be cross span or center cantilever arm type OCS as approved by KCMO.

#### 10.4.3.8 Disconnect Switches

Disconnect switches will be mechanically operated switches mounted on OCS poles wherever possible, preferably pole top mounted. Switches located in areas accessible by the public will be provided with locking mechanisms to guard against unauthorized operation.

#### 10.4.3.9 OCS Surge Arresters

Surge arrester units shall be installed between the contact wire and the pole ground rods on all feeders and at regular intervals along the OCS system. A study of the lightning strike density of KCMO area shall be performed to determine the optimum spacing of the intermediate surge arrester units.

#### 10.4.3.10 OCS Grounding and Bonding

All OCS support structures will be grounded.

## 10.5 NEGATIVE RETURN PATH AND STRAY CURRENT CONTROL

Running rails will be of the continuous welded type. Where it is necessary to have a bolted connection, the bolted joints will be electrically bonded. At locations requiring insulated joints, impedance bonds will be used to maintain continuity of the dc negative return circuits when warranted. The negative return rails in the yard will be grounded to corresponding TPSS.

Insulated joints will be installed at the entrance to the yard and to the shop buildings to prevent any connection between the traction power system in the shop and on the main line.

The final design team will employ designs that will mitigate stray currents and to provide means of monitoring any potential stray current conditions as directed by KCMO. As a minimum, the following measures will be employed to mitigate stray current conditions. Running rails will be isolated to the extent practical from ground. The mainline traction power system will be isolated from the shop and the yard traction power systems. All traction power distribution system design will be coordinated with the Corrosion Control Chapter.

**This page intentionally left blank**

# 15.0 STRAY CURRENT AND CORROSION CONTROL

This chapter will apply to corrosion control design for underground metallic structures and pipes, storage facilities, and any other facilities where corrosive conditions can occur, Types of corrosion control include stray current mitigation, protective coating, and cathodic protection.

## 15.1 Purpose

These criteria describe design requirements necessary to accomplish corrosion control measures for rail transit projects utilizing electric traction. Design factors to consider for each system include plans to minimize stray current at the source, prevent premature failures of transit facilities, and other underground structures to be installed, operated, and maintained in a cost effective manner. Corrosion control requirements will be coordinated with all applicable engineering disciplines.

## 15.2 Standards and Codes

Standards, codes, and recommended practices for corrosion control include, but are not limited to, the following publications and/or codes:

- NACE International
- National Fire Protection Association
- American National Standard Institute
- American Standards for Testing Materials
- American Water Works Association
- American Electric Railway Association
- Department of Transportation
- Steel Structures Painting Council
- Institute of Electrical and Electronic Engineers
- Underwriters Laboratories, Inc
- The Occupational Safety and Health Act
- National Electrical Code
- Military Specifications
- National Electrical Manufacturer's Association
- National Electrical Safety Code

Local and state codes also apply. Designers will consult these publications and provide systems in accordance with the most stringent applicable code, or industry practice.

## 15.3 Scope

### 15.3.1 General

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

- Realize the design life of transit facilities by avoiding premature failure caused by corrosion.
- Minimize annual operating and maintenance costs associated with material deterioration.
- Ensure continuity of operations by reducing or eliminating corrosion-related failures of transit facilities and subsystems.
- Minimize detrimental effects to facilities belonging to others as may be caused by stray earth currents from transit operations.

### 15.3.2 Stray Current Corrosion Control

Stray current control will be based on the following principles:

- Increasing the conductivity of the return circuit
- Increasing the resistance between the return circuit and the earth
- Increasing the resistance between the earth and underground metallic structures
- Increasing the resistance of underground metallic structures
- Providing Sacrificial Anodes when warranted

Stray current control measures will be installed on traction power and track systems to obtain minimal flow of direct current (DC) stray current into the surrounding environment. Protection measures will be applied to assure that stray earth currents are maintained within acceptable ranges to avoid deterioration of buried metallic structures. Prior to construction and final design KCMO will conduct Baseline Stray Current Tests to determine the effects and/or magnitude of stray currents, if present, on existing utility installations, and to serve as documented reference for future investigations as prescribed by KCMO.

Turnouts will be isolated for stray current protection by encapsulating the turnout components in a combination of isolative coating and rail boot prior to installation. The turnout will then be set in place and embedded in concrete. This method is less labor intensive and more cost effective than the traditional isolating bath tub design typically used in the past.

### 15.3.3 Soil Corrosion Control

Soil and ground water corrosive characteristics will be determined and documented during the Baseline Stray Current Surveys. Analysis of the data obtained, or from supplemental on-site measurements, will be the basis for corrosion control designs. Structures will be protected against the environmental conditions by use of coatings, insulation, cathodic protection, and electrical continuity as appropriate.

### 15.3.4 Atmospheric Corrosion Control

The atmospheric corrosion conditions such as temperature, relative humidity, wind direction and velocity, solar radiation, and amount of rainfall will be determined during the Baseline Stray Current Survey. The areas with corrosive atmospheres (industrial, marine, rural, etc.) will be identified. Materials selection, designs, and associated coatings will be based on recommendations of the survey and will be used to prevent metallic structures and hardware from atmospheric corrosion.

### 15.3.5 Grounding

Due to the natural difference between safety grounding and corrosion control requirements, the guidelines provided in these Criteria will be followed. Grounding designs for traction power substations, passenger stops (when warranted) shops and yards, aerial structures, and other wayside locations, will be reviewed by KCMO to assure corrosion control designs are not compromised.

## 15.4 Interfaces

Corrosion control will be interfaced and coordinated with other engineering disciplines and designs, including the utility, mechanical, civil, structural, electrical, trackwork, traction electrification, environmental, geotechnical, architectural, signals, communications, and safety and security designs.

## 15.5 Applicability of Criteria

Since the streetcar system may be designed and constructed in segments, corrosion control criteria will be applicable throughout the design, installation, and start-up process of all segments.

City of Kansas City Missouri Water Services Department has corrosion design criteria as part of Water Corrosion Control Design Standards.

## 15.6 Expansion Capability

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

## 15.7 Special Design Provisions

During the pre-design and design phases of the project, the corrosion control designer will identify unique and special design cases such as existing building foundations, paralleling power lines, and unusual soil conditions. In these cases, the corrosion control designer will evaluate and recommend special design measures to KCMO as appropriate. KCMO will review and approve cases as necessary.

# 15.8 Stray Current Corrosion Prevention

## 15.8.1 Purpose

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

- Under normal conditions, operate the transit system without direct or indirect electrical connections between both the positive or negative traction power distribution circuits and ground.
- Traction power and the trackwork will be designed to minimize stray currents during normal revenue operations.

## 15.8.2 Scope

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

- Trackwork components
- Traction electrification system components
- Metallic pipes and casings
- Reinforced concrete structures

Designs will be coordinated with the outside agencies through KCMO.

# 15.9 Stray Current Corrosion Prevention Systems

The design of stray current corrosion prevention systems will be based on results of Stray Current Simulation model studies. The studies will predict magnitude of anticipated stray currents considering the variation of key parameters, including:

## 15.9.1 Traction Power Substations (TPSS)

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

The traction power substation will include a separate DC traction ground electrode. The DC ground electrode will be electrically isolated from facilities in the substation.

Substations will be provided with access to the DC negative bus for stray current monitoring, utilizing corrosion control junction boxes. The location of these boxes will provide ready access for maintenance personnel and area utility personnel.

### 15.9.1.1 Positive Distribution System

- Resistance-to-Earth Criteria. The positive distribution system will be normally operated as an electrically continuous bus, with no breaks, except for sectionalizing and during emergency or

fault conditions. Intentional electrical segregation of mainline, yard, and shop positive distribution systems is also required.

- Electrical Ground Connections, Overhead Contact System (OCS) Support Poles. For locations other than at aerial structures, electrical ground facilities for adjacent OCS support poles will not be interconnected. This will eliminate the possible transference of stray earth currents from one portion of the transit system to another because of an electrically continuous ground system.

Where OCS poles are to be located on aerial structures, provision will be made to interconnect these electrically and connect them to a ground electrode when required.

#### 15.9.1.2 Negative Distribution System

- General. The following industry-accepted standards will be included in designs to afford an electrically isolated rail system to control stray current at the source.
  - Continuously welded rail;
  - Rail bond jumpers at mechanical rail connections for special track work when required;
  - Insulating pads and clips on concrete ties for ballast track work;
  - Insulated rail fastening system for wood ties at a special track-work installation for ballast track work;
  - Ballast on at-grade sections maintained a minimum of 25 mm (1 in) below the bottom of the rail for ballast track work outside the Maintenance and Storage Facility (MSF);
  - Insulating direct fixation fasteners on concrete aerial structures not embedded when possible;
  - Insulating rail boots for embedded trackwork and at all roadway and pedestrian crossings and at the MSF storage yard;

    Cross-bonding cables installed between the rails to maintain equal potentials on all rails when warranted.

- Resistance-to-Earth Criteria. The mainline running rails, including special trackwork and all ancillary system connections will be designed to have the following minimum in-service resistance per 1,000 feet of track (2 rails):
  - At-grade ballasted track with cross-ties (wood or concrete): 300 Ohms
  - Ballast deck aerial structures: 300 Ohms
  - Direct fixation track: 500 Ohms
  - Embedded track: 500 Ohms

Resistance may be attained by use of insulating track fastening devices such as insulated tie plates, rail clips, and direct fixation fasteners.

Supplemental insulated negative drainage return cables will be considered where extensive utility installations exist, or where major high pressure transmission pipelines are present.

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

#### 15.9.1.3 Grade Crossings, Embedded Track

Rails, rail fasteners, and related metallic components will be electrically isolated from ground by coatings and insulating components as much as possible.

#### 15.9.1.4 Yards

The yard/mainline traction power segregation point will be located such that yard/mainline track are electrically isolated from each other, and from ground connections.

Yard track will include the following provisions:

- Ballast will be clean, well drained, high-resistivity material.
- A 1-inch minimum clearance between the ballast and all rail surfaces and electrically connected metallic track components for sections not embedded

For embedded sections in the yard (on wood or concrete ties) the rail will be placed in rail boot.

#### 15.9.1.5 Maintenance Shops

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

Shop tracks will be electrically grounded to the shop grounding system.

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

#### 15.9.1.6 Water Drainage

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

### 15.9.2 Electrical Bonding

#### 15.9.2.1 Aerial Structures

All longitudinal bars in the top layer of reinforcement will be tack welded at all overlaps to insure electrical continuity.

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

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

Structural deck members will be electrically insulated from support piers and abutments as much as possible.

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

#### 15.9.2.2 Retaining Walls

Protection of retaining walls will be examined by a case by case basis by KCMO. Protection of retaining walls will be via all longitudinal bar overlaps in both faces of the wall, including the top and bottom bars of the footing, will be tack welded to insure electrical continuity. Longitudinal bars in the footing will be made electrically continuous to the longitudinal bars of the walls. Collector bars and bonding cables will be installed as stated in Section 11.9.2.1 above.

#### 15.9.2.3 Utility Structures

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

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

Replaced, relocated, and maintained-in-place utility structures, owned by others, will be provided with corrosion measures as required by individual master agreements. Existing utilities which may be affected by probable stray current may remain in place as reviewed on a case by case basis by KCMO.

### 15.9.3 Drainage Facilities

The corrosion control design will consider stray current control when warranted at drainage facilities including but not limited to inlets, manholes, catch basins, pipes, junction boxes, and other associated equipment. Substations will be provided with equipment described in Section 11.10.1 below.

### 15.9.4 Test Facilities

Test facilities will be required on all electrically bonded structures owned by KCMO for the streetcar system to measure and monitor stray currents. The corrosion control design will provide test facilities for individual protected structures as defined in Chapter 4, Utilities.

### 15.9.5 Quality Control

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

## 15.10 Soil Corrosion Control of Buried Structures

### 15.10.1 General

This section provides criteria for the design of systems and measures to prevent corrosion from soils and ground waters on fixed facilities. Designs will be based on achieving a 50-year design life for buried structures through consideration of the following:

- Materials of Construction: All piping (pressure and non-pressure) and conduit will be non-metallic unless metallic materials are required for specific engineering purposes. Use of metallics will be supported by engineering calculations when used in lieu of non-metallics. Aluminum and its alloys will not be used for direct burial purposes.
- Safety and Continuity of Operations: Corrosion control provisions will be required for all facilities, regardless of location or material when failure of such facilities caused by corrosion will affect safety or interrupt continuity of operations.

### 15.10.2 Scope

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

- Ferrous pressure piping (water, fire water, gas, sewage ejectors, etc.)
- Buried and on-grade reinforced concrete structures
- Support pilings
- Underground storage tanks
- Other underground structures

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

## 15.11 Soil Corrosion Prevention Systems

### 15.11.1 General

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

### 15.11.2 Materials and Structures

#### 15.11.2.1 Ferrous Pressure Piping:

All buried cast iron, ductile iron and steel pressure piping within the streetcar project limits will be cathodically protected for those utilities as prescribed by KCMO. Designs should include, but not limited to, the following:

- Application of a bonded protective coating to the external surfaces of the pipe (see Section 11.13.2);
- Electrical insulation from interconnecting piping, other structures, and segregation into discrete electrically insulated sections depending upon the total length of the piping (see Section 11.11.4);

- Electrical continuity through installation of insulated copper wires, across all mechanical joints other than intended insulators (see Section 11.11.5);
- Permanent test/access facilities, to allow for verification of continuity, effectiveness of insulators and coating, and evaluation of protection levels; will be installed at all insulated connections and at intervals not greater than 200 feet;
- Impressed current anodes and rectifier units or sacrificial anodes; the number of anodes and size of rectifier will be determined on an individual structure basis.

#### 15.11.2.2 Reinforced/Pre-stressed Concrete Pressure Pipe:

Design and fabrication of new reinforced concrete pipe and steel cylinder prestressed concrete pipe will include the following:

- Establish a low permeability concrete by controlling the water/cement ratio, ratios of 0.3 for core concrete and 0.25 for mortar are preferred, industry practices may result in significant increases and wide variations to these levels;
- Maximum of 200 ppm chloride concentration in mixing water for concrete;
- Use of Type I Portland Cement generally. Type II Portland Cement should be used in selected locations.

#### 15.11.2.3 Concrete/Reinforced Concrete

Design will be based on the following for concrete in contact with soils:

- Use of Type I Portland Cement, or Type II Portland Cement in selected locations;
- Maximum water/cement ratio of 0.45 by weight;
- Maximum 200 ppm chloride concentration in mixing water and admixtures combined;
- Minimum 2-inch concrete cover on the soil side of all steel reinforcement when the concrete is poured within a form, or a minimum 3-inch cover when the concrete is poured directly against soils.

#### 15.11.2.4 Support Pilings

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

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

#### 15.11.2.5 Non-Metallic Materials

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

- Manufacturer's recommendations
- Mechanical strength and internal pressure limitations
- Elasticity/expansion characteristics

- Comparative costs
- Expected life
- Failure modes
- Local codes
- Prior experiences with the proposed non-metallic material in similar applications

#### 15.11.2.6 Electrical Conduits

Buried metallic conduits will include the following minimum provisions:

- Galvanized steel with a PVC topcoat or other coating acceptable for direct burial, including coupling and fittings;
- Galvanized steel with a minimum of 3 inches concrete cover on soil sides within duct banks;
- Electrical continuity through use of standard threaded joints or bond wires installed across non-threaded joints.

### 15.11.3 Coatings

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

### 15.11.4 Electrical Insulation

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

- Devices will have a minimum of 10 mega-ohms prior to installation and will have mechanical and temperature rating equivalent to the structure in which it is installed;
- Devices will have sufficient electrical resistance after insertion into the operating piping system such that no more than two percent of a test current applied across the device flows through the insulator, including flow through conductive fluids if present;
- Devices installed in chamber or otherwise exposed to partial immersion or high humidity will have a protective coating applied over all components.

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

Wherever possible, a minimum clearance of 6 inches will be provided between new and existing structures. When field conditions prohibit a 6-inch clearance, the design will include special provisions to prevent electrical contact with the existing structure(s).

### 15.11.5 Electrical Continuity

Electrical continuity will be provided for all underground non-welded pipe joints and will meet the following minimum criteria:

- Use direct burial insulated, stranded copper wires with the minimum length necessary to span the device being bonded;
- Wire size will be based on the electrical characteristics of the structure and resulting network to minimize attenuation and allow for cathodic protection;
- A minimum of two wires will be used per joint for redundancy.

### 15.11.6 Cathodic Protection

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

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

- Cathodic current density (minimum 1.0 mA/ft$^2$ of bare area)
- Current requirements
- Anticipated current output/anode
- Assumed percentage bare surface area (minimum 1 %)
- Indicated total number of anodes, size, spacing
- Anticipated anode life
- Anticipated anode bed resistance

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

#### 15.11.6.1 Impressed Current Rectifier Systems

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

### 15.11.7 Test Facilities/Testing

Test stations consisting of two structure cables, one reference electrode, conduits, and termination boxes will be designed to permit initial and periodic tests of cathodic protection levels, interference currents, and system components (anodes, insulated fittings, and continuity

bonds). The corrosion control design will specify the locations and types of test facilities for each cathodic protection system.

### 15.11.8 Water Treatment

For heating and air conditioning systems, chemical treatment of chiller, condenser and boiler supply and return systems will be designed to minimize internal corrosion and to prevent component fouling. Water treatment systems will be designed to prevent corrosion rates in excess of 2.0 mils per year for steel and 0.1 mil per year for copper. Provisions for corrosion rate measurements will be made in the return lines. All chemical treatment systems will comply with environmental protection requirements. The corrosion control design will include appropriate measures and provide space requirements for treatment equipment.

## 15.12 Atmospheric Corrosion Prevention

### 15.12.1 General

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

- Materials selection: Materials will have established performance records for the service intended;
- Sealants: Sealants will be used in crevices to prevent the accumulation of moisture;
- Protective coatings: Barrier or sacrificial coatings will be used on steel;
- Design: Use of dissimilar metals and recesses or crevices that might trap moisture will be avoided.

### 15.12.2 Scope

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

- OCS structures and hardware
- Vehicles
- Exposed metal surfaces on aerial and mainline structures
- Exposed metal at passenger stops
- Right-of-way and enclosure fences
- Shop and yard exposed metal surfaces
- Electrical, mechanical, signal and communication devices and equipment and traction power substation housings

# 15.13 Atmospheric Corrosion Prevention Systems

## 15.13.1 Materials

Metals exposed to the atmospheric environments will be selected and provided as follows:

- Steels and Ferrous Alloys
  - Carbon steel and cast iron exposed to the atmosphere will have a coating applied to all external surfaces. Rail and rail fasteners will not require coatings.
  - High strength low alloy (HSLA) steels will be protected similarly to carbon steels except where used as weathering steel exposed to the outside environment. Coating of metallic contacting surfaces, crevice sealing and surface drainage will be addressed in the designs. Staining of adjacent structures will be considered.
  - Series 200 and 300 stainless steels are suitable for use in any exposed situation without future protection. Series 400 stainless steels are acceptable, but must be evaluated due to possible staining.
  - Stainless steel surfaces will be cleaned and passivated after fabrication.
- Aluminum Alloys
  - Use an anodized finish to provide the best weather resistant surface.
- Copper Alloys
  - Copper and its alloys can be used where exposed to the weather without additional protection. Bimetallic couplings will be avoided.
- Magnesium Alloys
  - Magnesium alloys will have a barrier coating applied when long term appearance is critical. Bimetallic coupling will be avoided.
- Zinc Alloys
  - Zinc alloys can be used without additional protection. Bimetallic coupling will be avoided.

## 15.13.2 Coatings

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

### 15.13.2.1 Organic Coatings

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

- Aliphatic polyurethanes
- Vinyl copolymers

- Epoxy - as a primer where exposed in the atmosphere or as the complete coating system where protected from direct sunlight
- Acrylic - where there is not exposure to direct sunlight
- Alkyd - where there is not exposure to direct sunlight

#### 15.13.2.2 Metallic Coatings (for Carbon and Alloy Steel)

Acceptable coatings are as follows

- Zinc (hot dip galvanizing)
- Aluminum
- Aluminum-zinc

## 15.14 Grounding

### 15.14.1 Purpose

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

### 15.14.2 Scope

Facilities addressed include the following:

- Traction Power Substations (TPSS)
- Aerial OCS Structures

## 15.15 Design and Coordination of Grounding Systems

### 15.15.1 Aerial OCS Structures

#### 15.15.1.1 General Requirements

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

#### 15.15.1.2 Coordination Requirements

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

- Ground electrode component materials
- Ground electrode locations
- Aerial component electrical continuity details
- Pier support/insulation details

### 15.15.2 Traction Power Substations

Corrosion control installations will be coordinated with grounding electrodes, grounding standards, grounding requirements, and IEEE Standard.