District Department of Transportation

DESIGN CRITERIA

2019

dc streetcar

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MESSAGE FROM THE CHIEF ENGINEER

We are very pleased to announce the completion of the technical update to the *DC Streetcar Design Criteria (January 2012)*. This document has been updated to reflect the latest streetcar industry standard and design guidelines, and lessons learned since the release of the first edition in 2012.

The *DC Streetcar Design Criteria (2019 Revision)* provides both general uniform and minimum guidelines and specific design criteria for use in the development, design and construction of the streetcar system. We are confident that the use of this document will enable the District Department of Transportation (DDOT), agencies, consultants, planners, engineers, architects and other professionals to more efficiently translate DC requirements into acceptable design solutions. The *DC Streetcar Design Criteria (2019 Revision)* is intended to serve as a living document that will evolve to reflect changes in industry, engineering, operation, and maintenance, and policy of DC Streetcar program.

Implementing a successful streetcar system that will serve the District of Columbia is our key goal. With the development and update of this Design Criteria and Standard Drawings we have taken a very important step towards this direction.

Dawit Muluneh, PE
Chief Engineer

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Associate Director

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FOREWORD

The *DC Streetcar Design Criteria* (2019 Revision) is a technical update to the previous Design Criteria issued in January 2012. This comprehensive document provides a general framework and the basis for a uniform design for the DC streetcar system. These criteria allow the city's project team and partners to develop preliminary and final designs for any streetcar project that might be undertaken by the District Department of Transportation (DDOT).

These criteria are not intended to replace the level of initiative and competence expected from DDOT, agencies, consultants, and professionals in the performance of their duties. It is not a substitute for engineering judgment and sound engineering practice. Professionals involved in the DC streetcar program are encouraged to carefully consider the principles of the *Design Criteria* in the context of the needs of individual projects. Exceptions may apply in special cases. If a guideline is not appropriate and that a more appropriate solution is available, suggestions to this effect should be raised for consideration by DDOT.

The *DC Streetcar Design Criteria (2019 Revision)* should be viewed as a "living document," which is subject to change or revisions as we continue to work towards our goal to implement a successful extensive streetcar system in the city. A strong foundation is needed that provides guidance to achieving this goal. The completion of this *Design Criteria* is one the steps towards achieving this foundation.

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ACKNOWLEDEMENTS

The *DC Streetcar Design Criteria (2019)* was prepared under the guidance of the District Department of Transportation with the assistance of HDR Engineering Inc. in association with ZGF Architects LLP and LTK Engineering Services, and Jacobs Engineering Group Inc.

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Chapter 1

Introduction

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1.1 PURPOSE AND SCOPE

The purpose of the *DC Streetcar Design Criteria* is to establish guidance for application of standards and design policies for all preliminary engineering and final design phases of the DC Streetcar System (System). The material contained herein provides a uniform basis for the design of any project in the System that might be undertaken by the District Department of Transportation (DDOT). Its purpose is to provide sufficient information to allow the development of preliminary and final designs including drawings, design specifications, estimates of capital, safety and security verification checklists, operation and maintenance costs, and determination of potential impacts of operations and construction to the surrounding environment.

The *DC Streetcar Design Criteria* provides the basis for uniform design and is not a substitute for engineering judgment and sound engineering practices during project development. It shall also serve as a supplement to existing DDOT standards and guidelines, in addition to the guidelines published by other District of Columbia government agencies. It is the responsibility of the designer to expand upon the general framework of the *DC Streetcar* Design Criteria to a level of detail consistent with the appropriate level of design. Engineers and designers are encouraged to analyze alternative approaches to solving design problems to determine the most cost-effective and environmentally sound solution.

The *DC Streetcar Design Criteria* is to be used to develop designs that meet the stated intent and fulfill the purpose and need of the project. In situations where deviations to the guidance provided in this document are encountered, the designer shall submit a request for a design exception to DDOT, based on the process stated within the DDOT Design and Engineering Manual. Final submission of the Plans, Specifications, and Estimates (PS&E) shall include all deviations and design exceptions approved by DDOT and should be filed for review by the Quality Auditor. The designer should also consider the potential effects of any significant change in design on historic properties. Any noticeable changes in the location, size, scale or other design aspects of streetcar facilities may result in adverse effects that should be coordinated with the State Historic Preservation Office of the District of Columbia (SHPO) before they are incorporated into the design.

As our Nation's Capital, an area rich in cultural and historic resources, the District of Columbia has a unique obligation to maintain visual and aesthetic quality when implementing infrastructure projects. This obligation is most imperative within the area of the city laid out as part of L'Enfant's plan for the federal district that became Washington, DC. The area within the L'Enfant Plan is the city's historic core and contains the most important landmarks, buildings and vistas. Within this context, the presence of overhead catenary system and other wires within the L'Enfant Plan area is not encouraged. Therefore, DDOT is seeking to pursue less visually intrusive technologies for vehicle propulsion and traction power distribution. Additional detailed information regarding traction power supply and distribution can be found in Chapters 5 and 6.

1.2 STREETCAR SYSTEM PARAMETERS

Chapter 2 defines streetcar system parameters, with the overarching goal of providing transit patrons and commuters with the benefits of improved public transportation in a cost-effective, environmentally sensitive and socially-responsible manner. The chapter also provides a functional overview for the operation of the DC Streetcar system. DDOT's objective is to operate a safe, reliable, clean and efficient streetcar system and to integrate its operation with other transit modes for the convenience of the public. Lastly, applicable requirements, regulations, and codes are laid out, including climate and environmental conditions, and the appropriate application of the codes and standards.

1.3 STOPS, TERMINALS, INTERMODAL

Chapter 3 defines the regulations for streetcar stops. This includes preferred siting criteria, stop locations and guidance, and streetcar platform design parameters. Figures within this chapter illustrate several platform design options to be considered. Design parameters such as platform length, height, and ADA requirements are discussed. In addition to platform parameters and platform amenities, this chapter discusses fare collection equipment and structures, including where collection and validation equipment should be located on streetcar stop platforms. A list of applicable streetcar standard drawings is provided at the end of the chapter.

1.4 STREETCAR VEHICLES

Chapter 4 provides guidance for streetcar vehicles and vehicle clearances in technical aspects. Vehicle guidance includes vehicle length, floor height, number of passenger doors per side, single and double unit operation, towing capabilities, ADA compliance, future growth and demand, procurement, and alternative propulsion. There are further subsections detailing the operating environment, vehicle weight and passenger loadings, electromagnetic interference and compatibility, and vehicle performance, including noise and vibration. The vehicle clearance section establishes the basic clearance criteria to be used in the design and the maximum dimensions required to assure proper clearances between the streetcar vehicles or transit structures and wayside obstructions involved.

1.5 GUIDEWAY & TRACK ELEMENTS, SITEWORK & SPECIAL CONSIDERATIONS, ROW, LAND & EXISTING IMPROVEMENTS

Chapter 5 defines the improvements along the transit alignment required to ensure well-coordinated design and engineering for the areas beyond the stop areas, and necessary to meet the goals of complete streets. Each section should be considered within the context of the other sections within the chapter during design and Quality Assurance/Quality Control (QA/QC) processes. Sections include track alignment, civil work, integrated ROW and alignment improvements, trackwork, structures, utilities, and traffic.

1.6 SYSTEMS

Chapter 6 provides guidance for the design of traction power supply, distribution, and communication. This guidance includes functional and design requirements for the supply and distribution of the traction power supply system to transmit electric energy from its source to the vehicles. The chapter describes stray current and corrosion control, applicable to the design of underground metallic structures and pipes, storage facilities, and any other facilities where corrosive conditions can occur due to stray current. The signal and route control section, includes applicable controls and standards, functional design requirements, electromagnetic interference, switch machines, growth and expansion, and traffic signal interface and streetcar signals. The communications section provides guidance for the design of the communications system to be provided for the interfacing of major subsystems. The communications system shall provide the necessary functions to support the operational requirements of the streetcar system.

1.7 SUPPORT FACILITIES, YARDS, SHOPS, ADMINISTRATIVE BUILDINGS

The DC Streetcar System, as discussed in Chapter 7, may include a range of Maintenance and Storage Facilities (MSF), including the Car Barn Training Center (CBTC). MSF may include full maintenance capabilities, as well as facilities with light maintenance of varying sizes - large, medium, small and micro. MSF should, as applicable, accommodate daily and routine inspections, maintenance, on-car repairs, and interior and exterior cleaning of the streetcars, as well as providing storage and component change-out locations. Guidance covered in this chapter include applicable codes and standards, site selection, materials of construction, structural requirements, facility vehicle interface, corrosion control, and safety grounding, acoustics, maintenance, mechanical system, and access for mobility impaired.

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Chapter 2

Project Parameters

Content

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2.1 DC STREETCAR SYSTEM GOALS

The goal of the DC Streetcar System (system) is to provide the residents, workers, and visitors of the District of Columbia with the benefits of improved public transportation in a cost-effective, environmentally sensitive, and socially responsible manner.

2.1.1 PROVEN HARDWARE

The system shall be designed to use proven subsystem hardware and design concepts. All of the major subsystems, such as streetcar vehicles, signal, and traction power equipment, shall be supplied by established manufacturers, have a documented safe and reliable operating history of previous and current usage in an operating environment similar to the District, and be available off-the-shelf, so far as practical. The same requirements shall apply to spare parts. Any exceptions made for these requirements shall be considered only where the alternative subsystem offers substantial technical and cost advantages, is in an advanced stage of development and has accumulated substantial test data under near-revenue conditions.

2.1.2 Design Life

The system's fixed facilities (structures and buildings) shall be designed for continued operation over a minimum period of 50 years before complete refurbishment and renovations are necessary due to wear and tear and obsolescence.

Major system equipment (such as substation gear, shop machinery and the streetcar vehicles) shall be designed for a minimum of 30 years before complete replacement becomes necessary, assuming that approved maintenance policies are followed.

2.1.3 Service Integration

The streetcar line is to be a viable public transit component of the overall transportation system in the District. Specific provisions shall be made for the efficient interchange of passengers with public, private and other transportation modes.

2.1.4 Land Use Guidance

The system shall be designed, where possible and desirable, to stimulate urban development and redevelopment, while avoiding drastic changes that disrupt public commerce or social interactions. Positive changes such as streetscape improvements shall be incorporated, where feasible.

Displacement of buildings and public activity areas shall be minimized. Retail establishments shall be protected from construction activities to the extent practicable to maintain reasonable access to the establishment in a manner consistent with the District Department of Transportation’s (DDOT) Right of Way Policies and Procedures Manual. Creation of physical barriers to land use functions and reduction in traffic circulation capacity shall be avoided to the maximum extent practicable.

The system shall be implemented in such a way as to maintain consistency with local and regional land use plans. Exceptions shall be coordinated with the appropriate jurisdictions.

2.1.5 Urban Design Guidance

The design of the system shall consider the viewpoint of the user, the adjacent residential or business community and the nearby pedestrian, cyclist, or motorist. In this regard, the items of concern include streetcar stop access, continuity and transition of structures, separation of alignment, common system elements, maintenance, historic preservation, visual intrusion and barriers, residential access, potential noise and vibration impacts and mitigation measures. The streetcar system shall be designed, within practical limits, to minimize the impact on public and private spaces. To the greatest extent possible, streetcar projects shall be designed and constructed in a manner consistent with the District's public space management standards.

2.2 SYSTEM DESCRIPTION

2.2.1 General

This section provides a functional description for the operation of the system. DDOT's objective is to operate a safe, accessible, reliable, clean, and efficient streetcar system and to integrate its operation with other transit modes for the convenience of the public.

2.2.2 Operations

A specific operation plan for each DC Streetcar route shall be determined during the planning and environmental phases based on ridership demand and future land uses. Operating plans should consider exclusive guideway where applicable. Regulation and supervision of streetcar operations and the supervisory control of associated electric, mechanical, and communications subsystems shall be performed by designated personnel in the Operations Control Center (OCC) located in the Maintenance and Storage Facility (MSF). Streetcar operations related to stops, door operation, acceleration, deceleration, and speed maintenance will be controlled by the streetcar operator. Streetcar operation will be performed by the streetcar operator with approval from the OCC.

The design team and streetcar operator shall coordinate with DDOT in the development of specific requirements for future corridors or line extensions. The design team and streetcar operator shall also work with DDOT to determine conditions under which other rail transit services will be allowed to use streetcar rights of way or facilities. The streetcar operator is required to collaborate with other transit operators in the District of Columbia to coordinate their services to the extent practical within the streetcar service times and frequencies described below.

2.2.2.1 Span of Service

The system operates 18 hours per day Monday through Thursday, 20 hours on Friday, 18 hours on Saturday, and 14 hours on Sunday and holidays. Consideration should be given to special event operation where applicable.

2.2.2.2 Service Frequency

Currently, streetcar service frequency is 12 minutes, seven days a week for the H Street and Benning Road Line (H/Benning Line), during the entire span of operation. Service frequency on other lines in the system shall be developed during planning development phase. Demand will be used as a mechanism to refine operating plans. For run time modeling purposes dwell times at each stop should be assumed to not exceed 20 seconds on average. Hours of operation are as follows:

- Monday through Thursday – 6:00 AM to 12:00 AM (midnight)
- Friday – 6:00 AM to 2:00 AM
- Saturday – 8:00 AM to 2:00 AM
- Sunday and Holidays: 8:00 AM to 10:00 PM

DDOT may require operation of non-scheduled service such as special event trains. DDOT may also require special event schedules and routing if part of the system is shut down for events, construction work, or holidays. The designer shall accommodate these movements in the design to the extent practicable to avoid or minimize impacts on scheduled service.

2.2.2.3 Operating Speeds

Operating speeds shall be dependent on civil and alignment characteristics, the maximum posted speed of adjacent roadway traffic, on-street traffic conditions, and vehicle performance characteristics. However, the maximum operating speed of the vehicles will typically not exceed 30 mph. Future extensions of the system, particularly if using exclusive guideway, may exceed 30 mph. A noise and vibration analysis will need to be conducted during the environmental phase to better understand the potential impact of the proposed service.

2.2.2.4 Street Operations

Operation in mixed street traffic shall be by line-of-sight. Streetcars shall be governed by the traffic signal system for the majority of the alignment, which shall incorporate progression for the streetcars and traffic. At locations where the movement of the Streetcar may conflict with other vehicular traffic, transit style bar signals shall be used to control the Streetcar movement.

Traffic signal requirements, roadway signage, and traffic interfaces for in-street operation are described in **Chapters 5** and **6**.

2.2.3 EQUIPMENT AND FACILITIES

2.2.3.1 Streets

The designer and operator shall develop coordination and communication procedures with DDOT, other DC Government agencies, other transit operators, and utility companies regarding street maintenance, special events and other activities that affect operation. These procedures shall address any approvals and permits to be obtained from the governing agency prior to the start of any maintenance, special events or other activities, especially if the aforementioned activities may impact the daily commute.

2.2.3.2 Revenue Vehicles

The DC Streetcar shall be designed to fit the scale, ridership needs and traffic patterns of the District of Columbia and the applicable project corridor. Refer to **Chapter 4** for vehicle dimensions.

The current streetcar vehicles provide seating for approximately 30 passengers and space for two wheelchairs. At maximum load the vehicles could accommodate 120-127 standees. Level access boarding shall be used to accommodate boarding and alighting by wheelchairs, baby strollers, bicycles or any other passengers requesting assistance.

Streetcars will not have couplers; only single-unit streetcars will operate on the system. Streetcars shall be provided with tow bars with the capability to push or tow a disabled streetcar back to the maintenance facility.

The Streetcars shall have both air-conditioning and heating equipment sufficient to accommodate climatic extremes.

2.2.3.3 Streetcar Passenger Stops

Streetcar passenger stops function as the entrance and exit points for the system. They also serve as transfer points between streetcar and other modes of travel. Stops shall provide facilities for information on system use.

Streetcar stops have the following ADA compliant basic amenities:

- Boarding platform
- Shelter or Canopy providing protection from rain and wind (where not in conflict with surrounding environment)
- Seating, such as benches, and leaning rails
- Lighting
- Fare Ticket Vending and Validation Equipment
- Passenger Wayfinding and User Information

- Trash and Recycling Receptacles
- System maps
- Streetcar arrival information system

Streetcar stops shall be designed as barrier-free, unmanned stops. Although the current platforms height is constructed at 14 inches above top-of-rail to match the floor height of the vehicle, operation is also viable using a curb height of 10 inches above the top-of-rail and streetcars equipped with bridge plates, which could accommodate potential shared platform use with WMATA low-floor buses. All platforms shall be accessible in accordance with ADA and local applicable regulations.

2.2.3.4 Signal System

Streetcar operators shall operate streetcars under line-of-sight controls with assistance (where needed) from the Operations Control Center (OCC). Streetcar operation shall be governed by posted speed limits and local traffic signals.

A Train-to-Wayside Communication (TWC) system shall allow the streetcar operator to initiate signal priority as well as route selection. The TWC system shall enable the streetcar operator to execute the following functions:

- Activate powered track switches
- Automatically initiate requests for traffic signal priority

At major junctions and terminal stations, streetcar operators select their route from the cab using the TWC control panel. Transit bar style signal heads shall indicate at specific locations confirmation of the operation and locking of powered switches.

2.2.3.5 Maintenance and Storage Facility

The administration, dispatching, storage, maintenance, and monitoring of streetcar operations occur at Maintenance and Storage Facilities. Storage track capacity shall be sufficient to store the fleet of streetcars overnight. Shops shall provide preventive and unscheduled maintenance functions. Shops shall include parts storage, maintenance bays, a wash area, and ancillary tools and equipment. Each maintenance and storage facility shall be approved by the D.C. Department of Consumer and Regulatory Affairs and other supporting agencies prior to construction to ensure proper building codes and construction standards are followed. Where applicable, these facilities will adhere to the District's Sustainability and Green standards. Maintenance and Storage Facility functions are described in **Chapter 7**. Maintenance and storage facilities shall be ADA compliant.

2.2.4 System Technology Description

For the purpose of the applicability of the Design Criteria specified herein, the term 'Streetcars' denotes an urban transit system technology featuring electrically propelled modern articulated low floor vehicles that ride on steel wheels, run on steel rails, and utilizes power drawn from a source which is safe for operating within an urban roadway (e.g. overhead wire, super capacitor/battery, or non-contact inductive power transfer).

2.2.5 Fare Collection and Enforcement

An ADA compliant self-service, proof-of-payment fare collection system shall be employed on the system. Passengers shall purchase fare media via platform fare vending machines or other purchase methods and passes or cards as developed with DDOT. Ticket inspection shall be performed. Fare collection equipment is further described in **Chapter 3**.

2.2.6 Supervisory Control

2.2.6.1 Streetcar Supervision

The supervision of streetcar operation shall be accomplished by both field and Streetcar Control Center (SCC) personnel. The SCC shall be incorporated into the Maintenance and Operations Facility.

Road supervisors shall be assigned to specific locations when and where streetcar congestion is likely to occur and will also rove in assigned territories around the system.

System-wide streetcar operation shall be under the supervision of the dispatchers located at the SCC. Streetcar operations are continually monitored from the information received from streetcar operators and road supervisors. Dispatchers shall also be able to communicate with streetcar operators via the radio subsystem described in **Chapter 6**.

2.2.6.2 Records and Availability

The Contractor is required to operate the system during the specified time periods of operation and at the specified headways, within the specified reliability standards. The Contractor shall maintain a level of staffing, supervision and technical support that ensures system availability, minimizes service interruptions, and promotes timely response to problems. The Contractor shall monitor operations and maintain detailed records of all aspects of normal operation and incidents.

2.2.7 Communications

The communications system shall be designed to provide safe, reliable and secure operation of the streetcar system. The system will permit voice communication between streetcar operators and SCC and enable the System Operator to effectively monitor service and direct field personnel. It will capture the required levels of operations performance data.

Communication procedures shall be developed to maximize safety and operational efficiency both for the DC Streetcar System and with the District of Columbia emergency personnel.

2.3 SAFETY AND SECURITY

The modern streetcar design shall address system elements according to the requirements of the applicable standards listed. Should any standard or requirement conflict with another, the most stringent standard shall apply. The purpose of this section is to establish the safety and security standards for the design of all elements of the Streetcar project. To ensure the safety and security of the system and to resolve hazards and mitigate vulnerabilities on the project, the designer and contractors shall comply with the current version of the Streetcar Project's Safety and Security Management Plan (SSMP), Safety and Security Certification Plan (SSCP), and with the State Safety Oversight Agency (SSOA)-approved System Safety Program Plan (SSPP) and Security Emergency and Preparedness Plan (SEPP). These documents describe the process for approving the Streetcar system's safety and security design criteria, and for making changes to, or approving deviations from, the approved safety and security criteria.

Once these design criteria are approved, all changes to or deviations from them must go through a formal review process, as described in the SSMP, SSCP, DC Streetcar Administrative Procedures or Standard Operating Procedures. This formal review process is needed to assure that all potential safety or security impacts of the suggested guidance change, or deviation, have been adequately assessed and found acceptable before it is approved. The Project Manager, Project Management Consultant, or Design Engineer shall formally present recommended changes in, or deviations from, the manner described in the DC Streetcar SSCP and Procedures manuals.

2.3.1 General Safety and Security Requirements

Standards, specifications, regulations, design handbooks, safety design checklists and other sources of design guidance will be reviewed for pertinent safety and security design requirements applicable to the system. The design shall establish guidance derived from all applicable information. General system safety and security design requirements are:

- Identified hazards and vulnerabilities shall be eliminated, or associated risk shall be reduced, through design including material selection or substitution. When potentially hazardous materials must be used, such materials selected shall pose the least risk throughout the life cycle of the system.
- Hazardous substances, components and operations shall be isolated from other activities, areas, personnel and incompatible materials.
- Equipment shall be located so that access during operations, servicing, maintenance, repair or adjustment minimizes personnel exposure to hazards (e.g. hazardous chemicals, high voltage, electromagnetic radiation, cutting edges or sharp points) and threats.
- Risk resulting from excessive environmental conditions (e.g. temperature, pressure, noise, toxicity, acceleration and vibration) shall be minimized.

- Risk resulting from human error in system operation and support shall be minimized as part of the design effort.
- Risk resulting from excessive vulnerability to threats (e.g. theft, vandalism, sabotage, assault) shall be minimized as part of the design effort.
- In the case of risk from hazards and vulnerabilities that cannot be eliminated, alternatives that will minimize such risk shall be considered (e.g., interlocks, redundancy, fail safe design, system protection, fire suppression and other protective measures, such as clothing, equipment, devices and procedures, fencing, lighting, CCTV surveillance, and alarm systems).
- Power sources, controls and critical components of redundant subsystems shall be protected by physical separation or shielding, or by other suitable methods mutually agreeable to the design and the project team.
- When alternate design approaches cannot eliminate the hazard, safety and warning devices and warning and cautionary notes shall be provided in assembly, operations, maintenance and repair instructions. Distinctive markings shall be provided on hazardous components, equipment, and facilities to ensure personnel and equipment protection. These shall be standardized in accordance with commonly accepted commercial practice or, if none exists, normal procedures. Where no such common practice exists, the design shall propose the method or methods to be used for review and approval. The design shall provide all warnings, cautions, and distinctive markings proposed for review and comment.

Qualitative and quantitative analyses shall be performed, documented and furnished as part of the design process to ensure adequate consideration of safety and security. At a minimum, a Preliminary Hazard Analysis (PHA) and initial Threat and Vulnerability Assessment (TVA) shall be conducted for the project, and additional HAs and TVAs may be conducted as the need arises. The process for identification, assessment and resolution of hazards is fully described in the DDOT Hazard Assessment and Resolution (HAR) Procedure, and the process for identifying and managing threats and vulnerabilities is fully described in the DDOT TVA Procedure. If the recommended hazard resolutions or vulnerability mitigations conflict with the approved design criteria, they will be evaluated through the same process as any other deviation from the approved design criteria.

The Safety and Security Certifiable Items List (CIL) shall be used as the basis to develop design modifications and operating and maintenance procedures to eliminate or control the hazards and vulnerabilities. Approved resolutions of hazards or mitigations of vulnerabilities will be included on the CIL and other documentation as described in the SSCP.

Safety and security information and procedures shall be developed for inclusion in instructions and other publications. These shall include, but not be limited to, testing plans and procedures, operational training, the book of operating rules, maintenance procedures, and standard operating procedures (SOPs) which must also include emergency operating procedures.

2.3.2 Project Safety and Security Organization

The Project's safety and security organization is described in the DC Streetcar SSMP and detailed in support plans such as the SSCP. Refer to those plans for information on the Project safety and security organization and individual and committee responsibilities.

The Streetcar design shall address system elements according to the requirements of the applicable standards listed. Should any standard or requirement conflict, the most stringent standard shall apply. Standards, specifications, regulations, design handbooks, safety and security design checklists, and other sources of guidance shall be reviewed for pertinent safety or security design requirements applicable to the system. The design shall establish criteria derived from all applicable information. General safety criteria that shall be adopted, general security criteria, project-specific safety and security criteria, a listing of applicable codes and standards, as well as reference documents are provided here.

2.3.3 General Safety Criteria

These criteria for systems, fixed facilities, structural designs, and subsequent operational procedures shall ensure that the system safety goals are implemented and documented through all aspects of design development, construction, implementation, testing, operations, and maintenance. General system safety criteria include:

1) Minimize exposure of personnel operating, maintaining, or repairing equipment to hazards such as entrapment, chemical burns, electrical shock, cutting edges, sharp points, electromagnetic radiation, or toxic atmospheres.
2) Emergency equipment and devices for public use shall be clearly identified and accessible in accordance with ADA requirements. Interlocks, cutouts, fittings, etc., shall be accessible through access panels, which shall be secured to prevent tampering and vandalism.
3) Where failures could result in personal injury, major system damage, or inadvertent operation of safety critical equipment, redundancy or fail-safe principles shall be incorporated into the design.
4) Physical and functional interfaces between subsystems shall be analyzed. Those hazards associated with interfaces shall be specifically identified as system integration hazards and tracked for effective resolution.
5) There shall be no single-point failures in the system that can result in an unacceptable or undesirable hazard condition.
6) If an unacceptable or undesirable hazard condition can be caused by combining multiple incident failures, then the first failure shall be detected, and the system shall achieve a known safe state before subsequent failures occur.
7) All safety critical elements in a vital system shall be designed and implemented with fail-safe principles. Fail-safe principles shall be realized by designing the system to have intrinsically safe failure characteristics or by designing the system with verifiable techniques that detect potentially unsafe failures and ensure that the system reverts to a known safe state.

- The following criteria shall be used, as a minimum, for implementing fail-safe functions and vital circuits:
    - Component failures or loss of input signals shall not cause unsafe consequences and shall not, when added to other failures, cause unsafe consequences.
    - Neither loss of electric power nor spikes in power delivery shall cause unsafe consequences.
    - Any number of simultaneous component failures attributable to the same cause or related causes shall not result in an unsafe condition.
- The following criteria shall apply to electrical and electronic circuits:
    - Broken wires, damaged or dirty contacts, relays failing to respond when energized, or loss of power shall not result in an unsafe condition.
    - The relays used in vital circuits shall conform to all applicable parts of the AREMA Communications and Signals Manual of Recommended Practice, Section 6, Relays.
    - Circuitry components shall be considered able to fail in either the open or shorted condition. It shall be assumed that multi-terminal devices can fail with any combination of opens, shorts, or partial shorts between terminals. Protection shall be provided in the event that any amplifier is subject to spurious oscillations at any frequency.

8) Where redundancy is used in a safety critical area, there shall be no single point of failure that would result in the loss of safety protection. Redundant paths shall not contain a common predominant failure mode.
9) Design shall include component interlocks wherever an out-of-sequence operation can cause a hazard.
10) Suitable warning and caution notes in operating, assembly, maintenance and repair instructions, and distinctive markings on hazardous components, equipment, or facilities for personal protection, shall be provided.
11) Color-coding used for equipment and facilities shall be uniform.
12) Each design shall be evaluated for hazards to identify basic deficiencies, inherent hazards of operation, safety critical malfunctions, maintenance hazards, human factors deficiencies, environmental hazards procedural deficiencies, and for compliance with codes, standards, and regulations. Written documentation of this evaluation shall be provided at the time final design is accepted.
13) The system safety analysis shall include review of fixed facilities and structures for employee access and maintenance safety.
14) Maintenance activities required to preserve or achieve risk levels shall be prescribed to the Rail Operations Manager during the design phase. These maintenance activities shall be minimized in

both frequency and in complexity of their implementation. The personnel qualifications required to adequately implement these activities shall also be identified.

15) Software faults shall not cause an unacceptable or undesirable hazard condition.
16) Unacceptable hazards shall be eliminated by design.
17) Hazardous substances, components and operations shall be isolated from other activities, areas, personnel and incompatible materials.
18) Risk resulting from excessive environmental conditions (e.g. temperature, pressure, noise, toxicity, acceleration, and vibration) shall be minimized.

2.3.4 Security Criteria

System security shall be provided by a combination of procedures, subsystems and devices to assure security of passengers, employees, equipment, and facilities. Operating procedures shall be developed to maintain the fullest use of the security systems provided.

2.3.4.1 General Security Criteria

The system security goal is to provide transit system facilities and operations that minimize threats to the employees, passengers, contractors, first responders, and the general public that operate, maintain, construct, use or are in the vicinity of transit operations. To accommodate this goal, engineering designs shall be reviewed to determine if threats and vulnerabilities have been identified and eliminated, or minimized or controlled to an appropriate level throughout the intended service life. Engineering designs must satisfy security design requirements applicable to the individual systems and elements.

More detailed goals of the system security program include:

- Design security into the Streetcar Project by using such concepts as Crime Prevention through Environmental Design (CPTED), Situational Crime Prevention (SCP), and security technology.
- Incorporate security features into the designs to reduce threats and vulnerabilities, such as: fencing, lighting, guard shacks, security office, gates, sensors or motion detectors, burglar and intrusion alarm systems, closed circuit TV (CCTV), public address systems, emergency telephones, silent alarm, card or controlled access.
- Employ a continuing Threat and Vulnerability Assessment (TVA) process.
- Implement the recommendations included in the FTA's Transit Security Design Considerations, (FTA-TRI-MA-26-7085-05, November 2004).
- Comply with any U.S. Department of Homeland Security, Office for Domestic Preparedness directives.
- Use the Transportation Research Board Report Deterrence, Protection, and Preparation as guidance throughout the design.

The security design shall incorporate the following mitigation strategies as an integral part of the design process of new facilities:

- Defensive layering: Defensive layering provides multiple levels of security in order to slow or prevent an adversary's access to a site.
- Crime Prevention through Environmental Design (CPTED) principles: One of the primary goals of CPTED is to reduce the opportunity for specific crimes by creating an environment that deters crime. It focuses on design techniques and use of a particular space to deter crime with four basic elements: natural surveillance, natural access control, territorial reinforcement, and maintenance. CPTED strategies include: maximizing visibility of people, passenger flow areas, and building and structure areas; providing adequate lighting and minimizing shadows; landscape plantings that maximize visibility; gateway treatments; perimeter control; elimination of structural hiding places; and open lines of sight.
- Target hardening: Target hardening employs structural techniques to increase the ability of a facility to minimize vulnerability to criminal activity. It might range from structure techniques employed in facility design or construction to withstand an explosion while minimizing the loss of life and property damage to employing graffiti or other forms of vandalism guards for protection of walls or glass to prevent marring or shattering.
- Situational Crime Prevention (SCP) principles: SCP is closely related to CPTED. Its premise is that the physical environment can be managed to produce desired behaviors in those who enter a facility by such factors as assuring cleanliness, the type and amount of staffing, and various operational and physical measures.
- Physical security system elements: Physical security elements are intended to: 1) delay an intruder to allow time to detect them, and 2) inform responders of a penetration of a facility or protected area.
- Passenger security: a Train-borne intercom system shall be provided for passengers to notify the operator of any urgent incidents on board the vehicle. All such systems shall satisfy accessibility requirements and effective communication requirements set forth in the ADA standards.
- Public security: In addition to application of CPTED design principles, public street areas where the vehicles will pick up and discharge passengers should be designed to enable them to be maintained in a clean and secure manner. Stop areas should be marked and illuminated for maximum assurance of safety and security, and shelters designed to minimize vandalism and graffiti.
- Employee security: The operator shall be provided the capability of activating a "silent alarm". Activation of this alarm shall alert the central control facility of a problem on the train.
- Facility Security: CCTV cameras shall be provided at the Maintenance and Storage Facility, and in storage areas of high value equipment and parts. Fire and intrusion alarm systems shall be provided to monitor critical facilities and equipment such as traction power substations and communications equipment. Alarms and CCTV will be monitored at the central control facility.

- Information and Information System Security: Sensitive data such as personal identification information, procurement documents, and security information storage systems must be fortified against unauthorized access. Additionally, contract specifications will require contractors to establish a formal information protection program and plan that meet federally-mandated Security Sensitive Information (SSI) requirements and other requirements as set by the Streetcar System, including:
    - Compliance with the Code of Federal Regulations regarding the release of transit-related SSI.
    - Protected security related information may not be subject to subpoena or discovery and not subject to inspection by the general public, and shall include:
        - Assessments, plans or records that reveal DDOT susceptibility to terrorism.
        - Drawings, maps, or plans showing location and vulnerabilities of infrastructure.
        - Records or other information that detail specific emergency response plans.
        - Written information detailing response agency plans to a terrorist attack.
        - Identification of equipment used for covert, emergency, or tactical operations.
        - Response agency radio frequencies, codes, passwords, or programs.
    - Personal, financial, and medical information shall be protected in accordance with relevant federal regulations (e.g., Freedom of Information Act, Privacy Act, Health Insurance Portability and Accountability Act [HIPAA], and Health and Human Services Standards for Privacy of Individually Identifiable Health Information).
    - Information technology systems used to store and process security and personal information shall be protected, as the stored data would warrant.

Individuals who require access to sensitive, personal, or proprietary information in order to accomplish their duties shall sign and comply with a non-disclosure agreement. This agreement prohibits an employee from disclosing designated information, even after their employment ceases. Individuals who require access to documents labeled SSI shall comply with the System-developed procedures that comply with the Code of Federal Regulations (CFR) pertaining to such access.

2.3.4.2 Project-Specific Criteria

Safety and security criteria are interspersed in respective sections of the *DC Streetcar Design Criteria*. Detailed safety and security-related criteria for the various subsystems of the streetcar project can be found in the applicable chapters and sections of the *DC Streetcar Design Criteria*:

- Track Geometry and Clearances, and Rail: 4, 5
- Vehicular traffic Interface with streetcar: 5

- Traffic Signals: 5, 6
- Utility relocations: 5
- Communications: 6
- Structural Elements: 5
- Traction Power and OCS: 6
- Vehicle: 4
- Maintenance and Storage Facility: 7
- Lighting: 3, 5, 7
- Grounding: 6, 7
- Corrosion Control: 6
- Passenger areas: 3

Additional information relating to safety and security criteria and the processes with which they were developed can be found in the following documents, separate from the Design Criteria:

- Safety and Security Management Plan (SSMP)
- Safety and Security Certification Plan (SSCP)
- Hazard Analyses (HAs)
- Threat and Vulnerability Assessments (TVAs)
- Rail Activation Plan (RAP)
- System Integration Test Plan (SITP)
- Start-Up and Pre-Revenue Operations Plan (PROP)
- Transportation and Maintenance Operations Plan (TMOP)
- System Safety Program Plan (SSPP)
- System Security Plan (SSP)
- Security and Emergency Preparedness Plan (SEPP)

The Design Engineer shall identify those system elements and design standards to comply with the major steps in the safety certification process. These steps are implemented beginning with system design and continuing through the start of revenue operation.

- Define and identify those safety-critical system elements to be certified.

- Define and identify those security-related elements to be certified in a Certifiable Elements List (CEL).
- Define and develop a Certifiable Items List (CIL) for each Certifiable Element.
- Identify safety and security requirements for each certifiable item.
- Verify and document design compliance with the safety and security requirements.

Each design certifiable item shall have an associated verification form with two sections. As detailed in the SSCP, the designers and design supervisors will complete the first section, which will then be reviewed and signed by a safety and security manager. After design for an element is completed and certified, the associated forms will be transferred to Construction Management. Inspectors will verify that each identified design item has been constructed, and tested as necessary, and then sign the form in the second section, which then will be verified and signed by the Construction Manager, and then will be reviewed and signed by a safety and security manager. After all design items in an element are certified for design and construction, the element will be safety and security certified by the process described in the SSCP.

2.3.5 Safety- and Security -Related Codes and Standards

Detailed safety-related and security-related criteria for various systems and subsystems of the system are covered in the applicable section of this Design Criteria. This list is not exhaustive, but is provided below to assist the designer.

- AREMA Manual for Railway Engineering
- TCRP Report 155 Track Design Handbook for Light Rail Transit
- APTA Guidelines for Design of Rapid Transit Facilities
- NESC sections 25, 26, rule 261H, Article 225
- FHWA MUTCD
- AASHTO Policy on Geometric Design of Highways and Streets
- AASHTO Roadside Design Guide
- 49 CFR Part 192; ASME Standard for Gas Transmission and Distribution Piping Systems
- Occupational Safety and Health Administration (OSHA)
- IEC 61287-1, EN12663-2000, EN15227, EN1993-1-9
- ANSI/UL 1995, Section 33
- ANSI/ASHRAE Standard 15
- ANSI Z26.1

- NFPA 70, 72, 101, 130
- ISO 2204, 3381, 3095
- AREMA Manual for Railway Engineering, Chapter 33 – Electrical Energy Utilization,
- International Building Code (IBC)
- FTA's Transit Security Design Considerations, FTA-TRI-MA-26-7085-05, November 2004.
- Applicable Federal, state, and local codes and standards

The following documents shall be used as guidance or reference for the design criteria and shall be used as such for all phases of the design process:

- Compliance Guidelines for States with New Starts Projects, DOT-FTA-MA-5006-00-1, U.S. Department of Transportation, Federal Transit Administration, June 2000.
- Manual for the Development of Rail Transit System Safety Program Plans. American Public Transit Association, September 1991.
- MIL-STD 882D, System Safety Program Requirements, U.S. Department of Defense, January 19, 1993.
- FTA Regulations, 49CFR, Part 659, Rail Fixed Guideway Systems; State Safety Oversight, U.S. Department of Transportation Federal Transit Administration, April 29, 2005.
- Handbook for Transit Safety and Security Certification, DOT-FTA-MA-90-5006-02-01, U.S. Department of Transportation Federal Transit Administration, November 2002.
- Hazard Analysis Guidelines for Transit Project, DOT-FTA-MA-26-5005-00-01, U.S. Department of Transportation Federal Transit Administration, January 2000.

In addition to the documents listed above, the design shall be in accordance with the following standards. If the standards requirements conflict, the most stringent requirement shall apply.

- Standards for Rail Fixed Guideway Systems, CCR 723-14.
- National Fire Protection Association (NFPA) – 1, 2, 10, 13, 14, 70, 72, 90A, 101, 130
- Federal Occupational Safety and Health Administration (OSHA) Standards
    - (General Industry), 29 CFR 1910
    - (Construction Industry), 29 CFR 1926
- Uniform Building Code (UBC) or International Building Code (IBC), as applicable, supplemented by local municipal code amendments.
- Uniform Fire Code (UFC) or International Fire Code (IFC), supplemented by local municipal code amendments.

The following regulations and guidelines shall be considered in the design of the Streetcar System, where applicable:

- Federal Railroad Administration - 49CFR 51, 201, 202, 205, 207, 209, 211, 213, and 241.
- TCRP Report 17: Integration of Light Rail Transit Into City Streets
- TCRP Report 175: Guidebook on Pedestrian Crossings of Public Transit Rail Services
- TCRP Report 153: Guidelines for Providing Access to Public Transportation Stations
- American Public Transit Association (APTA) Guidelines for the Design of Rapid Transit Facilities
- APTA Crime Prevention through Environmental Design (CPTED) for Transit Facilities (APTA SS-SIS-007-10)
- National Association of City Transportation Officials (NACTO) Urban Street Design Guide

2.4 APPLICABLE REQUIREMENTS, REGULATIONS, CODES, AND STANDARDS

2.4.1 Climate and Environmental Conditions

The system is located in a region that has a humid subtropical climate. Summers are hot, humid and wet. July is the warmest month, with an average high of 88°F (31°C) and an average low of 70°F (21°C). Winters are generally cool to cold, with occasional snowfall. January is the coldest month, with an average high of 42°F (6°C) and an average low of 27°F (-3°C). Precipitation is fairly evenly distributed each month, averaging 40 inches of rainfall and 15 inches of snowfall, annually. **Table 2-1** shows the average, maximum and minimum temperatures within the District of Columbia.

The system's structural integrity, with trains stopped on any guideway section, shall withstand wind pressures determined in accordance with the District of Columbia Building Code (DCBC), as adopted by the District of Columbia, with no damage to the streetcar or other appurtenances. Wind velocity for computing the previous when the train is not in sheltered storage shall be 65 mph. When the train is in sheltered storage, the wind velocity shall comply with the requirements of the DCBC. The minimum safety factors against failure shall be per the DCBC.

The system shall be capable of operating under varying wind conditions. In sustained winds up to and including 45 mph, the System shall be capable of normal operations, meeting all requirements of the contract. In sustained wind conditions above 45 mph and below 65 mph, the system shall operate safely, but allowing up to 25 percent degradation in overall performance (e.g. train velocity, acceleration, and deceleration).

For wind velocity above 65 mph, there is no requirement for any system operation. However, vehicles and all other equipment shall be able to safely withstand the wind pressures due to design wind speeds as per the DCBC.

The District of Columbia has a humid environment that actively supports the growth of fungi and various corrosion reactions on metals. System materials and equipment shall be selected and designed accordingly. Average and record monthly temperatures are as follows:

Average Minimum: 27° F (-3° C) Record Minimum: -15° F (-26° C)

Average Maximum: 88° F (31° C) Record Maximum: 106° F (41° C)

- Precipitation shall be based on the Official Weather Observation Station closest to the System. Average precipitation is:

  Maximum monthly rainfall: 3.8 inches (96 mm)

Table 2 - 1 | District of Columbia Climate Data

Climate Data for District of Columbia													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record High °F (°C)	79 (26)	84 (29)	93 (34)	95 (35)	99 (37)	102 (39)	106 (41)	106 (41)	104 (40)	96 (36)	86 (30)	79 (26)	106 (41)
Average High °F (°C)	42.5 (6)	46.5 (8)	55.7 (13)	66.3 (19)	75.4 (24)	83.9 (28)	88.3 (31)	86.3 (30)	79.3 (26)	68.0 (20)	57.3 (14)	47.0 (8)	66.4 (19)
Average Low °F (°C)	27.3 (-3)	29.7 (-1)	37.7 (3)	45.9 (7)	55.8 (13)	65.0 (18)	70.1 (21)	68.6 (20)	61.8 (17)	49.6 (10)	40.0 (4)	32.0 (0)	48.6 (9)
Record Low °F (°C)	-14 (-26)	-15 (-26)	4 (-15)	15 (-9)	33 (1)	43 (6)	52 (11)	49 (9)	36 (2)	26 (-3)	11 (-11)	-13 (-25)	-15 (-26)
Rainfall inches (mm)	3.2 (81)	2.6 (67)	3.6 (91)	2.8 (70)	3.8 (97)	3.1 (80)	3.7 (93)	3.4 (87)	3.8 (96)	3.2 (82)	3.0 (77)	3.1 (78)	39.4 (1000)
Snowfall inches (mm)	5.9 (150)	5.1 (130)	1.6 (41)	0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.7 (18)	1.4 (36)	14.7 (373)
Source: NOAA, (1971 – 2000)													

2.4.2 Application of Design Criteria

The material contained in the following sections provides a uniform basis for design and is expected to be refined and expanded during engineering design.

The *DC Streetcar Design Criteria* (criteria) represents a recommended set of uniform and minimum guidelines for use in the development, design, engineering, and implementation of the DC Streetcar System. It is not a specification; therefore, the following guidance is intended to set minimum guidelines to assure design uniformity and consistency of systems, components, and facilities of streetcar infrastructure.

These criteria do not substitute for engineering judgment and sound engineering practice. Specific exceptions may apply in special cases. The designers are responsible for identifying any necessary departure from the criteria contained in this document, and then notifying DC Streetcar System Manager. Any exceptions from or changes to the criteria must be reviewed and approved by DDOT prior to use in the design. Applications for change in the criteria, additions to the criteria, and other questions shall be submitted in writing.

This Design Criteria may periodically require revisions to reflect changes in environment, industry, engineering practices, operation, and maintenance, or to reflect policy changes.

2.4.3 Codes and Standards

The designer is fully and solely responsible for determining all applicable codes and standards for the proposed work. The designer, at a minimum, shall comply with the requirements of the following codes. Additional codes and standards, laws and ordinances and requirements shall be determined by the designer. In case of conflicts between the criteria, standards, codes, regulations, ordinances, etc. the more stringent requirement shall govern unless otherwise directed, in writing, by the District Department of Transportation. Some applicable codes, standards and guidance documents are:

- AASHTO, A Policy on Geometric Design of Highways and Streets
- AASHTO, Guide for Design of Pavement Structures
- AASHTO, Guide for Geometric Design of Transit Facilities on Highways and Streets
- AASHTO, Roadside Design Guide
- AASHTO, Guidelines for Skid Resistant Pavement Design
- AASHTO, Roadway Lighting Design Guide
- AASHTO, Guide for Development of Bicycle Facilities
- AASHTO LRFD Bridge Design Specifications, Customary U.S. Units
- American Society for Testing of Materials (ASTM), various standards
- FHWA, Manual on Uniform Traffic Control Devices (MUTCD)
- Code of Federal Regulations (CFR)
- United States Access Board, ADA Accessibility Guidelines (ADAAG) for Buildings and Facilities
- United States Access Board, Uniform Federal Accessibility Standards (UFAS)
- DDOT, Design and Engineering Manual

- DDOT, Standard Specifications for Highways and Structures
- DDOT, Standard Drawings
- DDOT Green Infrastructure Standards
- DDOT Design Guidelines for Traffic Calming Measures for Residential Streets in the District of Columbia
- DDOT Public Realm Design Manual
- DDOT Right of Way Policies and Procedures Manual
- DDOT Temporary Traffic Control Manual
- DDOT Work Zone Safety and Mobility Policy
- DDOT, Pedestrian Master Plan
- DDOT, Bicycle Facility Design Guide
- Anacostia Waterfront Transportation Architecture Design Standards
- DDOT, Policy and Process for Access to the District of Columbia Interstate and Freeway System
- District of Columbia Traffic Calming Policies and Guidelines
- WMATA LRT and Streetcar Project Interface: Coordination for the Washington DC Metropolitan Area Technical Memorandum: Compatibility of Systems and Infrastructure WMATA Adjacent Construction Project Manual
- DC Water, Standard Details and Guidelines
- DC Water, Standard Specifications
- DOEE, Stormwater Management Guidebook
- DOEE, Erosion and Sediment Control Manual
- TCRP Report 155 – Track Design Handbook for Light Rail Transit
- Catalog of Recommended Pavement Rehabilitation Design Feature for the District of Columbia
- Catalog of Recommended Pavement Reconstruction Design Feature for the District of Columbia
- FHWA, Technical Bulletin FHWA-SA-98-79 Life-Cycle Cost Analysis in Pavement Design
- District of Columbia Zoning Regulations

The designer shall be responsible for determining all entities and the Authorities Having Jurisdiction (AHJ) that may be impacted by the designer’s work or may have jurisdiction over the designer’s work. The design shall conform to all the requirements and minimum guidance adopted by the AHJ. In cases of conflict, the more stringent requirements shall govern. It is the responsibility of the Designer to determine and comply with the most severe requirements of applicable codes, standards, laws, and the Contract requirements. The designer's team should include a person solely focused on the end goal of obtaining the necessary permits to construct the various Streetcar components. An experienced permit expeditor should have the ability to assist the designer's team on critical design elements and general plan notes that will help to accelerate the review process with the governing agencies. A clear line of communication shall be established with each governing agency, including, but not limited to, DCRA, DOEE, DC Water, and DDOT.

Where no provision is made in the codes for particular features of the design, the best current industry practice shall be followed. The list below is a preliminary guide of applicable codes and standards and requirements in which the design should comply. The designer shall evaluate and include all other applicable codes and standards in the design. The latest edition of the applicable codes and standards shall be followed.

- DC Building Code (as applicable) and all references and standards cited therein; governed by DCRA
- DC Accessibility Code and the Americans with Disabilities Act (ADA)
- AASHTO A Guide for Geometric Design of Transit Facilities on Highways and Streets
- District Department of Transportation requirements
- Relevant ASHRAE, ASPE, ANSI, NFPA, and ASTM Standards
- National Electric Code (NEC)
- District of Columbia Ordinances

Agencies or entities who publish codes, standards and other requirements that may be applicable to the project are listed below. The following is a partial list of Entities and AHJ include. It is the designer's legal, contractual and professional duty to design in accordance with all the applicable requirements, whether or not referenced herein.

- American Association of State Highway and Transportation Officials (AASHTO)
- Americans With Disabilities Act (ADA)
- American Concrete Institute (ACI)
- American Society for Testing Materials (ASTM)
- American Institute of Steel Construction (AISC)
- American National Standards Institute (ANSI)
- American Public Transportation Association

- American Society of Mechanical Engineers (ASME)
- American Welding Society (AWS)
- Anacostia Waterfront Initiative (AWI)
- Concrete Reinforcing Steel Institute (CRSI)
- Concrete Specifications Institute (CSI)
- District of Columbia Statutes, Rules and Regulations
- District of Columbia Accessibility Code for Building Construction
- District of Columbia Building Code
- District Department of Transportation (DDOT)
- DC Water and Sewer Authority (DC Water)
- District Department of Energy and Environment (DOEE)
- National Fire Protection Association (NFPA)
- National Electric Code (NEC)
- National Electrical Manufactures Association (NEMA)
- National Association of City Transportation Officials (NACTO)
- North of Massachusetts (NoMa) Business Improvement District
- Occupational Safety & Health Administration (OSHA)
- Precast Concrete Institute (PCI)
- Underwriters Laboratories (UL)
- Transportation Research Board (TRB)
- Washington Metropolitan Area Transit Authority (WMATA)

District Department of Transportation

Chapter 3

Stops, Terminals and Intermodal

Content

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3.1 STREETCAR STOPS

3.1.1 Preferred Siting Criteria

Coordination with Plans, Projects, and Adjacent Land Uses

The location of streetcar stops shall take into consideration recommendations identified in relevant neighborhood plans, District plans, opportunities and plans to complement revitalization projects, and supportive land use. Streetcar stops shall also take into consideration streetcar vehicle size, streetcar platform length, integration with WMATA Metrobus and DC Circulator bus where applicable, and traffic engineering considerations. All necessary permits and inspections will be conducted in accordance with the District Department of Consumer Regulatory Affairs (DCRA) and supporting agencies (e.g., DOEE and DC Water). DDOT and its designated team shall work closely with DCRA throughout the permitting process and address all review comments.

The system shall be designed in accordance with the following documents:

- DDOT Design and Engineering Manual
- DDOT Public Realm Design Manual
- DC Streetcar Land Use Study
- Small Area Plans and Studies
- Americans with Disabilities Act (ADA) Standards for Accessible Design
- Memorandum of Agreement Between State Historic Preservation Office (SHPO) and DDOT (dated 5/26/2013 - valid through 2023)

3.1.2 Guidance for Streetcar Stop Locations

Streetcar stops should be located in areas of highest pedestrian activity and development concentration, with consideration given to both existing conditions and future improvements. Stop locations should be coordinated with the SHPO as part of the Section 106 review process during the environmental phase. The stop locations are based on the guidance provided by the selection criteria listed below, as well as adhering to all ADA requirements:

- ***Locate streetcar stops at major intersections*** – This will maximize convenience and minimize disruption to existing transit operation, traffic flow and land uses. Major intersections provide customers with a street crossing when walking to or from streetcar stops and create greater consistency for motorists regarding where they will have to stop for boarding or alighting customers. Streetcar stops should have access from both sides of the platform where feasible.

They shall provide access from the nearest intersection to the boarding and alighting area and shall require ADA compliant access to any facility that is provided in support of streetcar service.

- ***Increase accessibility and mobility to major activity and neighborhood centers*** – Activity centers, such as central business districts, shopping and retail areas, parks, public buildings, medical facilities, etc. are major trip generators for streetcar passengers. In addition, neighborhood activity centers, such as libraries, convenience stores, and schools also generate trips. Identifying the location of these trip generators is a very important step in the streetcar stop selection process. Locating the streetcar stops close to these activity centers encourages transit use and reduces automobile use.

- ***Promote transfer opportunities and connectivity to existing and planned transit services*** – Location of streetcar stops shall be coordinated with existing Metrorail stations, Metrobus stops and DC Circulator stops. Locating streetcar stops in proximity to major Metrorail stations and Metrobus stops facilitates transfers from one transit mode to another. These connections must provide an accessible pedestrian route.

- ***Maintain stop spacing of approximately ¼ mile to ½ mile*** – Spacing of streetcar stops should be evaluated on a corridor-by-corridor basis. Providing ideal stop spacing with a 5 to 10-minute walk supports walkability and access to the system if sufficient infrastructure is provided for the user. It is also important to maintain consistent spacing to provide access and uniform transit coverage in the District. It is recommended that the stops be no farther apart than ½ mile but can vary based on activity centers and operational characteristics. To make transit services faster, and reduce customer journey times, the streetcar stops should not be located any closer than a ¼ mile, unless providing direct connections to major transfer locations or activity centers in high activity locations in the core of the system. Ideal stop spacing also promotes better efficiencies and performance for the streetcar operations.

- ***Fill gaps where existing transit services may not be currently provided*** – Locate streetcar stops in areas that have limited or inadequate transit service. The design of streetcar routes and the location of alignments should take into consideration the need for providing transit services where existing services are limited or inadequate, providing better coverage in the un-served and under-served areas of the District.

- ***Ensure consistency with local land use plans, urban design efforts and historic preservation concerns*** – DDOT and DCOP will coordinate to ensure consistency between transportation and land use planning studies. The location of the streetcar stops requires an understanding of the neighborhood vision, existing conditions, market trends and the proposed development in the area. The small area plans (SAP) may include recommendations for transportation improvements in that neighborhood or area and also provide valuable insight regarding a community's urban design aspirations. DDOT reviews relevant planning studies and SAP's and coordinates with DCOP to ensure that SAP recommendations are taken into consideration when streetcar stop locations are determined.

- ***Promote safety and a pedestrian friendly environment*** – Considerations should be incorporated into streetcar stop location and design that reduce safety concerns and incidents involving streetcar vehicles, riders, bicyclists and pedestrians. Safety issues may include interfaces with adjacent traffic and pedestrian crossings and access to and from streetcar vehicles from the platform. Safety must encompass access to and from the platform and the pedestrian accessible route within the sidewalk.

3.2 STREETCAR STOP PLATFORMS

The intent of this section is solely to provide guidance for the design of streetcar stop platforms. Other streetcar infrastructure elements pictured in this section are for illustrative purposes and not intended to indicate design guidance for those elements. Non-platform elements are shown in this section only to provide context for the platforms themselves. Design criteria for non-platform elements are provided elsewhere in this document.

It should also be noted that for all sections of this document, the guidance presented in this document is intended to serve as the baseline for the design of the various elements of streetcar infrastructure. It should be noted that various areas of the District may have additional guidelines or review processes in place that may alter the final design criteria for any or all elements. Additionally, specific guidance for the design of streetcar elements may be provided by the environmental planning and review process for a given streetcar line. The final guidance associated with any environmental review or action shall be consulted as part of the design process.

Minimizing (and when possible eliminating) negative visual impacts of all elements of streetcar infrastructure is one of the goals of the DC Streetcar Program and the design criteria. To the extent that safe and reliable service can feasibly be provided, the design and installation of infrastructure elements shall reinforce the goal of minimizing negative visual impacts associated with any element of streetcar infrastructure.

3.2.1 Platform Configuration

Several types of streetcar platform configurations may be used in the DC Streetcar system. In all cases, considerations for pedestrian and bicycle accessibility, traffic, parking, loading zones, bus operations, platform size, and local land use and economic development need to occur when choosing the appropriate configuration for streetcar stops and platforms. The streetcar platform configuration types are:

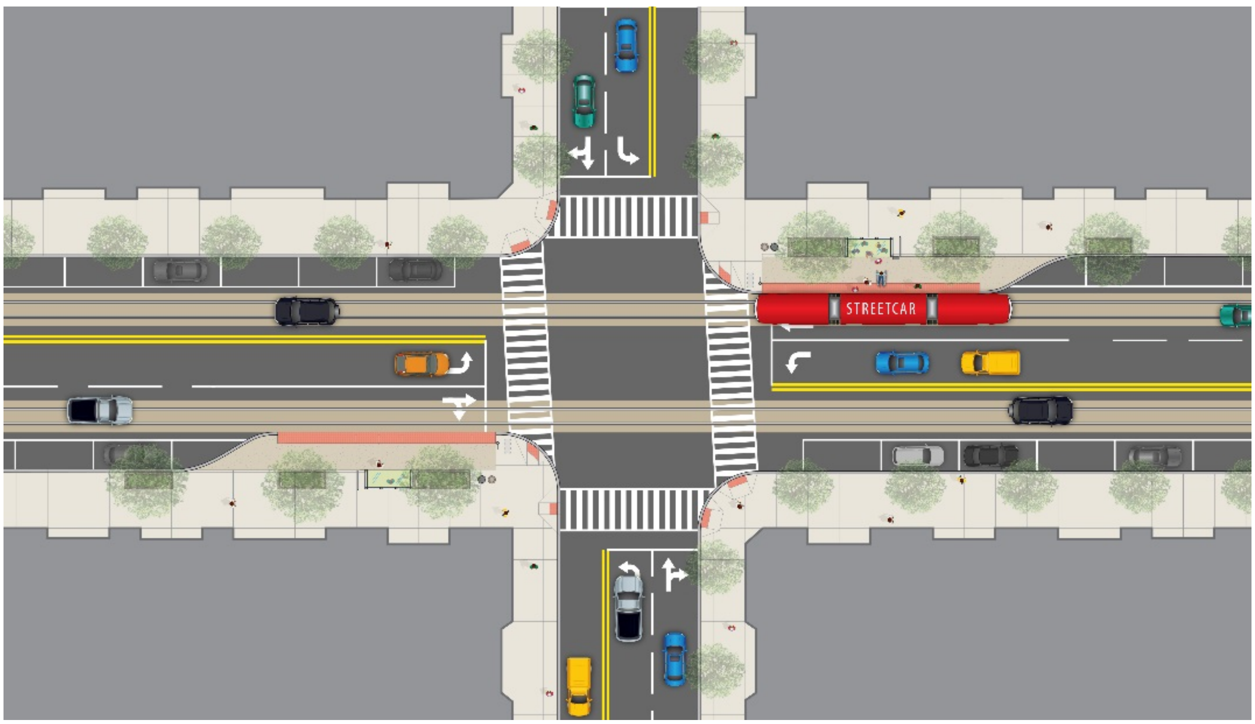
- Curb extension stop or “bulb-outs”
- Curbside stop: streetcar only, and shared bus and streetcar
- Median stop: shared platform and shared travel lanes, shared platform and dedicated streetcar lanes)
- Median in dedicated ROW stop: side median or staggered
- Pedestrian plaza stop

Figure 3-1 through **Figure 3-7** illustrate these streetcar platform types. These graphics are conceptual and are not intended to show the exact location and spacing of stop amenities. The planning, design and construction of streetcar stops will be determined on case-by-case basis and will require coordination between business owners, the public, and various agencies including the SHPO. During design, DDOT will evaluate bicycle usage and consider integration within the corridor or on adjacent corridors. Bicycle storage and interaction at streetcar platforms will be evaluated on a case-by-case basis.

3.2.1.1 Curb Extension Stop ("Bulb-out") Platforms

Curb extension stops are used for streets with on-street parking (**Figure 3-1**). The stop area uses a "bulb-out" design, which offers additional pedestrian space adjacent to the sidewalk. Curb extension platforms may be either near or far side stops depending on particular site conditions. The streetcar stop location shall be coordinated with existing bus stop locations.

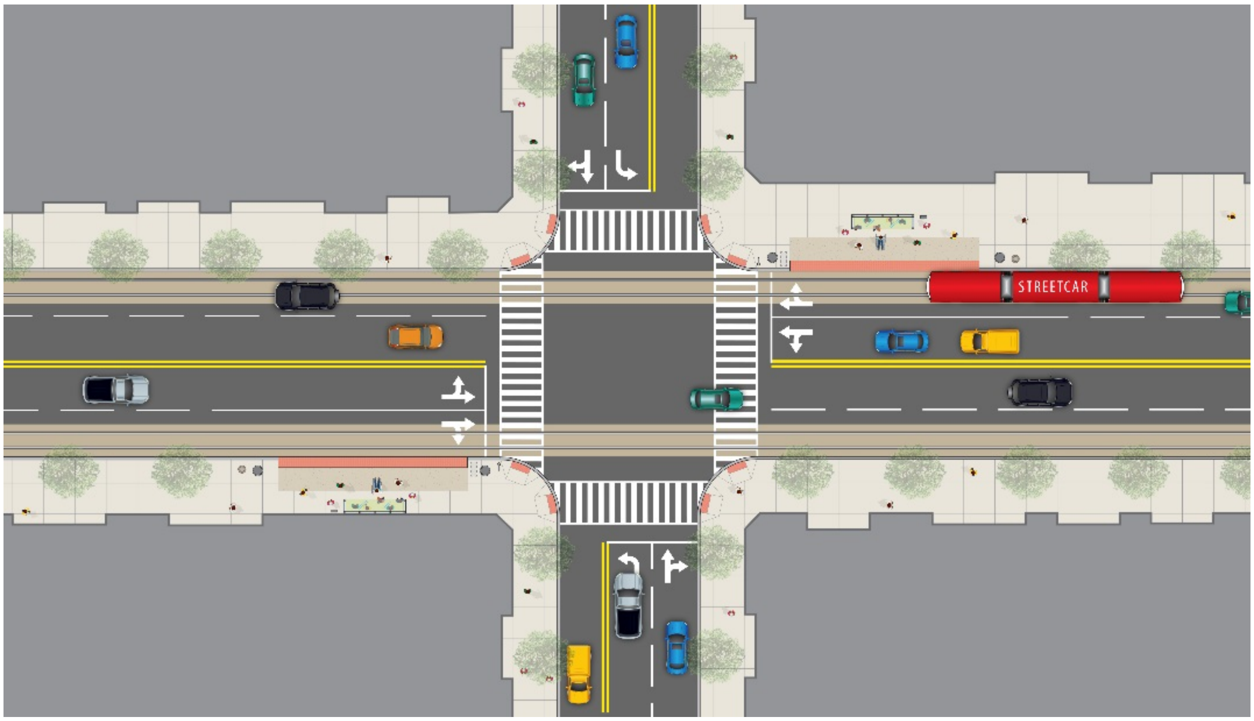
Figure 3-1 | Curb Extension Stop Platform



3.2.1.2 Curbside Stop Platforms (Streetcar Only)

Curbside stops are used for streets without on-street parking. The streetcar runs in the travel lane adjacent to the curb with loading and unloading directly from the sidewalk. Curbside platforms may be either near or far side stops depending on particular site conditions. The streetcar stop location shall be coordinated with existing bus stop locations.

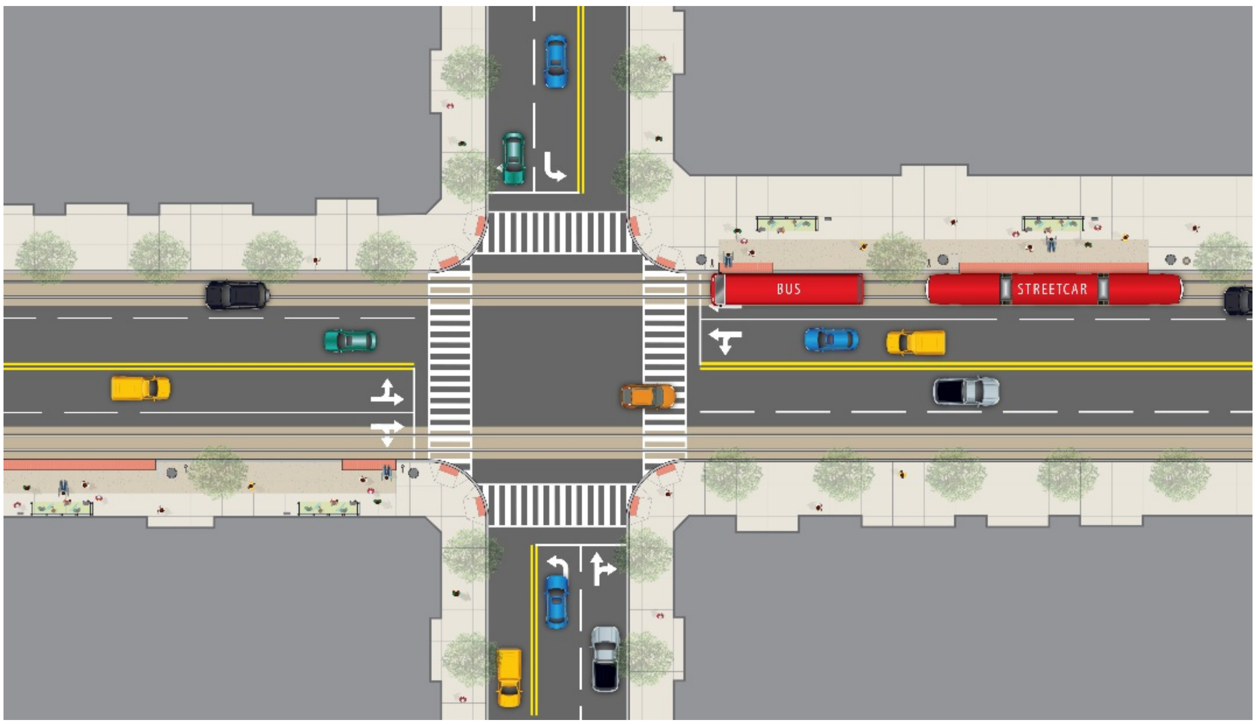
Figure 3-2 | Curbside Stop Platform (Streetcar only)



3.2.1.3 Curbside Stop Platforms (Streetcar and Bus Shared)

Curbside (Streetcar and Bus) stops are used for streets without on-street parking. This streetcar runs in the right travel lane, where curbside platforms are shared between streetcar and bus service with separate loading and unloading areas directly from the sidewalk. Curbside platforms maybe either near side or far side stops depending on particular site conditions.

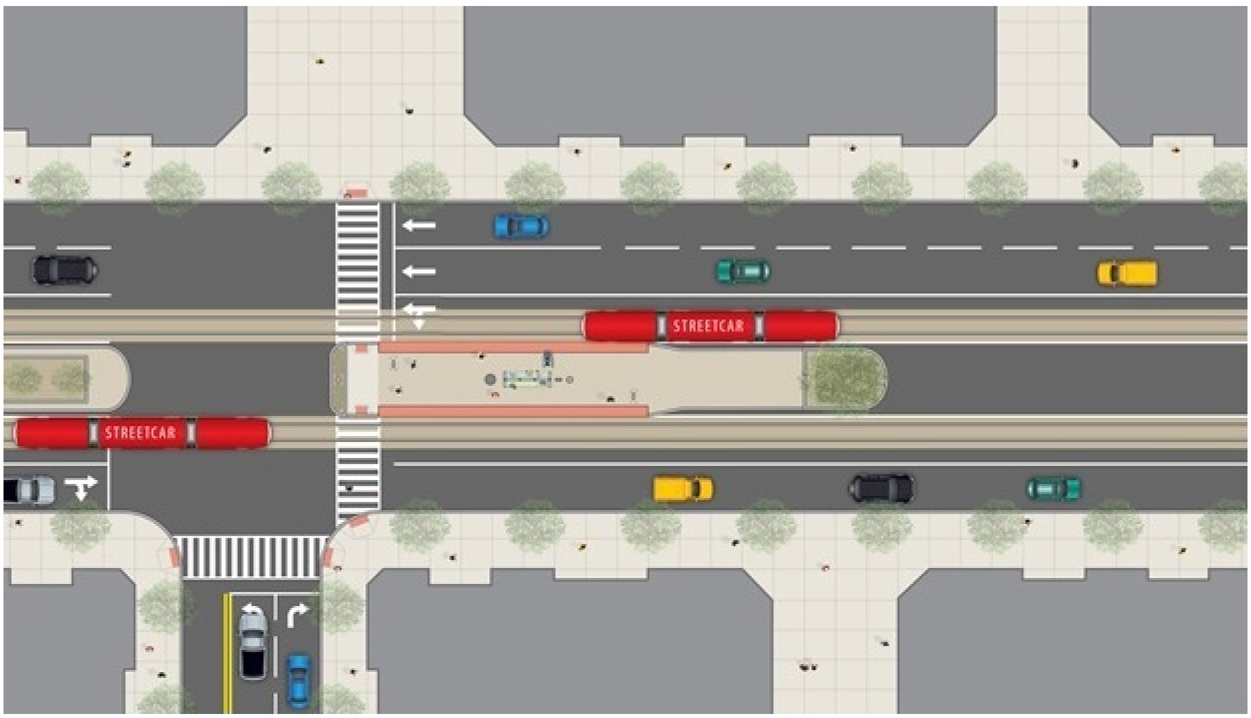
Figure 3-3 | Curbside Stop Platform (Streetcar and Bus)



3.2.1.4 Median Stop (Shared Platform and Shared Travel Lanes)

Median stop platforms are used for two-way streets where the streetcars are operating towards the center of the street. One variation accommodates streetcars within the shared travel lanes closest to the median. Streetcar stop platforms are located between the two tracks and are bidirectional/shared (**Figure 3-4**) for each direction. Median stop platforms may be either near or far side stops depending on particular site.

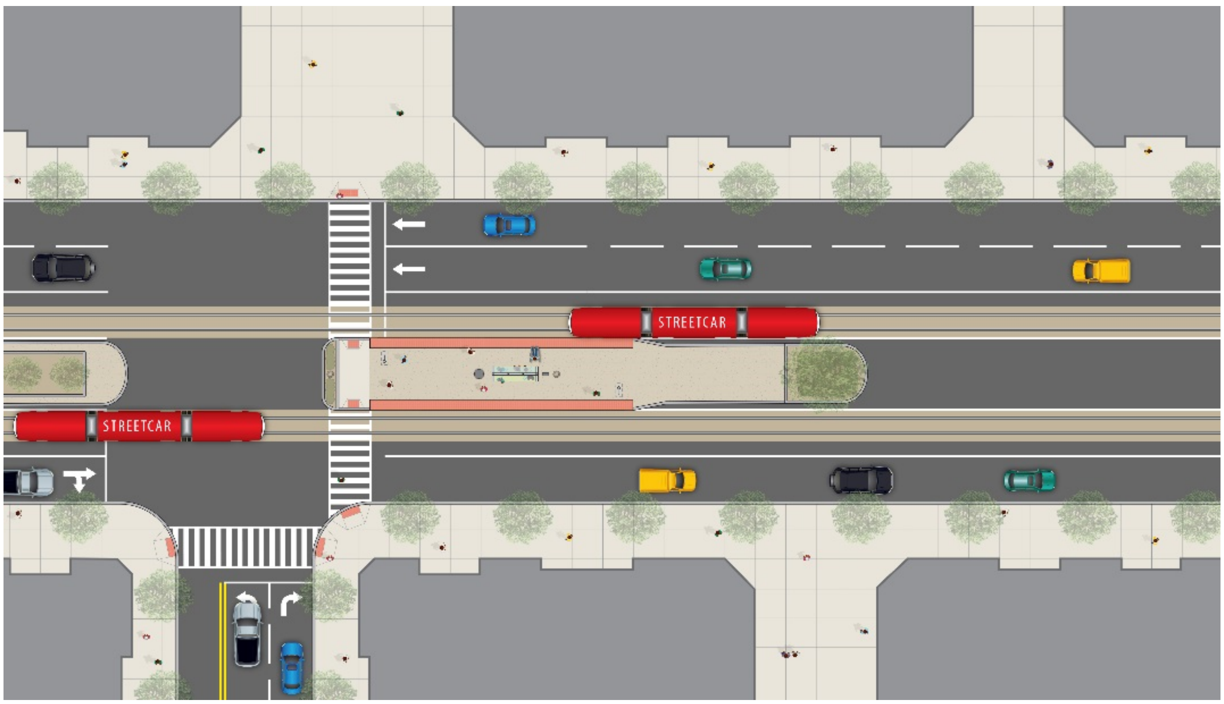
Figure 3-4 | Median Stop (Shared Platform and Shared Travel Lane)



3.2.1.5 Median Stop (Shared Platform and Dedicated Streetcar Lane)

Median stop platforms are used for two-way streets where the streetcars are operating towards the center of the street. One variation accommodates streetcars within the dedicated streetcar only lane closest to the median. Streetcar stop platforms are located between the two tracks and are bidirectional and /shared (**Figure 3-5**) for each direction. Median stop platforms may be either near or far side stops depending on particular site.

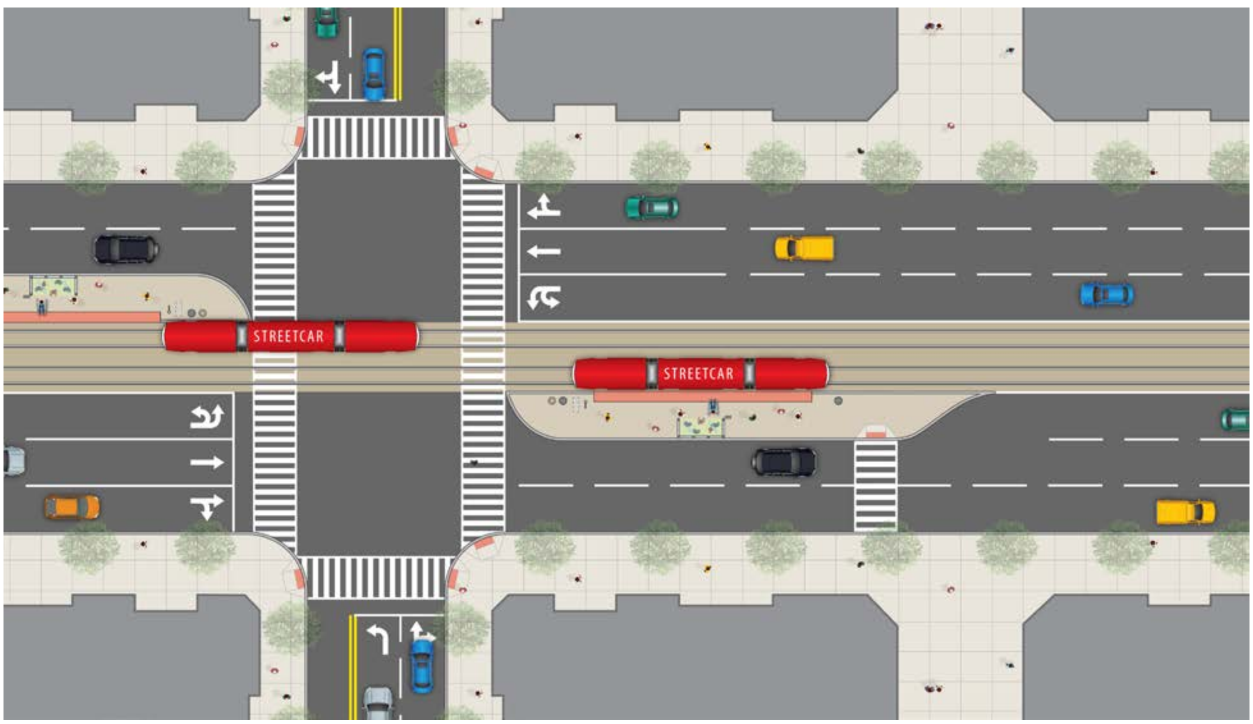
Figure 3-5 | Median Stop (Shared Platform and Dedicated Streetcar Lane)



3.2.1.6 Median Stop (Side Median or Staggered) in Dedicated ROW

Other median stop variations involve a center median, which may accommodate streetcars traveling in both directions in either a dedicated guideway. Within the dedicated right-of way, side median platforms (**Figure 3-6**) which may be parallel or staggered can be used. Median platforms may be either near or far side stops depending on the particular site conditions. The streetcar stop location should be coordinated with existing bus stop locations. Staggered median platforms are typically used for wider streets in far-side configuration, naturally accommodating left turn lanes for roadway traffic.

Figure 3-6 | Median Stop (Side Median or Staggered)



3.2.1.7 Pedestrian Plaza Stop

Pedestrian plaza stops are used when streetcars are running in pedestrian-only environments.

Figure 3-7 | Pedestrian Plaza

3.2.2 Platform Location in Relation to Intersections

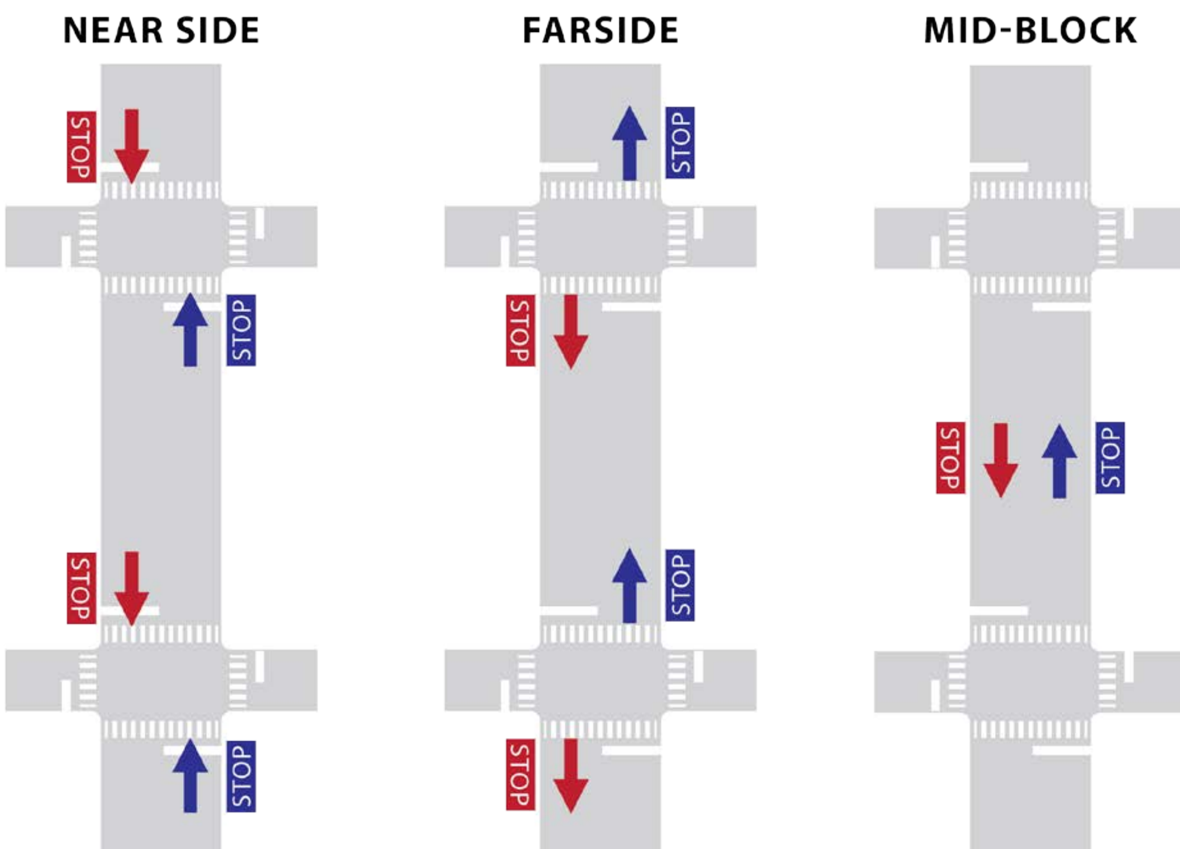
Streetcar stop platform locations are defined in relation to the intersection. The selection criteria for the type of streetcar stop location are similar to the criteria for bus stops as defined by DDOT Design and Engineering Manual. Streetcar stop locations should be closely coordinated with WMATA. Opportunities for joint stops may exist depending on the specific streetcar corridor. Platform height and length are two critical components that will need to be coordinated, especially if shared stops are considered in the future. The basic platform locations are:

- Near Side: stops located upstream of the intersection
- Far Side: stops located downstream of the intersection
- Mid-Block: stops are located between intersections

Stops adjacent to intersections are preferred.

Figure 3-8 provides an illustration of each of the platform types. These illustrations are conceptual and are only meant to show the location of the streetcar stop in relation to the intersection.

Figure 3-8 | Platform Loading



3.2.2.1 Platform Loading - Right or Left Side

The majority of loading at platforms should be right side loading. Left side loading may be used on streets with one-way traffic where the streetcar is running in the left most travel lane, or for center platforms.

3.2.2.2 Coordination with Bus Stops – Lengths, Shared Loading

To provide convenient transfers, consideration should be given to designing streetcar platforms, or adjacent sidewalk areas, to accommodate bus loading. The configuration of the platform for low-floor vehicles should provide access to the front and middle doors of 40 feet standard and 66 feet articulated buses. The current fleet of streetcar vehicles is 66 feet; however, future consideration should be given to vehicles 80-90 feet in length. The length of the future streetcar platforms should be coordinated with WMATA.

3.2.3 Streetcar Platform Design Parameters

Refer to *DC Streetcar Standard Drawings*.

3.2.3.1 Lengths

To accommodate the current double articulated, 66 feet low floor streetcar vehicle, the platform length for one vehicle ranges from 60 to 70 feet long. However, longer vehicles may be required as the system expands, which will inform the length of the platforms. In addition, any shared use of a platform with buses, would require a longer platform and coordination with WMATA.

3.2.3.2 Loading and Unloading Areas – ADA and Non-ADA

There are two loading areas on the platform – the leading edge of the platform accommodates access to the front door of the vehicle (on left side platforms, the rear door) and the middle section of the platform provides ADA-compliant access.

3.2.3.3 Platform Heights and Clearances – With/Without Bridge Plates

Streetcar platform height may vary from the standard 7 inch curb at the leading edge, sloping up to 14 inches to accommodate vehicles with level boarding, or 10 inches for vehicles with bridge plates (see **Figure 3-9**). For shared platforms where buses and streetcars are loading and unloading (see **Figure 3-3**), the curb height for the bus loading/unloading should be 7 inches.

Note – the current vehicle fleet is not equipped with bridge plates.

Figure 3-9 | Bridge Plate

3.2.3.4 Pedestrian Safety and ADA Requirements

Platforms require ADA-compliant tactile warning strips at the platform edge (see **Figure 3-10**). At sidewalks adjacent to curb-side running alignments, the area within the dynamic envelope of the vehicle must be designed with consideration for pedestrian safety. Hazards may be mitigated using tactile warning strips, fencing, landscaping, or any combination of industry standard practices. Curb extensions adjacent to platforms, the curb extension should be shortened or barriered to prevent pedestrians from standing within the dynamic envelope. Landscape can also be used. Accessible pedestrian signals shall be provided at all pedestrian crossings for pedestrians with hearing and visual disabilities adjacent to streetcar stops.

Figure 3-10 | Tactile Platform Warning Strip

3.2.4 Streetcar Platform Amenities

Streetcar stops should include accessible amenities, such as shelters, benches, system information (i.e. fares, routes, and schedules) and raised platforms with level boarding to allow for passengers to move directly into the streetcar from the platform. All amenities must comply with ADA requirements.

3.2.4.1 Shelter

Platforms shall include the standard DDOT shelter. The majority of platforms should use the narrow-body streetcar shelter (see **Figure 3-11**). The standard depth bus shelter may be used on wider platforms. Center median bi-directional platforms should include two shelters to accommodate passengers traveling in both directions (see **Figure 3-12**), or use a bi-directional shelter. Opportunities may arise for shelters to be customized to reflect the neighborhood or community where they are located, subject to direction from DDOT.

Figure 3-11 | Shelter Perspective View

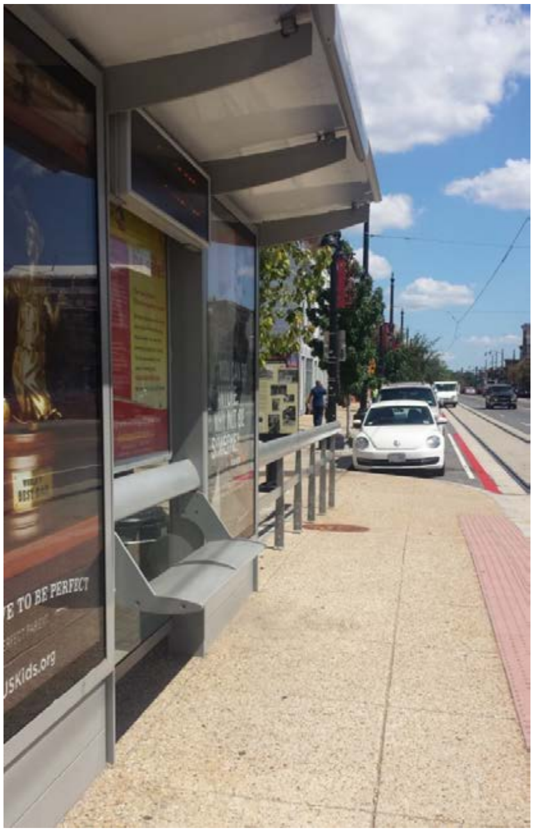


Figure 3-12 | Median Streetcar Stop at Oklahoma Ave. and Benning Rd.

3.2.4.2 Pylon and Informational Signage Shelter

Each platform should include one of the standard Pylons at the leading edge (**Figure 3-13**). Real time signage is provided at the shelter. The pylon shall include a panel for visually impaired that meets the current ADA requirements at the time they are procured. Depending on platform layout, a second pylon may be used (as seen in **Figure 3-12**).

Figure 3-13 | DC Streetcar Pylon Signage

3.2.4.3 Lighting Shelter

Platform lighting is primarily provided by street lighting and should meet DDOT lighting requirements for streetscape projects. Additional lighting may be required depending on specific site conditions and should be evaluated on a case-by-case basis.

3.2.4.4 Seating

Shelters should include a bench in the middle of the shelter. Based on a case-by-case evaluation, additional seating may be required. Factors that could influence the evaluation of the amount of seating include existing pedestrian activity, transit boarding, and land uses around the streetcar stop.

3.2.4.5 Leaning and Guard Rails

A leaning rail should be provided at the back edge of each platform and may also function as a guard rail where there is a grade change between the platform and the adjacent sidewalk. Lengths of leaning rails may vary depending on specific grading consideration.

3.2.4.6 Trash Receptacles

One DDOT standard trash receptacle should be provided at each platform. The receptacle should generally be located at the leading edge of the platform.

3.2.4.7 Real-Time Transit Information

The streetcar system should provide real-time transit information at each streetcar stop to give patrons information regarding scheduled streetcar arrivals. The real-time transit information system should consider the following:

- ADA requirements (audible announcements for visually impaired)
- Automatic vehicle location (AVL) and Global Positioning Systems (GPS) to provide estimate arrival times
- Accessible through dynamic signs at streetcar stop, online, and through mobile applications

3.2.4.8 Fare Collection and Validation Equipment

See Section 3.3.

3.2.4.9 Integration of Public Art

The incorporation of public art at the platforms will be dependent on location. Opportunities for the integration of public art could include: special benches, paving, lighting and free-standing sculptures. The DDOT's team will collaborate with the SHPO, CFA, DCRA, and other partnering stakeholders to make certain public art is thoughtfully integrated and representative of the community.

3.3 FARE COLLECTION

The fare collection system for the DC Streetcar System shall use a barrier-free, self-service method similar to other Streetcar and Light Rail Systems in the United States. The fare collection system equipment to be selected shall have been proven in transit revenue service.

Fare payment collection and validation equipment will be located on streetcar stop platforms, including but not limited to ticket vending machines and fare validators. There will not be a system of stop attendants, physical barriers, or gates preventing access to the system without prior payment. All fare collection equipment shall be installed to meet ADA requirements.

3.3.1 Fare Equipment

The fare equipment shall consist of ticket vending machines (TVM) on the platforms at the streetcar stops and fare validators. The stop platform TVMs shall be installed in an illuminated area and monitored by the video monitoring system. TVMs shall have the capability to vend single-ride tickets as well as multiple ride passes. They shall have the capability to accept United States currency and credit and debit cards that are in compliance with the latest industry standards and requirements. TVMs shall be able to dispense a ticket imprinted with the current date, time, and vending machine code. They shall also accommodate smart card electronic readers and targets shall function with WMATA's integrated fare collection system and compatible with any future open-platform for the region's transit operators. The readers and targets will be the components of the platform validators.

3.3.2 Fare Structure

The proposed single ride fare structure is provided in **Table 3-1**. Along with DC Circulator, the DC Streetcar fare structure will be integrated into the regional transit fare table and regional transit system configuration.

Table 3-1 | Proposed DC Streetcar Fare Structure for Single Ride

Fare	Cost
Persons between the ages of five (5) and sixty-four (64)	$1.00
Persons sixty-five (65) years of age and older, with valid government-issued photo with their current age discernible or a valid Medicare card.	$0.50 (half-fare)
Persons with a valid Metro Access card	Free
Persons with disabilities with a valid Metro Disability Identification Card or a valid Medicare card with a photo identification card	$0.50 (half-fare)
Attendant of a person with disability meeting the standards above	$0.50 (half-fare)
Up to three persons under the age of five (5), accompanied by a paying adult	Free
Persons between the ages of five (5) and twenty-one (21) who are enrolled in schools in the District, with a valid Kids Ride Free SmarTrip Card.	Free

There is no plan to initiate fare collection.

3.4 APPLICABLE STREETCAR STANDARD DRAWINGS

- A-01 Prototype Platform Curb Extension A
- A-02 Prototype Platform Curb Extension B
- A-03 Prototype Platform Two Side Curbs
- A-04 Prototype Platform Center Median
- A-05 Prototype Platform Split Median
- A-06 Platform Transition Conditions
- A-07 Streetcar Platform Edge Details
- A-08 Streetcar Platform Furnishings
    - Leaning Rail Plans, Elevations, and Sections

- A-09 Streetcar Platform Leaning Rail
    - Foundation and Curb Details
- A-10 Streetcar Pylon Plans and Elevation
- A-11 Streetcar Pylon Details

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District Department of Transportation

Chapter 4

Vehicles

Content

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4.1 STREETCAR VEHICLES

4.1.1 General Streetcar Vehicle Guidance

- Low Floor Streetcar Vehicle – Minimum low floor entry provided in center section of vehicle
- Articulated streetcar body
- Minimum two passenger entry doors per side
- Double-ended (cab at each end)
- Single and double unit operation
- Vehicle size (larger vehicles based on future growth and demand)
- Capability of towing one other streetcar

Future streetcar procurements will consider alternative propulsion, such as a hybrid streetcar that can operate on-wire and/or off-wire, as well as vehicles of different lengths.

The use of alternative propulsion (off-wire) for streetcars will be expected at some locations within the District of Columbia. DDOT is at the beginning stages of exploring the use of alternative propulsion for streetcars on specific projects. Once the final and specific decision is made regarding this, the *DC Streetcar Design Criteria 2019* will be updated to provide design guidance for the use of alternative propulsion streetcar based on the latest technical information available at that time.

4.1.2 Compliance with Americans with Disabilities Act (ADA)

Streetcar vehicles shall be compliant with accessibility guidance:

- Existing streetcars to provide level boarding from 14 ± 1/8 inch stop platforms
- Future alignments may be required to provide accessible boarding at platforms with a maximum height of 10 ± ¼ inch platform height (for which bridging devices may be considered).
- Access for a minimum of one door may be provided through the provision of bridge-plates or other proven technology
- Space for at least two wheelchairs shall be provided in each car.
- Special door control devices shall provide extra boarding and alighting time for wheelchairs and riders with other special needs.
- Onboard broadcasting system shall announce the streetcar stops and deliver other streetcar system management messages for visually challenged riders.
- All newly-purchased streetcars must comply with the regulations set forth in DOJ 36CFR Subpart D, Subsection 1192.

4.1.3 Streetcar Vehicle Dimensions

4.1.3.1 Streetcar Body Dimensions

Streetcars shall be constrained by the dimensions provided in Table 4-1: Carbody Dimensions.

Table 4-1 | Carbody Dimensions

Description	Dimensions
Vehicle length	62.3 feet to 80 feet (18.98m to 24.384 m)
Vehicle width	8.07 feet (2.460m)
Floor height above T/R at AW0, low floor section	see low floor guidance
Minimum interior ceiling height, finished floor to finished ceiling, along vehicle centerline	6.56 feet (2.0 m)
Minimum accessible side door opening width	4 feet (1.219 m)
Minimum side door opening height	78 inches (1.981 m)
Maximum roof-mounted equipment height, excluding pantograph, above T/R with new wheels, and AW0 passenger weight	11.6 feet (3.535 m)
Minimum depth of interior step treads (if used)	11 inches (2.794 m)
Minimum height of interior step treads (if used)	11 inches (2.794 m)

4.1.3.2 Pantograph Dimensions

Streetcar pantographs shall be constrained by the dimensions provided in Table 4-2: Pantograph Dimensions.

Table 4-2 | Pantograph Dimensions

Description	Dimensions
Maximum height above T/R in the lockdown position, with new wheels, vehicle at AW0 passenger weight	12.5 feet (3.810 m)
Pantograph operating height under dynamic conditions, vehicle weight from AW0 to AW3, and with new to fully worn wheels	Minimum: 13.0 feet (3.962 m) Maximum: 20.5 feet (6.248 m)
Maximum collector width over horns	5.577 feet (1.70 m)
Minimum carbon shoe length	41.338 inches (1.05 m)
Maximum longitudinal distance from vehicle pivot point to centerline of pantograph shoe, locked down	4.183 feet (1.275 m)

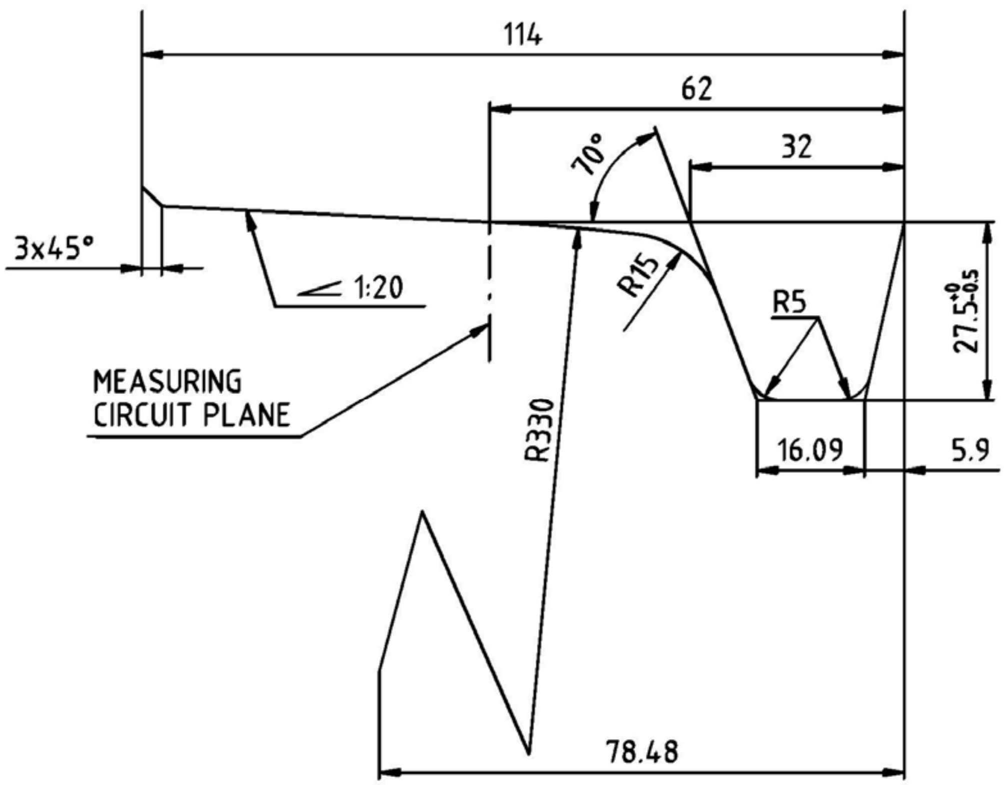
4.1.3.3 Wheel Dimensions

Streetcar wheels shall be constrained by the dimensions provided in Table 4-3: Wheel Dimensions.

Table 4-3 | Wheel Dimensions

Description	Dimensions
Nominal diameter, new	19.7 to 24 inches (500.38 to 609.60 mm)
Minimum allowable wheel diameter wear	2 inches (50.8 mm)
Profile: A preferred wheel profile is shown in **Figure 4-1**. The final wheel profile shall be recommended by the vehicle manufacturer and approved by DDOT	
Back-to-Back dimension	53.819 inches (1,367 mm)

Figure 4-1 | Preferred Wheel Profile



DIMENSIONS ARE IN MILLIMETERS NOT TO SCALE

4.1.3.4 Truck Dimensions

Streetcar trucks shall be constrained by the dimensions provided in Table 4-4: Truck Dimensions.

Table 4-4 | Truck Dimensions

Description	Dimensions
Centerline-to-centerline truck spacing	Sufficient to comply with dynamic envelope
Truck wheelbase	67 to 75 inches (1.701 to 1.905 m)

4.1.4 Operating Environment

4.1.4.1 Right of Way (ROW) Description

Streetcars shall operate on city streets, in dedicated alignments and/or in mixed traffic, with a speed of no more than 30 mph (50 km/h) or as regulated by corridor speed limits. In areas where the streetcars will operate in exclusive ROW, the speed will be adjusted to accommodate the geometry but should be evaluated on a corridor by corridor basis.

Streetcar stops that include curbside, curb extensions, and center medians, are sized to accommodate all doors of the streetcar, but may not extend the entire length of the streetcar.

4.1.4.2 Guideway Design Guidance

Streetcar guideway guidance relevant to the vehicle design is provided in Table 4-5: Guideway Design Guidance. Should any conflict exist between this Table 4-5 and Chapter 5, the guidance defined in Chapter 5 shall prevail.

Table 4-5 | Guideway Design Guidance

Description	Dimensions
Rail types	AREMA 115RE Tee-Rail or Girder Rail
Minimum horizontal curve radius	65.62 feet (20.0 m)
Minimum vertical curve, crest	820.21 feet (250.0 m)
Minimum vertical curve, sag	820.21 feet (250.0 m)
Minimum turnout size	65.62 feet (20.0 m)
Track gauge	56.5 inches (1.435 m)
Maximum track cross slope	3 inches (76.2 mm) –Maximum Superelevation
Maximum gradient	9 %
Reverse vertical curves	Either a crest and sag of 820 feet (249.936 m) separated by a tangent section of 24.6 feet (7.498m) or a crest and sag of 1,148.3 feet (350.001m), separated by no tangent track
Compound vertical curves	A 65.6 feet (19.994 m) curve superimposed on a 1,476.4 foot (450.006 m) vertical crest or sag
Spirals	See Chapter 5

4.1.4.3 Clearance Envelopes

- The vehicle shall meet the clearance requirements of Vehicle Clearance described later in this chapter and Track Alignment in **Chapter 5 Section 5.2**.

4.1.4.4 Climate Conditions

- See **Chapter 2, Section 2.4.**

4.1.4.5 Traction Power Supply Voltages

The guidance upon which the design of the traction power distribution system will be based is provided in Table 4-6: Traction Power Supply Voltages.

Table 4-6 | Traction Power Supply Voltages

Description	Rating
No Load Catenary Voltage (Nominal)	750 Vdc
Maximum Catenary Voltage	925 Vdc
Vehicle Operating Voltage (Normal)	750 Vdc
Vehicle Operating Voltage (Minimum)	650 Vdc
Vehicle Operating Voltage (Absolute Minimum)	525 Vdc

*Streetcar Manufacturer's Recommended Maximum Voltage

4.1.5 Streetcar Vehicle Weight and Passenger Loadings

4.1.5.1 Weight Definitions

- AW0: Maximum 1,000 lb/ft (1,500 kg/m) of length (weight of unloaded vehicle)
- AW1: AW0 + full seated passenger load + operator weight
- AW2: AW1 + standees at 2.7 square feet per person (4 persons per m^2)
- AW3: AW2 + standees at 1.8 square feet per person (6 persons per m^2)
- AW4: AW3 + standees at 1.63 square feet per person (6.6 persons per m^2)
- Average person weight: 165lbs (75 kg).

Weight Imbalance Limits:

- Wheel loadings within the same truck shall not vary by more than 10%
- Axle loadings between trucks of the same type shall not vary more than 10%

4.1.6 Streetcar Vehicle Performance

4.1.6.1 Propulsion and Braking General Guidance

All acceleration, braking, and jerk rates are based on level, tangent, dry track in still air, unless otherwise noted.

Propulsion equipment shall be designed for nominal performance at 750 Vdc, over a range of 525 Vdc to 925 Vdc, except that:

- The initial rate need only be available in the speed range of 0 to 20 mph (0 to 32 km/h) and at voltages of 700 Vdc and above. Below 700 Vdc, the speed to which the initial acceleration rate is held may decrease proportional to the OCS voltage.
- Braking rates shall be independent of the OCS voltage and once initiated, shall not require the presence of OCS voltage.
- All specified performance shall be provided over the full range of:
    - Wheel wear
    - Climatic conditions

4.1.6.2 Acceleration Requirements

Table 4-7 | Acceleration Requirements

Description	Dimensions
Maximum acceleration, at all vehicle weights from AW0 to AW2. Rate may decrease linearly from AW2 to AW4	3.0 mph/s (1.34 m/s^2) + 5%
Time to reach 25 mph (40 km/h) from a standing start at AW2 loading	10 seconds

4.1.6.3 Continuous and Balancing Speed Requirements

The vehicle shall be capable of operating at any speed from 0 to 30 mph (50 km/h) continuously, at AW2 loading, on any portion of the alignment, without overheating or damage to the vehicle. Operating speeds could exceed 30 mph in a dedicated guideway, which should be evaluated on a corridor by corridor basis. Any variance in speed could impact the continuous and balancing speed requirements.

The vehicle shall have a minimum balancing speed of 30 mph (50 km/h) on level tangent track, over the specified range of wheel wear, at nominal line voltage (750 Vdc), and at AW2 loading in still air.

Maximum safe speed with fully worn wheels on tangent track shall be at least 42 mph (68 km/h)

4.1.6.4 Deceleration Requirements

Service Brake Requirements:

- Full service braking effort shall be provided by dynamic braking.
- Dynamic braking shall be a blend of regenerative and resistive braking.
- Braking rate for all vehicle weights from AW0 to AW3 shall be 3.0 mph/s (1.34 m/s^2), +5%, from 30 mph (50 km/h) to 6 mph (10 km/h). The instantaneous variation in braking rate shall not exceed 0.34 mph/s (0.15 m/s^2) for any requested braking rate. Service braking rates may be

reduced linearly for vehicle weights above AW3 to a minimum of 3.0 mph/s (1.34 m/s^2) times the AW3 weight divided by the loaded vehicle weight.

- Dynamic brake fade shall not occur above 3 mph (5 km/h).
- In the event of a dynamic brake failure, the friction brake system shall be capable of continuous operation at full brake rate from 25 mph (40 km/h).

Emergency Brake Requirements:

- Emergency braking shall use a combination of friction brake plus track brake and sanding to produce a high rate brake stop.
- Dynamic braking may be included in emergency braking so long as the combination of friction brake plus track brake and sanding produces the minimum required rate at AW0 (see below).
- Spin/slide shall be disabled during emergency braking.
- Emergency brake rate:
  - For entry speeds greater than 15 mph (25 km/h) and less than 30 mph (50 km/h), the average emergency brake rate shall not be less than 5 mph/s (2.23 m/s^2), and shall not exceed this rate by 30%.

    For entry speeds of less than 15 mph (25 km/h), the instantaneous emergency braking rate after rate build-up shall be a minimum of 5 mph/s (2.23 m/s^2) and the maximum rate shall follow the characteristics of the track brake.

4.1.6.5 Wheel Spin/Slide

The spin/slide system shall be functional under acceleration and braking commands on an individual axle basis except for emergency braking.

Sanding shall be applied automatically during correction of major spins and slides.

The wheel spin/slide system shall function properly with differences up to 2 inches (50 mm) in diameter between wheels of one truck as compared to wheels of another truck. Automatic wheel size adjustment shall be provided.

4.1.6.6 Jerk limits

In response to a step input command signal, the average rate of change of actual acceleration or deceleration, after any mode change dead time, for maximum power or maximum service brake, shall be between 2.5 mph/s/s (1.1 m/s3) and 4.5 mph/s/s (2.0 m/s3).

For lower power and brake applications, average jerk rate shall be between 1.0 mph/s/s (0.45 m/s3) and 4.5 mph/s/s (2.000 m/s3).

Release of power when traversing overhead primary power isolation gaps need not be jerk limited; however, the reapplication of power must be jerk limited. OCS power isolation gaps do not exceed 12 inches (304.800 mm).

Emergency brake applications shall not be jerk limited.

4.1.6.7 Mode Change Dead Times

Mode change dead time shall be less than 400 ms for the following direct mode changes, with one exception as noted:

- Power to brake
- Power to coast
- Coast to brake
- Coast to power
- Brake to power below 6 mph (10 km/h). For the direct mode change brake to power above 5 km/h (3.2 mph), the mode change dead time shall be 600 ms.

Mode change dead times for emergency brake applications shall be 400 ms or less, regardless of the original mode.

Mode change dead time shall be measured from the time that the control trainline(s) changes state until the new commanded acceleration or deceleration reaches 90% of its former commanded value for mode changes to coast, or 10% of the new commanded value for mode changes from coast, or 10% of the new commanded value for mode changes between brake and power.

4.1.6.8 Parking Brake

The parking brake shall be capable of holding a vehicle (under power and off line) at all weights up to AW4 on a grade of 9%

4.1.6.9 Duty Cycle

The vehicle shall be capable of operating continuously at AW2 passenger loading on a duty cycle comprised of full power acceleration, 30 mph (50 km/h) speed limit cruise, full service deceleration and 10 second dwell times over the specified alignment.

An operating vehicle shall be capable of towing an inoperative vehicle with the brakes released (not functional). Full acceleration and braking tractive effort shall be available on the operative vehicle. Operative vehicles at AW0 weight shall have the capability to tow an inoperative vehicle at AW3 weight to the next available stop (at any location on the alignment), unload all passengers, and then move the empty, inoperative vehicle to the shop via the worst-case routing.

If dynamic braking on a vehicle or truck becomes inoperative the vehicle may have a speed restriction imposed of no less than 20 mph. A vehicle in this state shall have the capacity to perform a full round trip at restricted speed and AW2 load weight.

4.1.7 Vehicle Noise

4.1.7.1 General Guidance

All sound measurements shall be performed using methods and equipment meeting IEC 179 and ISO 2204

Unless otherwise noted, noise limits given below apply only to continuously operating equipment.

4.1.7.2 Interior Noise Limits

Measurements of interior noise shall be taken in accordance with ISO 3381.

The noise level measured per ISO 3381 shall not exceed 68dBA with the vehicle stationary, all doors and windows closed, and all auxiliary equipment operating simultaneously under normal conditions.

Interior noise shall not exceed 75 dBA as measured per ISO 3381 operating on smooth rail at any speed up to 30 mph (50 km/h) and under any acceleration or deceleration condition.

4.1.7.3 Exterior Noise Limits

Exterior noise, when measured on a horizontal plane five feet above the height of the Car floor, shall conform to the following requirements:

- Stationary: At a stop with no canopy or vertical obstruction, with all doors and windows open, and all auxiliary systems including the air compressor and HVAC system in operation, the noise level shall not exceed 75 dBA at eight feet from the track centerline for any location along either side of the Car.
- Moving: On continuously welded rail with all auxiliary systems operating normally, the noise level shall not exceed 75 dBA at 25 feet from the track centerline for any operating condition when operated between 0 and 30 mph.
- Moving: At a stop with no canopy or vertical obstruction, with the Car accelerating or decelerating at low speeds (between 0 and 15 mph) with brakes fully or partially applied in the case of deceleration, the noise level shall not exceed 78 dBA at eight feet from track centerline.

4.1.8 Streetcar Vehicle Vibration

4.1.8.1 Vibration Limits

Equipment and auxiliaries mounted anywhere on the carbody or trucks shall not cause vertical or horizontal vibrations anywhere on the vehicle floor, walls, ceiling panels and seat frames, at any speed from 0 to 30 mph (50 km/h), and under any acceleration or braking condition (except emergency braking) in excess of the following:

Table 4-8 | Vibration Limits

Description	Frequencies
Below 1.4 Hz	Max. peak-to-peak deflection of 0.098 inches (2.489 mm)
1.4 Hz. to 20 Hz	Peak acceleration of 0.328 feet/s^2 (0.1 m/s^2)
Above 20 Hz	Peak velocity of 0.00246 feet/s (0.75 mm/s)

4.1.9 Electromagnetic Interference & Compatibility

4.1.9.1 General Guidance

Electromagnetic compatibility shall be consistent with EN5021-3-1 for railway applications.

4.1.9.2 Radiated Emission Limits

Radiated emission limits shall be in accordance with EN5021-3-1.

4.1.9.3 Conducted Emission Limits

Measurement procedures and terminology for conductive emissions shall be per UMTA-MA-06-0153-85-11. Frequency-specific limits are as follows:

Table 4-9 | Conducted Emission Limits (Frequency Specific Limits)

Description	Frequencies
From 0 to 40 Hz	10 Amperes maximum
From 40 Hz to 120 Hz	2 Amperes maximum
From 120 Hz to 320 Hz	10 Amperes maximum

4.1.9.4 Inductive Emission Limits

Measurement procedures and terminology for inductive emissions shall be per UMTA-MA-06-0153-85-8. Frequency-specific limits are as follows:

Table 4-10 | Inductive Emission Limits (Frequency Specific Limits)

Description	Frequencies
20 Hz to 20 kHz	20 mV, RMS, rail-to-rail

This condition shall be met by each piece of individual power equipment, as well as, the simultaneous operation of all the equipment.

4.2 STREETCAR VEHICLE CLEARANCES

4.2.1 Clearances – General

This section establishes the basic clearance guidance to be used in the design of the DC Streetcar System. Except for the requirements established in this guidance and the CAD standards, all clearances shall follow the AREMA Manual for Railway Engineering and Portfolio of Track Work Plans, The Track Design Handbook for Light Rail Transit TCRP Report 155 sponsored by the Federal Transit Administration, and the APTA Guidelines for Design of Rapid Transit Facilities modified as necessary to reflect the physical requirements and operating characteristics of the DC Streetcar System.

In addition, this section establishes the maximum dimensions required to assure proper clearances between the streetcar vehicles or transit structures and wayside obstructions involved. The vehicle dynamic envelope illustrated in Figures 4-2 and 4-3 are for the current streetcar vehicles. If different vehicles are procured in the future, it could change the dynamic envelope. Components of a streetcar vehicle that could change the dynamic envelope include length, width, and height.

4.2.1.1 Streetcar Vehicle Dynamic Envelope

Figure 4-2 | Streetcar Vehicle Dynamic Envelope

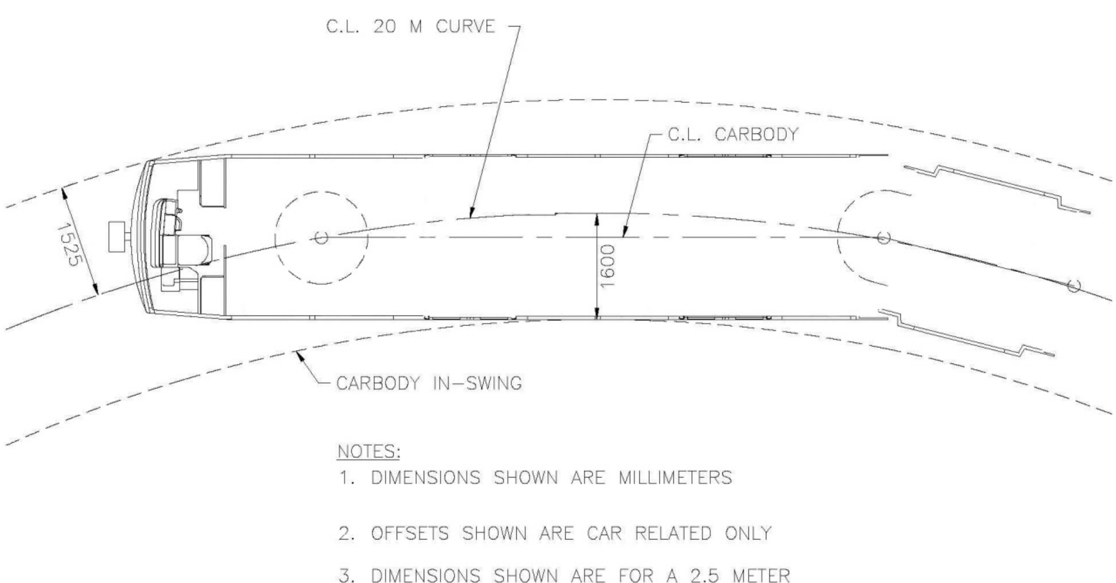
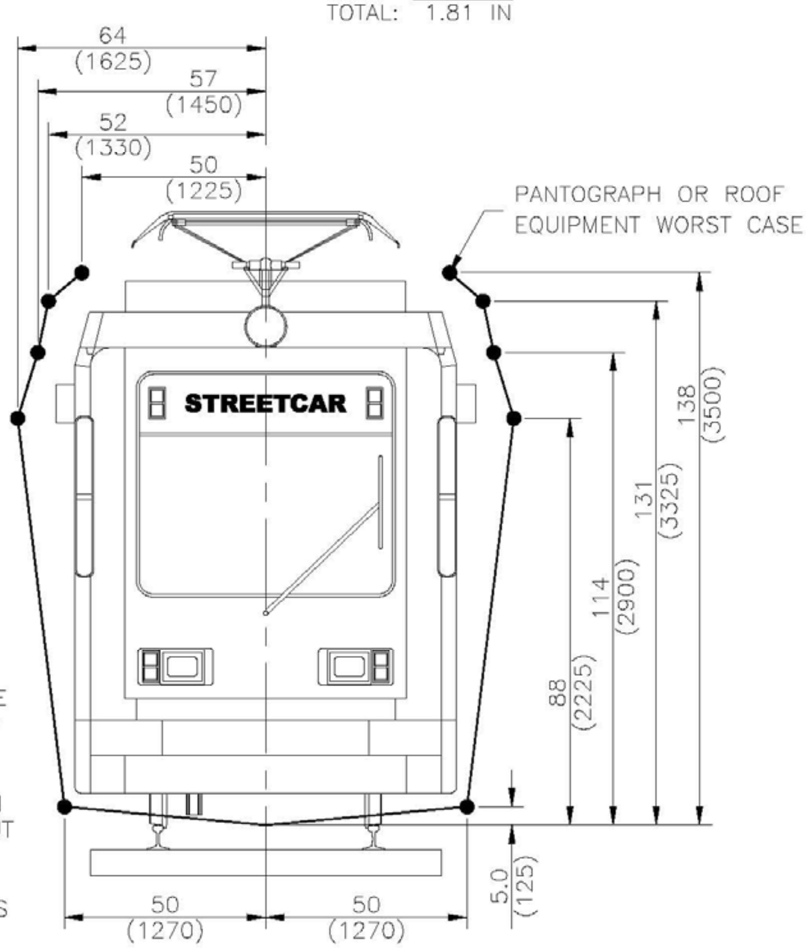


Figure 4-3 | Streetcar Vehicle Dynamic Envelope (Czech: Inekon / Skoda / OIW)

CONDITIONS:

1. MAXIMUM ROLL, FAILED SUSPENSION
2. WORST CASE VEHICLE CONSTRUCTION TOLERANCES
3. WORST CASE COMBINATION OF END TRUCK AND CENTER TRUCK SUSPENSION, CAR BODY, AND TRUCK MOTIONS
4. LEVEL TANGENT TRACK
5. NEW WHEELS AND RAILS
6. NOMINAL RAIL GAUGE
7. PANTOGRAPH LOCKED DOWN
8. LATERAL MOTION COMPRISED OF:

WHEEL GAUGE	.08 IN
NOMINAL SIDE PLAY	.40 IN
LATERAL SUSPENSION	1.33 IN
TOTAL:	1.81 IN



NOTES:

1. DIMENSIONS SHOWN ARE FOR A 98.5 IN (2.5 M) WIDE CARBODY
2. ALL DIMENSIONS SHOWN ARE SYMMETRICAL ABOUT CENTERLINE OF LRV
3. DIMENSIONS ARE INCHES (MILLIMETERS)
4. OFFSETS SHOWN ARE CAR RELATED ONLY

4.2.1.2 Streetcar Interface at Stop Platforms

At streetcar stops, the distance from the centerline of the track to the edge of platform shall be 4 feet 2 $^{5}/_{8}$ inches (1285mm). The nominal vertical height of the platform on level track shall be 14 inches +/- $^{1}/_{8}$ inch (356mm) for streetcar vehicles without bridge plates. The nominal vertical height of the platform on level track shall be approximately 10 inches +/- $^{1}/_{8}$ inch (254mm) where streetcar vehicles equipped with bridge plates share the platform with busses. The vertical height may need to be adjusted to accommodate the street cross-slope in order to ensure the vehicle-mounted bridging device is deployable under all loading conditions.

As vehicle selection process progresses for the various streetcar routes, the clearance envelopes shall match what is described above in order to accommodate already built routes within the District. Design should take into consideration the clearances required to provide parking, bike lanes, and delivery vehicles adjacent to the streetcar alignment.

4.2.1.3 Retaining Walls

Where retaining walls are used, they shall comply with the following guidance.

4.2.1.3.1 Cut Sections

In cases where a retaining wall along the streetcar system is in a cut section, the minimum clearance from the centerline of track to the near face of a retaining wall shall be 9 ft (2.743m) if the retaining wall is more than 6 inches higher than the top of rail elevation.

4.2.1.3.2 Fill Sections

In retained fill sections, the top of a retaining wall shall be at the same elevation as the top of the adjacent rail (the rail nearest to the wall), and the minimum distance from the centerline of track to any fencing or hand railing on top of the wall shall be 9 ft (2.743m).

4.2.1.4 Maintenance and Emergency Evacuation Paths

A minimum clear width of 30 inches (0.762m) shall be provided between the Dynamic Envelope and any continuous obstruction (i.e. wall) alongside the track to create a walkway for maintenance personnel and to create a designated passenger emergency evacuation path.

4.2.1.5 Track Spacing

The minimum allowable spacing between two exclusive streetcar mainline tracks, with equal super-elevation and no OCS support poles between them shall be determined from the following formula:

- $d = T_t + T_a$
  - where d equals the distance between the centerline of tracks

Along sections where OCS poles are located between track centerlines, the minimum track spacing shall be determined from the following formula:

- d(inches) = $T_t + T_a + 2 + P$
- d(mm) = $T_t + T_a + 50.8 + P$

Where	d	=	Minimum allowable spacing between track centerlines, in inches (mm)
	T_t	=	dynamic half width of vehicle towards curve center, in inches (mm) (see Figures 4-2 and 4-3 for dynamic envelope)
	T_a	=	dynamic half width of vehicle away from curve center, in inches(mm) (see Figures 4-2 and 4-3 for dynamic envelope)
	P	=	Maximum allowable OCS pole diameter (including deflection) of 18.5 in (459.900mm)

4.2.1.6 Other Wayside Factors

Other wayside factors (OWF) may add additional clearance to the streetcar dynamic clearance envelope. These include construction and maintenance tolerances (CMT) and chorded wall construction factor. Collectively,

- OWF = CMT + CW

Construction and maintenance tolerances accounts for the fact that neither the trackwork nor items that are constructed alongside of the track can be guaranteed to have been built exactly where planned. Further, as the system ages, wear and tear may result in movement of some items, further reducing actual clearances

The tolerances specified in **Table 4-11** shall not to be used for construction or maintenance of the system but rather represent a possible worst-case scenario in the event that substandard construction and maintenance goes undetected and uncorrected. Exact tolerances are provided in the standard DC Streetcar Specifications.

Table 4-11 | Construction and Maintenance Tolerances (CMT)

Description	Measurement*
Track Construction & Maintenance Tolerance for Embedded or Direct Fixation Track	0.5 in (12.7 mm)
Track Construction & Maintenance Tolerance for Primary Ballasted Track	2.0 in (50.8 mm)
Track Construction & Maintenance Tolerance for Secondary Ballasted Track	3.0 in (76.2 mm)
Construction Tolerance for OCS Poles or Signal Equipment alongside of the track	1.0 in (25.4 mm)
Construction Tolerance Along All Other Proposed Structures alongside of the track	2.0 in (50.8 mm)

**Measurements are from the correct vertical and horizontal position*

Chorded wall construction factor (CW) is applied when the item to which clearance is required is constructed nominally concentric to the curved track, but is actually constructed as a series of straight chords. The absolute value of this factor shall be calculated on a case-by-case basis.

4.2.2 Streetcar Vertical Clearances

Since the streetcar system will draw electric traction power from an overhead contact wire system, provide the following vertical clearances from the top of the high rail along any given section of track to contact wire, including mounting to the underside of any overhead structure, within the horizontal limits of the clearance envelope:

Table 4-12 | Vertical Clearance Requirements

Description	Measurement
Desirable Minimum	19 ft 0 in (5.791 m)
Absolute Minimum	18 ft 0 in* (5.486 m)

* Not to be lowered below desirable minimum without prior approval from the DDOT.

If no OCS is required, minimum vertical clearance shall be 14 feet (4.267 m).

Transit structures over public highways shall be in accordance with AASHTO Standard Specifications for Highway Bridges for existing structures, AASHTO LRFD Bridge Design Specifications for new structures and DDOT, whichever is applicable. Vertical clearances for transit structures over local public streets and roads shall be as required by the authority having jurisdiction over the street or road. The minimum vertical clearance for transit structures over public streets and roads is 19.5 feet while the maximum is 20 feet.

The National Electrical Safety Code (NESC) minimum distances between the streetcar wire and the rail or any other conductor in various situations shall be followed. Civil and structural designers shall coordinate their design related to any structures over the tracks to ensure that NESC and other DDOT criteria are met.

District Department of Transportation

Chapter 5

Guideway & Track Elements, Sitework & Special Considerations, ROW, Land & Existing Improvements

Content

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5.1 INTRODUCTION

This chapter is intended to guide improvements along the transit alignment to ensure well-coordinated design and engineering for the areas beyond the stop areas, and to meet the goals of complete streets. Each section should be considered within the context of other sections within the chapter during the design and QA/QC process.

5.2 TRACK ALIGNMENT

This section establishes the guidance for basic track geometry to be used in the design of the DC Streetcar System. Except for the requirements established in this guidance and DDOT CAD standards, all geometry shall follow the AREMA Manual for Railway Engineering and Portfolio of Trackwork Plans, The Track Design Handbook for Light Rail Transit TCRP Report 155 sponsored by the Federal Transit Administration, and the APTA Guidelines for Design of Rapid Transit Facilities, modified as necessary to reflect the physical requirements and operating characteristics of the DC Streetcar System.

5.2.1 Horizontal Alignment

Horizontal curvature and super-elevation shall be related to design speed, acceleration and deceleration characteristics of the design vehicle. Super-elevation may not be practical within at-grade segments where vehicles will operate on a shared right-of-way with vehicular traffic within city streets.

The track alignment shall be designed to accommodate a maximum design speed equal to the lowest applicable scenario:

- legal speed of the parallel street traffic
- 40 mph maximum

The design speed shall consider the spacing of stops, location of curves, construction limitations, and the performance characteristics of the design vehicle.

5.2.1.1 Tangent Alignment

5.2.1.1.1.1 Tangent Segments

The minimum length of tangent track between curved sections of track shall be as follows:

Table 5-1 | Minimum Length of Tangent Track between Curved Sections

Condition	Tangent Length
Minimum	33 ft or 3 times the design speed in mph, whichever is greater
Absolute Minimum*	0 ft (0m)

*Where absolute minimum is used, prepare documentation indicating its justification.

Refer to the section on reverse curves provided later in this chapter.

If adjacent curves in the same direction, which are in close proximity to one another, cannot be replaced by a single simple curve due to geometric constraints, a series of compound curves with connecting spirals shall be the preferred design method. Broken back curves (e.g., short tangents between curves in the same direction) shall be avoided whenever possible.

On tangent alignments within the roadway, the cross-slope on the track slab shall be 0%. Generally, curb elevations shall remain as-is and the roadway pavement cross slope shall be modified as necessary through milling or pavement replacement to achieve the proper cross slope. The profile grade line shall be identified by the lower rail elevation.

5.2.1.1.1.2 Switches

The minimum length of tangent track preceding a point of switch shall be as follows:

Table 5-2 | Minimum Length of Tangent Track Preceding a Point of Switch

Condition	Tangent Length
Minimum	10 ft (3.048m)
Absolute Minimum*	5 ft (1.524m)

* Where absolute minimum is used, prepare documentation indicating its justification.

5.2.1.1.1.3 Streetcar Stops

At streetcar stop platforms, the horizontal alignment shall be tangent throughout the entire length of the platform. Also, it is recommended that there be an additional 45 feet of tangent track before and after the platform to allow for the vehicle’s suspension to adjust. For platforms that are adjacent to curves sharper than 650 feet, the tangent track through the platform shall be extended beyond both ends of the platform so that the streetcar clearance envelope does not overhang any portion of the platform as the streetcar approaches and leaves the stop.

5.2.1.2 Curved Alignment

Intersections of horizontal tangents shall be connected by circular curves which may be either circular curves or spiraled curves as required by this guidance.

5.2.1.2.1.1 Circular Curves

Circular curves shall be specified by their radius. The minimum radius for tracks shall be 65.62 feet, (20.000m) unless otherwise approved by DDOT and the vehicle manufacturer. The minimum curve length shall be 42 feet (12.801m). Minimum radii shall be reviewed during the environmental and design phase to ensure that there are no conflicts with sensitive receptors.

The design speed for a given horizontal curve shall be based on its radius, length of spiral transition, and actual and unbalanced super-elevation through the curve as described in the following sections:

5.2.1.2.1.2 Super-elevation

Super-elevation is defined as the difference in inches the outer (high) rail is raised above the inner (low) rail. Equilibrium super-elevation is the amount of super-elevation that would be required so that the resultant force from the center of gravity of the streetcar vehicle will be perpendicular to the plane of the two rails and halfway in between them at a given speed.

Equilibrium super-elevation shall be determined by the following equation:

$$E_q\text{ (inch)} = E_a + E_u = 3.96\left(\frac{V^2}{R}\right);$$

$$E_q\text{ (mm)} = E_a + E_u = 117\left(\frac{V^2}{R}\right);$$

E_q = Equilibrium super-elevation, in inches (mm)

E_a = actual super-elevation, in inches (mm)

E_u = unbalanced super-elevation, in inches (mm)

V = design speed through the curve, in mph (km/h)

R = radius of curvature, in ft (m)

Calculated values for actual super-elevation shall be rounded to the nearest ¼-inch (6.35mm). For a total super-elevation (E_a + E_u) of 1 inch (25.4mm) or less, no actual super-elevation (E_a) shall be applied. Actual super-elevation (E_a) shall be attained and removed linearly throughout the full length of the spiral transition curve by raising the outside rail while maintaining the inside rail at the profile grade.

The maximum values for actual and unbalanced super-elevation shall be as follows:

Table 5-3 | Maximum Values for Actual and Unbalanced Super-elevation

Super-elevation	Maximum Value (Exclusive and Semi-Exclusive Track)
E_a =	4.0 in desirable (101.6mm) 6.0 in absolute (152.4mm)
E_u =	3.0 in desirable (76.2mm) 4.5 in absolute (114.3mm)
Super-elevation	**Maximum Value (Non-Exclusive/Mixed Traffic)**
E_a =	0.0 in desirable (0.0mm) 1.0 in absolute (25.4mm) ~2%
E_u =	3.0 in desirable (76.2mm) 4.5 in absolute (114.3mm)

On curved alignment sections within the roadway, a maximum pavement crown of 2 percent across the rails shall be maintained in the roadway pavement to promote drainage. In such cases, with the inner rail being the low rail, the E_a could either be positive or negative, depending on which side the of the roadway crown line the track is located. To minimize the need to extensively re-grade the roadway pavement and change drainage patterns, the E_u should be maximized prior to the addition of any additional actual super-elevation. Negative super-elevation can occur when the track conforms to the roadway cross slope within a curve or intersection. Negative super-elevation can be reduced or eliminated by bucking the roadway cross slope, potentially introducing a new drainage collection system and reconstructing the roadway or intersection. At locations where negative super-elevation cannot be eliminated spiral curves shall be introduced to reduce the jerk rate. When calculating E_u, the negative super-elevation shall be included.

5.2.1.2.1.3 Spiral Curves

Spiral curve length and super-elevation runoff are directly related to passenger comfort. However, spiral transition curves shall not be used in the guideway within shared right-of-way (ROW) nor shall it be used within areas with special track.

The desirable lengths of spiral shall be the greater of the lengths determined from the following formulae. The spiral length shall be rounded up to the nearest 5 feet (1.524m) increment.

$$L_S(ft) = 1.10\ E_a V$$

$$L_S(m) = 0.008\ E_a V$$

$$L_S(ft) = 0.82\ E_u V$$

$$L_S(m) = 0.006\ E_u V$$

$$L_S(ft) = 31\ E_a$$

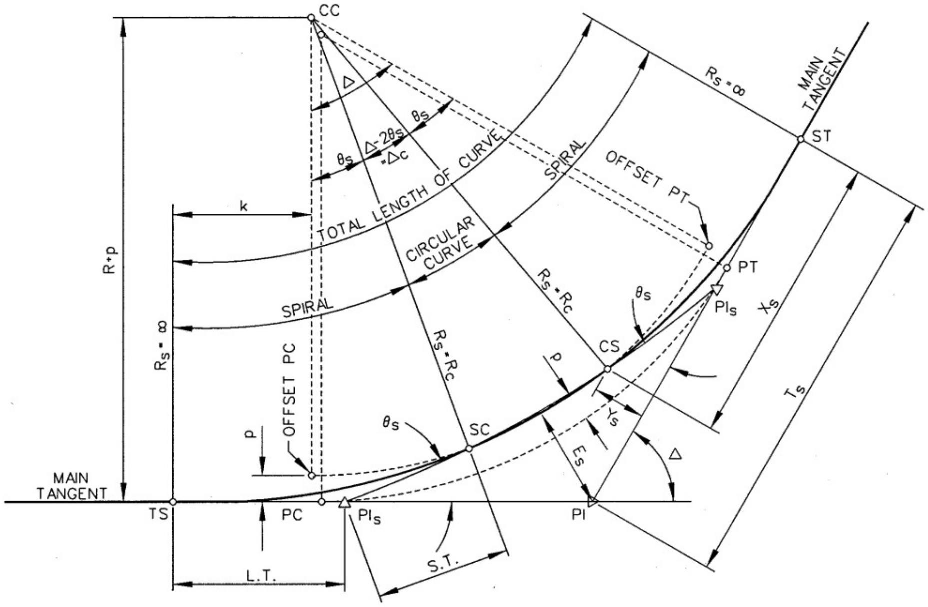
$$L_S(m) = 0.38\ E_a$$

Where Ls = spiral length in ft (m)
V = curve design speed in mph (km/h)
Ea = actual super-elevation in inches (mm)
Eu = unbalanced super-elevation in inches (mm)

The minimum spiral length shall be 30 feet (9.144m).

Spirals are not required when the calculated Ls < 0.01 R (where R is the radius of the curve).

Figure 5-1 | Curve and Spiral Nomenclature



NOTATIONS

CC - CENTER OF CIRCULAR CURVE

CS - POINT OF CHANGE FROM CIRCULAR CURVE TO SPIRAL

D_c - DEGREE OF CIRCULAR CURVE, ARC DEFINITION

E_s - TOTAL EXTERNAL DISTANCE OF A SPIRALIZED CURVE

k - TANGENT DISTANCE FROM TS OR ST TO PC OR PT OF THE SHIFTED CIRCULAR CURVE

L_c - TOTAL LENGTH OF CIRCULAR CURVE ARC

L_s - TOTAL LENGTH OF SPIRAL

L.T. - LONG TANGENT OF SPIRAL

p - OFFSET FROM THE MAIN TANGENT TO THE PC OR PT OF THE SHIFTED CIRCULAR CURVE

PC - POINT OF CHANGE FROM TANGENT TO CIRCULAR CURVE

PI - POINT OF INTERSECTION OF MAIN TANGENTS

PI_s - POINT OF INTERSECTION OF MAIN TANGENT WITH TANGENT THROUGH SC OR CS POINT

PT - POINT OF CHANGE FROM CIRCULAR CURVE TO TANGENT

R - RADIUS OF CIRCULAR CURVE

SC - POINT OF CHANGE FROM SPIRAL TO CIRCULAR CURVE

ST - POINT OF CHANGE FROM SPIRAL TO TANGENT

S.T. - SHORT TANGENT OF SPIRAL

T_s - TOTAL TANGENT DISTANCE FROM TS OR ST TO PI

TS - POINT OF CHANGE FROM TANGENT TO SPIRAL

X_s - TANGENT DISTANCE FROM TS TO SC OR ST TO CS

Y_s - TANGENT OFFSET AT SC OR CS

Δ - TOTAL CENTRAL ANGLE OF SPIRAL AND CIRCULAR CURVES

Δ_c - CENTRAL ANGLE OF THE CIRCULAR CURVE

θ_s - CENTRAL ANGLE OF SPIRAL

CURVE FORMULAS

$$D_c = \frac{5729.578}{R}$$

$$T_s = (R+p)\tan\frac{\Delta}{2} + k$$

$$E_s = (R+p)\left(\frac{1}{\cos\frac{\Delta}{2}} - 1\right) + p$$

$$L_c = \frac{\Delta_c}{D_c} \times 100 = \frac{\Delta - 2\theta_s}{D_c} \times 100$$

SPIRAL FORMULAS

θ_s IN RADIANS

$$X_s = L_s\left(1 - \frac{\theta_s^2}{10} + \frac{\theta_s^4}{216} - \frac{\theta_s^6}{9360} \cdots\right)$$

$$Y_s = L_s\left(\frac{\theta_s}{3} - \frac{\theta_s^3}{42} + \frac{\theta_s^5}{1320} - \frac{\theta_s^7}{75600} \cdots\right)$$

$$k = L_s\left(\frac{1}{2} - \frac{\theta_s^2}{60} + \frac{\theta_s^4}{2160} - \frac{\theta_s^6}{131040} \cdots\right)$$

$$p = L_s\left(\frac{\theta_s}{12} - \frac{\theta_s^3}{336} + \frac{\theta_s^5}{15840} \cdots\right)$$

$$L_s = 2R\theta_s$$

$$\theta_s = \frac{1}{2}\frac{L_s}{R}$$

$$L.T. = X_s - \frac{Y_s}{\tan\theta_s}$$

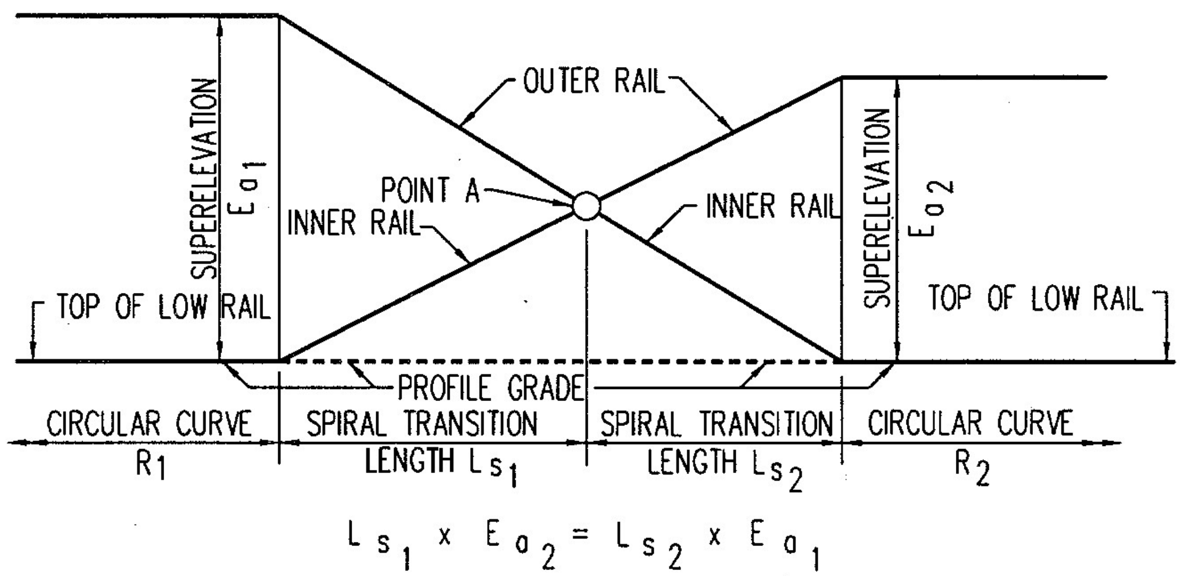
$$S.T. = \frac{Y_s}{\sin\theta_s}$$

5.2.1.3 Reverse Curves

Reverse curves shall be avoided on mainline track. Every attempt shall be made to use standard circular curves with tangent sections. For those sections where reverse curves must be used, the following guidance may be used with prior approval from DDOT.

Reverse curves shall have spiral transition curves that meet at the point of reverse curvature, with the rate of change of super-elevation constant through both spiral curves.

Figure 5-2 | Spiral Transition



5.2.2 Vertical Alignment

The vertical track alignment shall be composed of constant grade tangent segments connected at their intersection by parabolic curves having a constant rate of change in grade. The profile grade line on tangent track shall be along the lower rail. In curved track, the inside or low rail of the curve shall remain at the profile grade line (PGL) and super-elevation achieved by raising the outer rail above the inner rail. An exception is permitted where normally crowned streets result in a negative E_a on the outer rail of a curve.

5.2.2.1 Vertical Tangents

The minimum length of constant profile grade between vertical curves shall be as follows:

Table 5-4 | Minimum Length of Constant Profile Grade between Vertical Curves

Condition	Length
Desirable Minimum	33 ft (10.058m) or 3 times the design speed in mph (km/h), whichever is greater
Minimum	0 ft (0m)

The profile at stops shall be on a vertical tangent.

5.2.2.2 Vertical Grades

The following profile grade limitations shall apply:

5.2.2.2.1.1 Primary Track in Mixed-Traffic Lanes on City Streets

When the track occupies the travel lane or adjacent parking lane, the vertical profile should match the roadway profile and associated crown to the extent reasonable and practical without exceeding the design guidance. When setting initial profiles in roadway areas, an assessment shall be made of the amount of adjacent roadway pavement that may need to be reconstructed in any event due to requisite utility relocations. When such areas are considered, it may be found to be both practical and cost-efficient to further optimize the track profile by making minor pavement contour adjustments in the utility work areas.

5.2.2.2.1.2 Mainline tracks

Maximum	7.0% (Desired), 9.0% (Maximum)
Minimum (for drainage)	0.2%
Absolute Minimum[1]	0.5%

5.2.2.2.1.3 Passenger Stop Area

Maximum	2.0% (Desired)[2]
Minimum (for drainage)	0.2%
Absolute Minimum[1]	0.5%

[1]Per DDOT Design and Engineering Manual

[2]Any gradient that exceeds this maximum shall apply for an exception from the DDOT ADA Coordinator

5.2.2.3 Vertical Curves

All changes in grade shall be connected by vertical curves. Vertical curves shall be defined by parabolic curves having a constant rate of change in grade.

5.2.2.3.1.1 Vertical Curve Lengths

The desired minimum length of vertical curves shall be 50 ft. (15.240 m).

The absolute minimum length of vertical curves shall be the greatest value determined from the following equations: Every effort shall be made to maintain a constant grade in the vicinity of stops.

Crest curve (ft.): $$LVC = \frac{AV^2}{25}$$

Crest curves (m): $$LVC = \frac{AV^2}{215}$$

Sag curves (ft.): $$LVC = \frac{AV^2}{45}$$

Sag curves (m): $$LVC = \frac{AV^2}{317}$$

Where LVC = length of vertical curve

A = $(G_2 - G_1)$ = algebraic difference in gradients connected by the vertical curve, in percent

G_1 = percent grade of approaching tangent

G_2 = percent grade of departing tangent

V = design speed, in mph (km/h)

The minimum equivalent radius of curvature for vertical curves shall not be less than 1150 ft. (350.520m) for crests and 820 ft. (250m) for sags.

$$R_V = \frac{LVC}{0.01(G_2 - G_1)}$$

Rv = Minimum radius of curvature of a vertical curve in ft (m)

5.2.3 Special Trackwork

Special trackwork consists of switches, turnouts, and rail-to-rail crossing diamonds. In general, special trackwork shall be located on track segments that are tangent both horizontally and vertically, including tangent segments in advance of points of switch. For alignment requirements through special trackwork areas, refer to Section 5.4.4.

5.3 CIVIL WORK

This section establishes the basic civil engineering guidance to be used in the design of the DC Streetcar System. It includes guidance for surveys and the design of drainage, roadways and paving, and determination of required rights-of-way. The significance of the civil work is critical to the foundation of the constructability of the streetcar system.

5.3.1 Permitting requirements

Permitting requirements involve extensive and consistent communication with DDOT stakeholders and partners. The core team should employ a proven contractor that possesses expertise in utility coordination, public engagement, and permit expediting. Utility coordination efforts during the design and construction phases are important elements in the workflow. As a requirement, all major utility companies should be engaged throughout the process. The core team must make certain that the appropriate representatives from PEPCO, DC Water, Washington Gas, and applicable telecommunication provider (at a minimum) are actively involved. In addition, DDOT will assist the designer to coordinate efforts with the Districts Department of Consumer and Regulatory Affairs (DCRA) Chief Building Official to provide an initial review of plans at 65% completion. This interaction will allow the Design Team the opportunity to address any critical elements that may arise prior to the submission of the 100% plans.

The core team must provide key utility stakeholders with 30%, 65%, 90% and final design plans. This phased submission process will allow for more efficiencies and a greater level of communication throughout the process. There are two options to obtain the proper permits for conducting civil work. The first option is a standard building permit with a comprehensive set of architectural plans; Mechanical, Electrical and Plumbing (MEP) plans; and structural plans. The second option is a Civil/ Sitework (BCIV) permit. In most cases, DDOT recommends utilizing the BCIV permit option. The BCIV permit will allow the designer to acquire a permit to begin and complete all civil work while the full set of drawings is in progress. This permit is often used in situations when weather may adversely impact the construction schedule. The BCIV is reviewed by DOEE, DC Water, and DDOT. After obtaining the BCIV permit, the standard review time to acquire a building permit may be substantially reduced. Prior to any plans submissions, DDOT highly encourages the designer to meet with the Zoning Administrator to assure that the proposed locations comply with zoning regulations, if applicable.

5.3.2 Survey Control System

5.3.2.1 Horizontal Control

All horizontal controls for this project shall be based on survey control points established under DDOT direction. Coordinates for project control points established for the system shall be based on the Maryland State Plane Coordinate System. The North American Datum of 1983 (NAD83), 1990 or later readjustment shall be used to establish horizontal control.

The accuracy of the horizontal ground control and of supporting ground control surveys shall as a minimum be Second Order, Class I, as defined by the Federal Geodetic Control Committee and published under the title "Classification, Standards of Accuracy and General Specifications of Geodetic Control Stations, published by the National Geodetic Survey (NGS)" (February 1974).

5.3.2.2 Vertical Control

The vertical control for this project shall be based on the North American Vertical Datum of 1988 (NAVD88).

The accuracy of the vertical ground control and of supporting vertical ground control surveys shall be at least Second Order, Class I, as defined in the preceding section.

5.3.3 Drainage

The goal in the design of system drainage is to protect the track and facilities from stormwater runoff damage, provide proper drainage of the shared use roadway, and to minimize potential impacts to properties along the alignment from resulting stormwater runoff, either passing through or caused by streetcar construction, while maintaining consistency with the requirements of the Clean Water Act. The Department of Energy and Environment (DOEE) has jurisdiction over the stormwater quality criteria for this project. Drainage grates should be bicycle safe with cross bars to prevent tires from getting caught and possibly causing injury to a bicyclist.

The design of drainage facilities shall be in accordance with:

- District Department of Transportation, Design and Engineering Manual
- WMATA LRT and Streetcar Project Interface: Coordination for the Washington DC Metropolitan Area Technical Memorandum: Compatibility of Systems and Infrastructure WMATA Adjacent Construction Project Manual DC Water Standard Details
- DC Water Design and Construction Standards, and Standard Specifications
- Department of Energy and Environment Stormwater Management Guidebook

- District Department of Transportation, Green Infrastructure Standards and Supplements

5.3.3.1 Roadway Drainage

Roadway Drainage shall be designed according to the applicable section of the *DDOT Design and Engineering Manual* to accommodate the stormwater discharge based on a 15-year, 24-hour design storm, which shall be used for urban streets and a 25-year, 24-hour design storm, which shall be used for interstate systems to ensure that adequate flood protection is provided. For storm sewer pipes, a 50-year storm for pipes draining to the low point in sag shall be used. Maximum spacing between inlets on streets shall be the length of the block. The maximum spacing between manholes shall be 400 feet. The design discharge should be calculated using the Rational Method.

The DC Water Standard Details, Project Design Manual – Volume 3 and Specifications, shall be used for all proposed drainage facilities.

In addition, the DOEE *Stormwater Guidebook* defines the runoff depth to be treated on post-development land use for water quality treatment on transportation projects. DOEE requires that all projects meet the District water quality standards, as set forth in Chapters 1-5 of the *Stormwater Guidebook*. To ensure that this guidance is met, the Project must also meet the quantity control requirements, as described in the guidebook. It also requires that all projects meet the minimum control requirements for stormwater management and the selection of the most effective Best Management Practice (BMP) system.

5.3.3.2 Streetcar/Track Drainage

This guidance applies only to the design of drainage facilities applicable to the DC Streetcar guideway. Drainage of roadway facilities and connections to other drainage systems will be designed in accordance with the criteria of DDOT and DC Water.

Streetcar/Track drainage facilities will be designed to accommodate the stormwater discharge based on the 25-year storm frequency for track roadbed, longitudinal storm drains in roadways, all longitudinal drains or sub-drains at low points, and 100-year for all culverts and drainage facilities crossing the guideway.

In track sections, manholes or drainage inlets will be provided at maximum spacing for the selected type based on pipe cleaning requirements (300 feet maximum) or the restricting water depth encroachment from the tracks, whichever is less.

Designs of drainage facilities belonging to any other agencies, which are relocated or modified because of streetcar construction and which do not cross or parallel streetcar system guideway or facilities, shall conform to the design criteria and standards of the agency or jurisdiction involved.

5.3.4 Right-Of-Way (ROW)

ROW is the composite total requirement of all real property, interests and uses, both temporary and permanent, needed to construct, maintain, protect and operate the DC Streetcar. The intent is to acquire and maintain the minimum ROW to be consistent with the requirements of the DC Streetcar System.

The ROW take limit is influenced by the existing topography, drainage, service roads, utilities, nature of the streetcar structures selected, ADA accessibility requirements, and disaster and/or firefighting requirements.

Where property must be acquired to provide ROW for the DC Streetcar Program, such property acquisition shall be done in conformance with all appropriate city, state and federal regulations.

5.3.4.1 Definition of Types of Right-of-Way

Right-of-ways may consist of one or a combination of several types of real property interests. There are Fee Ownership, Joint Use of Public Right-of-Way, Permanent Easement, Construction Easement and Utility Easement.

5.3.4.1.1.1 Fee Ownership/Exclusive Right-of-Way

Fee ownership is a condition where ownership of property is purchased for project-related facilities and the ROW is used exclusively by the DC Streetcar.

5.3.4.1.1.2 Joint Use of Public Right-of-Way

Joint use of public ROW is a condition in which DC Streetcar facilities would be constructed in the public ROW. Existing and future facilities, such as sidewalks, gas lines, water lines, sewers and others not necessarily related to the DC Streetcar System, could also be contained in a portion of the same public ROW. Joint use of public ROW shall always be the first type of ROW considered for the DC Streetcar System.

5.3.4.1.1.3 General Easement Information

It is important for the designer to understand and plan for the time it takes to process and register an easement. The time will vary depending on the type of easement and the party responsible for processing the easement.

5.3.4.1.1.4 Permanent Easement

Permanent easement ROW is a condition in which ownership of the property is held in fee by others and an easement or right to occupy a certain limited portion of the property, usually for a specified use, is acquired from the Fee Owner.

5.3.4.1.1.5 Construction Easement

Construction easement ROW is a condition in which a temporary easement or short-term lease is acquired from the Fee Owner. A construction easement provides sufficient space to allow for the use of the property by the contractor during construction. This easement usually terminates soon after the completion of construction.

5.3.4.1.1.6 Utility Easement

Utility easement ROW is a condition in which ownership of the property is held in Fee by others and an easement or right to install and maintain utilities, either underground or overhead, on a certain limited portion of the property, is acquired from the fee owner.

5.3.5 Roadways

Roadway design in public ROW shall be in conformance with the specifications and guidance of DDOT. The structural cross section of the streetcar pavement shall be designed for a 20-year life to support the anticipated traffic use.

Road and parking surfaces shall be either Portland cement concrete pavement or Plant-Mix Bituminous Pavement. The criteria set forth in this section are applicable to the design or alterations to existing streets. Any other road or parking surfaces will require a design exception approval by DDOT.

5.3.5.1 Applicable Standards

Unless otherwise stated, roadway design shall be in accordance with the Codes and Standards described in Chapter 2. Those designs shall be in conformance with the current version of published standards and details of the local agency having jurisdiction.

The current versions of the following documents are incorporated into this guidance by reference, and they should be adhered to wherever possible in the design of roads, parking ,and related traffic control. In cases where DDOT design standards conflict with other applicable federally-published standards, a design waiver or exception shall be completed according to the process outlined in the *DDOT Design and Engineering Manual*. Also, while all references below shall be used as applicable, the final design considerations shall be made in consultation with the DDOT Program Manager (Construction and Engineering).

- DDOT Standard Specifications for Highways and Structures
- DDOT Standard Drawings
- DDOT Design and Engineering Manual
- DDOT Green Infrastructure Standards
- AASHTO Guide for Design of Pavement Structures

- The most current standards or Federal guidance or generally acknowledged best practices on ADA accessible design
- FHWA Manual of Uniform Traffic Control Devices (MUTCD)
- AASHTO A Policy on Geometric Design of Highways and Streets (Green Book)
- AASHTO Roadside Design Guide

5.3.5.2 Roadway Geometrics

Design of District of Columbia roadways shall be in accordance with the Policy on Geometric Design of Highways and Streets, latest edition published by the American Association of State Highway and Transportation Officials (AASHTO), requirements listed in Chapter 2 and as listed above.

5.3.5.2.1.1 Traffic Lane Widths

City streets shall have a minimum 10’-0” traffic lane width unless otherwise authorized in writing by DDOT. Designated transit (including streetcar) lanes shall have a minimum 11’-0” unless modified as necessary while still maintaining the minimum dynamic envelope of the streetcar vehicle.

Roads shall be designed in accordance with DDOT Standards and Specifications and the applicable section in the DDOT Design and Engineering Manual.

In cases of significant constraint, a width reduction may be specified with the approval of DDOT.

5.3.5.2.1.2 Number of Traffic Lanes

The number of traffic lanes and type of lanes (e.g. through, right, or left) shall be determined in consultation with DDOT, generally based on a traffic analysis which considers projected traffic volumes, streetcar vehicle intersection crossings, critical traffic movements, and geometric configurations. Wherever possible, the existing traffic lanes shall be maintained and only modified as approved by DDOT.

5.3.5.2.1.3 Parking Lanes

DDOT actively assesses the need for parking throughout the city and works to maintain the number of parking spaces where applicable. However, there are instances when the need to reduce or restrict parking is necessary (e.g. improved transportation systems, safety, or new design elements). DDOT will work with the designer to develop a streetcar system that will try to maintain the current levels of parking or minimize any reduction of parking along the designated streetcar corridor. If a parking space reserved for citizens with disabilities is removed, it must be re-established as close to the original location as possible and still comply with all applicable ADA accessibility requirements.

Parking lane locations shall be determined in consultation with DDOT based on traffic analysis, safety considerations, and demand for on-street parking. Twenty-four-hour parking restrictions shall be recommended at those locations (e.g., near intersections and at streetcar stops) where roadway width is not adequate to provide the necessary number of through lanes. Peak hour parking restrictions shall be recommended at those locations where traffic analysis shows that the capacity of the traveled way without the parking lane will not provide the level of service required. Parking lane widths shall be a minimum of 9'-0" adjacent to the streetcar guideway, and striped to delineate the limits of the streetcar dynamic envelope.

A stop location along a street with on-street parking is created by extending the sidewalk edge out to meet the travel lane (a bulb-out), which may result in the elimination of parking spaces, loading zones, etc. (as approved by DDOT).

5.3.5.2.1.4 Vertical Clearance

The minimum vertical clearance above traffic lanes and shoulders on all roadways shall be 19 feet. Clearance above the roadway when approaching or passing under an existing structure may be reduced, as compatible with the vehicle's pantograph, with approval of DDOT. The clearance shall apply over the entire vehicle roadway width including any contiguous auxiliary (turning) lanes and shoulders. Traffic signals, mast arms, and pedestrian bridges shall be relocated or modified as necessary to provide adequate clearance for the streetcar's overhead contact system.

Vertical clearances associated with railroad crossings shall be in accordance with affected agency requirements.

5.3.5.3 Curbs, Wheelchair Ramps, and Curb Cuts

Concrete curbs shall be installed along all new, widened or reconstructed streets, or access roads to be owned or maintained by DDOT. Existing granite curbs shall be replaced or restored in kind, and limestone curb shall be replaced with granite or concrete as directed by DDOT.

When new curb is constructed, the height of the face of curb above the finished pavement elevation shall be in accordance with DDOT standards. At streetcar stops, a raised curb line allows for ADA access to and from the streetcar stop. The raised curb shall be accomplished through ADA compliant ramps or slopes with the existing ADA compliant sidewalk, curb, or other facility. If the existing sidewalk, curb, or facility does not satisfy ADA requirements then it must be brought into compliance.

Where the streetcar operates along a travel lane adjacent to on-street parking, a stop location is created using a bulb-out; eliminating three to four parking spaces.

ADA ramps with curb cuts shall be provided in the following scenarios:

- Where there is a need to restore or replace any existing ramps

- Where alleys are encountered (with or without curb ramps) accessibility shall be handled by building the alley entrances as Modified Commercial Driveways – not with the use of standard curb ramps. The curb radius will generally be 4 feet but may vary depending on the width of the crossing sidewalk.
- Provide new ramps at intersections where sidewalk exists and the curb returns are modified as part of this project. It is not necessary to provide ramps and curb cuts where no sidewalk exists, unless the ramp is located at an intersection where no ramp exists.
- Provide ramps and curb cuts at intersections or mid-block locations where new curb and sidewalk will be constructed as part of this project

The design and location of curb cuts and ramps shall be in accordance with the applicable provisions of DDOT and USDOT's Standards for Accessible Transportation Facilities to comply with the Americans with Disabilities Act (ADA). The design and location of curb cuts and ramps shall also be vetted with the public during the environmental and design phases when applicable.

5.3.5.4 Sidewalks

Sidewalks shall comply with DDOT Standards and Specifications (including DC Streetcar Standard Drawings and Specifications). Cross slopes on sidewalks shall be a maximum of two percent. Existing sidewalks impacted by the project shall be repaired or replaced in kind where practical. New sidewalks may be required at stops.

At stops, the sidewalk shall adhere to the DC Streetcar Standard drawings per stop type. Access ramps for a stop with sidewalk behind the shelter would require some extra sidewalk to allow for maneuverability between the ramps and the sidewalk.

The design of sidewalks shall be in accordance with the applicable provisions of DDOT and USDOT's Standards for Accessible Transportation Facilities to comply with the ADA.

5.3.5.5 Driveways

Driveway pavement types and minimum widths shall be as per DDOT standards. In general, all existing driveways impacted by the project shall be replaced in kind, where practical. Driveway closings required to facilitate streetcar operations or construction must be approved by DDOT.

5.3.5.6 Roadway Paving

Restored or widened city streets shall be designed in accordance with DDOT Standards and Specifications.

Travel lanes, drop-off lanes, access driveways, stop bars, bike lanes and selected crosswalks shall be designated with striping as per DDOT standards.

Significant re-grading may be required at intersections, particularly at turns, to accommodate variable crowns. Drainage must be maintained, with particular attention given to curb ramps.

5.3.5.7 Traffic Maintenance and Protection

The maintenance of traffic plans shall be designed in accordance with the Manual on Uniform Traffic Control Devices (MUTCD) and the DDOT Temporary Traffic Control Manual. The maintenance of traffic plans shall be submitted to and approved by local agencies. The maintenance and protection of both vehicular and pedestrian traffic must be addressed on the plans.

Construction and installation of at-grade track crossings shall be completed in one full road or intersection closure to minimize delays on tracks. Approval of construction plans, construction sequencing and traffic staging is required by the railroad company. An agreement between DDOT and the railroad company may be required.

Pedestrian traffic shall be maintained where it is feasible in the safest manner possible. The designer shall include any site-specific requirements in the design drawings. Maintenance of pedestrian traffic shall be in accordance with the ADA, MUTCD, and DDOT standards, as appropriate.

5.3.6 Grading

All unpaved areas of proposed construction will be cleared and grubbed, including the removal of unsuitable backfill material and root mat. All areas disturbed by construction will be protected by an approved erosion and sediment control system as per DOEE Standards and Specifications for Soil Erosion and Sediment Control. Methods of erosion control to be considered may include seeding and mulching, sodding, application of geotextile fabrics to stabilize areas, and the application of a gravel or coarse aggregate.

Cut and fill slopes along the Streetcar/Track guideway shall be two horizontal to one vertical (2:1), or as otherwise determined by geotechnical analysis. Along roadways, cut slopes will generally be a maximum of 2:1 or flatter as required for sight distance around curved alignments. Roadway fill slopes will be a maximum of 2:1 but will be flattened to 4:1 where possible to minimize the need for guide rail.

5.3.7 Applicable Streetcar Standard Drawings

- C-01 Streetcar Typical Pavement Marking with Dedicated Bike Lane
- C-02 Streetcar Typical Traffic Signing with Dedicated Bike Lane
- C-03 Streetcar Typical Pavement Marking with Shared Bike Lane (2 Travel Lanes)
- C-04 Streetcar Typical Traffic Signing with Shared Bike Lane (2 Travel Lanes)
- C-05 Streetcar Typical Pavement Marking with Shared Bike Lane (3 Travel Lanes)

- C-06 Streetcar Typical Traffic Signing with Shared Bike Lane (3 Travel Lanes)

5.4 INTEGRATED RIGHT-OF-WAY AND ALIGNMENT IMPROVEMENTS

The implementation of streetcar alignments should be coordinated with other related infrastructure improvements, such as the Great Streets projects, redevelopment projects, traffic signal upgrades, utility projects, zoning and building codes, and historic designations.

5.4.1 Streetscape and Low Impact Development Strategies

5.4.1.1 Sidewalks – Through Zones & Furnishing Zones

The addition of transit infrastructure should not negatively impact existing sidewalk through and furnishing zones to the extent that they no longer meet DDOT standard width requirements. Transit infrastructure should be designed to improve the existing conditions where possible.

5.4.1.2 Curb Extensions

New curb extensions should be designed to provide adequate pedestrian safety adjacent to streetcar alignments.

Figure 5-3 | Curb Extensions

5.4.1.3 Tree Buffer and Landscaped Areas

The implementation of streetcar alignments should include landscape improvements where possible. The inclusion of a tree buffer is beneficial to reduce the visual impact of overhead wires (where installed) for pedestrians while also helping to restore the historic tree canopy of the District of Columbia. Tree maintenance and the selection of tree type are to be coordinated with DDOT Urban Forestry Administration. The designer shall make certain that all necessary permits have been obtained and reviewed by Urban Forestry Administration prior to any tree removal. The maintenance and design of trees and landscapes shall be consistent with ANSI A300 Standards for Tree Care Operations.

5.4.1.4 Street Lighting and Joint Use OCS Poles

Joint-use OCS poles should be used whenever possible to avoid pole clutter in the public realm. However, poles that serve a special function such as, but not limited to, feeder poles, section isolation poles, or special signal poles, shall be exclusively for streetcar use.

5.4.1.5 Coordination with On-Street Parking and Loading Zones

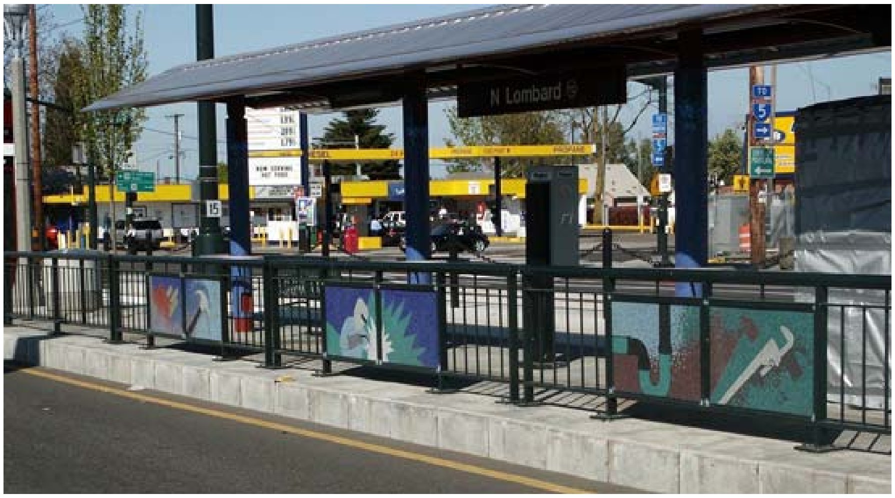
The location of stops and length of platforms should minimize reduction of on-street parking where possible. Careful consideration should be given to the distance between the on-street parking and the streetcar alignment to ensure sufficient space exists for both to coexist. Adequate signage and pavement markings should be placed along the corridor to warn drivers to park within the allotted area to avoid impacting the streetcar's dynamic envelope. In addition to on-street parking, truck loading and unloading should be coordinated to ensure that there are no conflicts with streetcar operations. Designated loading/unloading areas within the parking lane should be evaluated.

Figure 5-4 | Parking Stripe Signifying Edge of Dynamic Envelope

5.4.1.6 Integration of Public Art

The incorporation of public art at the stops will be dependent on location. Opportunities for the integration of public art could include special benches, paving, lighting, OCS pole decoration and free-standing sculptures.

Figure 5-5 | Public Art at Lombard Station (Portland, OR)



5.4.1.7 Bicycle Interactions and Streetcars

The interaction between streetcars and bicyclists must be considered in the planning and design of streetcar facilities. There are multiple current practices that exist that DDOT can use. The City of Portland's Lloyd District Transportation Management Association (LDTMA) prepared a document entitled "Bicycle Interactions and Streetcars, Lessons Learned and Recommendations", dated October 17, 2008. This document, together with the "DDOT Bicycle Facility Design Guide", provides guidance on how bike lanes can interact with the streetcar in the safest manner possible. In 2014, the District did adopt regulations that provide guidance on the conduct in the streetcar system (https://www.dcregs.dc.gov/Common/DCMR/RuleDetail.aspx?RuleId=R0016691, Section 18-1605). It provides guidance on acceptable and unacceptable behavior for bicyclists on the streetcar vehicle and on the streetcar platform. Some additional elements to be taken into consideration during the planning and design are provided below:

- Proposed streetcar routes relative to existing and proposed bike routes
- Streetcar lanes relative to bike lanes: Inside lane or outside lane for streetcar
- Impacts to current bike route users and the community

- Skew angle between the bike lanes and streetcar tracks shall be near perpendicular (no less than 60 degrees) to minimize interaction between the bike wheel and track flangeway, and reduce slippage on wet rails
- Bike lanes shall avoid track switches and tight radius curves
- Interaction between bike lane and stops
- Potential for providing a “grade separated cycle track”
- Appropriate signage and pavement markings and patterns
- Education – Cyclist, motorist, and streetcar operators outreach
- Signalization and button actuated countdown bicycle signal head
- Manholes and other utility covers
- Track drain grates

Refer to the DDOT Streetcar Standard Drawings for details of bicycle interactions with streetcars.

Figure 5-6 | Bike Lane Crossing Track

5.4.2 Guideway Design Goals

5.4.2.1 Selection of Guideway Materials

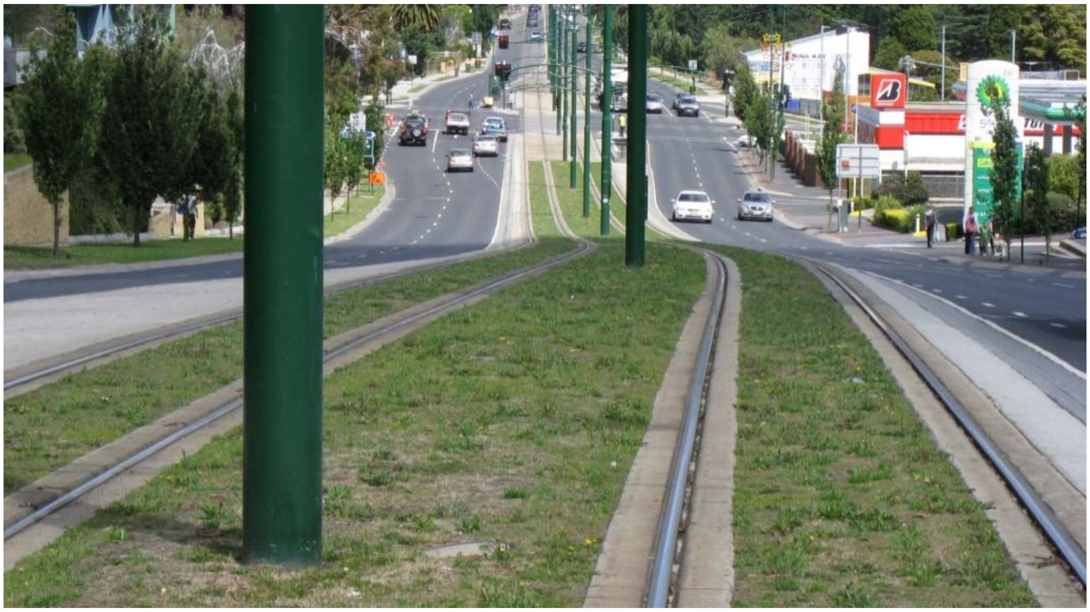
The selection of the track guideway material will be dependent on-site context. Concrete slab will be used for the track guideway. Ballast may be used in selected areas where a dedicated right-of-way is used for the alignment and aesthetic considerations are minor. Unit pavers may be used in special streetscape areas. Grass tracks may be used in various areas where appropriate. However, the grass track sections shall be designed to avoid the attraction of unwanted pedestrian foot traffic. The selection of track guideway materials should be discussed in the planning and environmental phase so that assumptions match subsequent mitigation and permitting requirements.

Figure 5-7 | Concrete Slab Track

Figure 5-8 | Ballast Track

Figure 5-9 | Unit Paver Track

Figure 5-10 | Grass Track



5.4.3 Infrastructure

5.4.3.1 Traction Power Substation Configuration, Access, and Landscape

The intent of this section is not to substitute for more detailed location specifications for traction power substations (TPSS.) Locations for TPSS shall be determined by consulting this design guidance and by conforming to other applicable regulations and review processes. Each TPSS shall be integrated within their architectural and applicable historic context. In certain areas of the District, TPSS may be restricted from being placed above grade within the public space. Design and locations for TPSS shall be coordinated with DDOT, SHPO, and other entities as needed to ensure conformance with these objectives. Additionally, specific guidance for the location of TPSS may be provided by the environmental planning and review process for a given streetcar line. The final guidance associated with any environmental review or action shall be consulted as part of the design process. The general location of power substations should be finalized during the planning and environmental phase and closely coordinated with the SHPO.

Generally, TPSS are spaced based on the traction power load requirements. Efforts should be made to minimize impacts of substation locations with architectural and landscape treatments. The TPSS are critical components to the success of the streetcar system.

The governing agency, DCRA, will review TPSS plans as a separate structure or part of the full system plan. DCRA will assign electric, fire, and structural as the primary reviewers for the TPSS. As DDOT considers alternative propulsion for future streetcar lines, TPSS and other infrastructure related to powering the streetcar vehicles should be coordinate with the appropriate agencies and community organizations.

Historic properties whose physical or visual environments may be altered by the project shall be identified during the environmental phase and will be coordinated with the SHPO. Standard practices shall be employed to minimize the impact on these properties. With regard to operational impact, standard methods of physical protection and photographic record keeping may be necessary. Photographic record keeping will be required and shall document the properties' environment before start-up of streetcar operations. The State Historic Preservation Office (SHPO) shall be consulted regarding the mitigation measures to be employed at each affected site to the degree specified in the Environmental Document. All work shall conform to the requirements and practices of the DDOT Environmental Manual.

5.5 TRACKWORK

This chapter establishes the basic guidance to be used in the design of streetcar trackwork.

5.5.1 Applicable Streetcar Standard Drawings:

- T-01 Standard Track Symbols, Abbreviations & General Notes
- T-02 Horizontal Curves
- T-03 Rail Section Details
- T-04 Embedded Track Slab Details
- T-05 20 Meter Curved Turnout Detail
- T-06 25 Meter Curved Embedded Turnout Detail
- T-07 25 Meter Straight Turnout Detail
- T-08 Trackwork Turnout Tub Details (Sheet 1 of 2)
- T-09 Trackwork Turnout Tub Details (Sheet 2 of 2)
- T-10 Track Drain Details
- T-11 Trackwork Restraining Rail Details
- T-12 Utility Impact Zones

5.5.2 Guideway

The guideway is defined as the portion of the streetcar system, which has been prepared to support the track and its appurtenant structures. The design guidance pertaining to the guideway for the DC Streetcar System is covered under two separate categories, mainline track and yard tracks.

5.5.2.1 Embedded Tracks

Embedded track shall be the typical type of track within the roadway. A reinforced concrete track slab shall provide the foundation for this type of track construction. The design of the track slab shall be based on automotive vehicle loadings, streetcar vehicles, and soil conditions. The reinforced concrete track slab shall utilize low permeability concrete that has an average chloride ion permeability level of less than 1,000 coulombs charge, with maximum permeability not more than 1,300 coulombs charge. Chloride ion permeability shall be tested in accordance with ASTM C1202.

Existing roadway pavement will be cut and trenched to sufficient width and depth to allow for the construction of the track slab, special trackwork reinforced concrete tub, and streetcar systems ducts, if required.

Figure 5-11 | Embedded Track Slab

Figure 5-12 | Embedded Track Slab Construction

5.5.2.1.1.1 Sub-base

The required thickness of sub-base for the track slab shall be determined through a structural analysis of the track structure and analysis of the geotechnical characteristics of the subgrade soils. The subgrade shall be evaluated and remediated as directed in the Geotechnical Report. In general, the sub-base layer for the embedded track slab shall consist of a uniform layer of aggregate base that is placed over and follows the profile and cross-section of the subgrade and is not less than 6 inches deep.

5.5.2.1.1.2 Embedded Special Trackwork

Special trackwork consists of switches, turnouts and rail-to-rail crossing diamonds. A reinforced concrete tub lined with electric isolation material shall be constructed for special trackwork that cannot be economically or effectively insulated using a rubber boot system. Special trackwork may include heaters as needed.

5.5.2.1.1.3 Embedded Track Drainage

Track drains shall be used in paved track areas to properly drain the rail flangeways and the pavement surface between the rails. In cases where girder rail is used, girder rail flangeway drain holes shall be slotted holes centered in the girder rail groove. Drain holes in the girder rail shall not impact the integrity of the rail. Track drains shall be spaced generally every 600 feet maximum on tangent level track. Drains shall also be located at the low points of the profile and immediately upstream to special trackwork to prevent water and dirt from entering critical areas. Track drains shall be electrically isolated from the running rails and include bicycle safe grates. Bicycle safe grates should have cross bars to avoid bicycle tires from getting stuck and possibility injuring bicyclists.

After the track has been installed, the specified embedment section will be applied to conform to the required street cross-section.

The design should ensure proper drainage for street-running track sections. Where practical, the adjacent pavement surface shall be designed so water will drain away from the track. Track drains shall be used to prevent water from standing or pooling. In areas of special trackwork, attention shall be directed to provide drainage for the special trackwork units and switch-throwing mechanisms. Where possible, track drains shall be in tangent track and should not be placed in pedestrian circulation paths (e.g., crosswalks).

Figure 5-13 | Track Drain Example

5.5.2.1.1.4 Embedded Trackwork on Existing Bridge Structures

All track designs and construction work that will be installed on existing bridge structures shall be coordinated with DDOT. Installation of embedded streetcar trackwork on existing bridge structures shall be in the non-structural concrete deck overlay portion of the bridges. Embedded track installed on an existing bridge deck overlay shall be designed and constructed in a manner that does not impact the structural load capacity and service life of the bridge structure. Embedded track designs and construction shall accommodate the existing drainage systems (drainage board and deck drains), maintaining the functionality of the existing system. Embedded track design and construction shall maintain the integrity of existing waterproofing system between the bridge deck and concrete overlay to not void any existing leakage warranties. If the track cannot be installed without voiding existing waterproofing warranties, then the contractor shall be required to provide a new warranty on the modified waterproofing system to meet or exceed the current warranty specifications and balance of the warranty period.

Where embedded track crosses existing bridge joints, the joint modifications shall be designed and constructed in a manner that effectively accommodates track expansion joints, thermal movements of the track and bridge structure. Joint modifications shall be designed and constructed in a manner that maintains existing water tightness and drainage of the existing joint system, preventing leakage of water into areas below the bridges.

Where embedded track encroaches upon existing bridge approach slabs, the approach slab modifications shall be designed and constructed to maintain the structural integrity and functionality of the existing approach slab and support the new embedded track or track slab. All approach slab designs and modifications shall be in accordance with pertinent AASHTO and the DDOT Design and Engineering Manual.

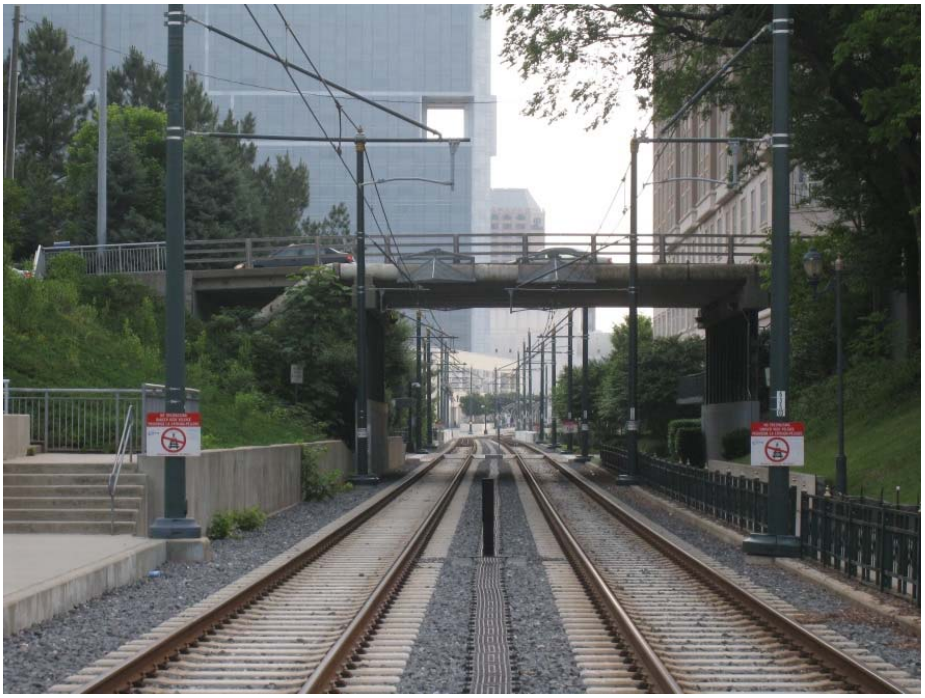
5.5.2.1.1.5 Trackwork Crossing Existing Subway Structures

In some cases, the proposed streetcar alignment will travel above existing Washington Metropolitan Area Authority (WMATA) subway tunnels. Coordination with the WMATA Office of Joint Development and Adjacent (JDAC) Construction is essential to design the track slab and OCS foundations such that they do not negatively impact the existing tunnel structure. Refer to the Adjacent Construction Project Manual (ACPM) for requirements.

5.5.2.2 Ballasted Tracks

Guideways located in exclusive rail transit right-of-way (non-street running) shall be constructed utilizing ballasted track unless otherwise required for paved areas surrounding the track, passenger stops, grade crossings and maintenance access.

Figure 5-14 | Ballasted Track



5.5.2.2.1.1 Sub-ballast

Sub-ballast is defined as a uniformly graded material that will provide a semi-impervious layer between the ballast and the subgrade. It facilitates drainage by shedding water off to the sides of the trackway, shielding the subgrade from moisture that percolates down through the ballast. Sub-ballast material shall be used beneath ballasted track sections.

The required thickness of sub-ballast shall be determined through a structural analysis of the track structure and analysis of the geotechnical characteristics of the sub-grade soils. In general, the sub-ballast layer for the track shall consist of a uniform layer of coarse aggregate that is placed over and follows the profile and cross-section of the sub-grade and no less than 6 inches deep.

5.5.2.2.1.2 Ballast

AREMA no. 5 ballast gradation of granite material shall be used within yard. The ballast gradation number shall be in conformance with the AREMA specifications. A minimum ballast depth of 12 inches shall be used between the bottom of tie and the top of the sub-ballast (beneath the low running rail). The shoulder ballast shall extend a minimum of 12 inches (.305 m) beyond the ends of the ties parallel to the plane formed by the top of the rails. Shoulder ballast shall then slope downward to the sub-ballast at a 2:1 slope. Use of a retaining wall will be investigated to prevent ballast from over spilling into pavement areas or in areas with limited right-of way. The final top of ballast elevation shall be 1 inch below the top of the ties, when compacted. Crushed slag or limestone ballast shall not be permitted.

5.5.2.2.1.3 Slopes

On ballasted sections, side slopes of earth shall generally be constructed two horizontal to one vertical (2:1) or flatter. Side slopes of earth steeper than two horizontal to one vertical (2:1) may be used in special situations to avoid excessive earthwork or right-of-way costs; however, such slopes shall not be used without a soil engineer's determination of slope stability.

5.5.2.2.1.4 Ballasted Track Drainage

Ditches, grate drains, and underdrains shall be provided at the edges of the track to prevent water from ponding or covering any part of the track structure or contributing to subgrade instability. Minimum ditch grade shall comply with the requirements of Chapter 2. In areas where the right-of-way does not allow use of the standard ditch section, underdrains shall be used.

5.5.3 Trackwork Components

5.5.3.1 Track Gauge

Track gauge shall be a standard gauge of 4 ft 8 ½ in (1435.099mm). The gauge is the distance between the inner sides of the head of rails measured $^{5}/_{8}$ in below the top of rails. Wider gauges may be used in some curves, depending on the radius. Track gauge shall be widened up to ½" in for any curve radius of 150 feet or less. Track gauge for curve radius less than 500 feet and greater than or equal to 150 feet shall be incrementally widened from ¼ inch to ½ inch. No gauge widening shall occur in tangent track, or curved track with a radius greater than 500 feet.

Gauge widening shall be at a constant transition rate and not more than ¼ inch in a distance of 31 feet, to a maximum of ½ inch in 62 feet. Full gauge widening shall be accomplished on the tangent in approach to the point of curve and removed following the point of tangent in simple curves. In spiral curves, gauge widening shall be applied and removed within the spirals. If the spiral is too short for full gauge widening to be accomplished beyond the rate exceeding ¼ inch in 31 feet, sufficient gauge widening shall be placed in the approach tangents to meet the rate of ¼ inch in 31 feet. If adjacent curves with both requiring widening are too close together to allow run out of the gauge widening, the widened gauge shall be maintained between the curves. The track gauge in paved track using AREMA 115RE tee rail shall be established by using TCRP Report 155, Track Design Handbook for Light Rail Transit Gauge Determination Analysis, and the track gauge in paved track using girder rail shall be established by using TCRP Report 155, Track Design Handbook for Light Rail Transit Gauge Determination Analysis. Gauge widening on curves is not required for girder or block rail.

5.5.3.2 Premium Rail

Premium high-strength rail shall be shall be fully heat treated or head hardened rail and is suitable for installation in ballasted and embedded track. Premium high-strength rail shall be used in the vicinity of stops, other areas of frequent starting and stopping, such as traffic signal locations, on grades of five percent of greater, on curves with radius equal to or less than 500 feet, and in areas where high wear rates or internal rail stresses are anticipated. Premium rail shall also be used throughout all special trackwork.

5.5.3.3 Running Rail

There are three types of rail sections that can be used and are listed below:

- AREMA 115RE tee rail
- 51R1 girder rail (formally Ri52) – Low profile rail (130mm) with wider groove
- 53R1 girder rail (formally Ri53) – Low profile rail (130 mm)
- LK1 grooved block rail

Selection of the running rail section must be performed with the consideration for economy, strength, and availability. AREMA 115RE tee rail is manufactured within the United States on a large scale and can be purchased "off-the-shelf". Currently, girder rail is not manufactured within the United States. The Federal Transit Administration (FTA) Buy America requirement (49 CFR Part 661) may not permit the purchase of girder rail, or any other materials not manufactured within the United States for projects receiving federal grants. LK1 grooved block rail is currently manufactured within the United States at a small scale.

The AREMA 115RE tee rail requires a formed flangeway within the concrete track slab to accommodate the streetcar wheel flange. Restraining rail (guarded track) is used on sharp curves to reduce wear by restraining the wheels away from the outer rail. Girder rail and LK1 grooved block rail do not require a formed flangeway since they both contain a "lip" which the concrete track slab would abut to. Both AREMA 115RE tee rail and girder rail have been used extensively within the United States for in-street track, however LK1 grooved block rail has been used extensively in Europe and at a limited level within the US. All new rails shall conform to the current AREMA Specification for Steel Rails.

Horizontal bending of rail should be performed in roller straighteners for curve radii below 120m (393.701 ft). All running rails shall be procured in the longest lengths practical for transportation logistics and then electric flash butt welded into the longest continuous length feasible for installation. Field welds that conform to AREMA specifications shall then be used to join the lengths of flash butt welded rail.

On existing bridge structures, a custom or modified rail may be required to permit installation of the rails into the 6-inch topping slab. The rail shall be designed to meet the above strength, durability, and installation criteria.

Where high strength premium rail is used on curves, it shall extend into tangent track on the approach and departure ends of the curve a minimum distance of 10 feet.

Rails shall extend beyond the end of track slab approximately 3 feet within the pavement to accommodate future extension.

Figure 5-15 | AREMA 115RE Tee Rail

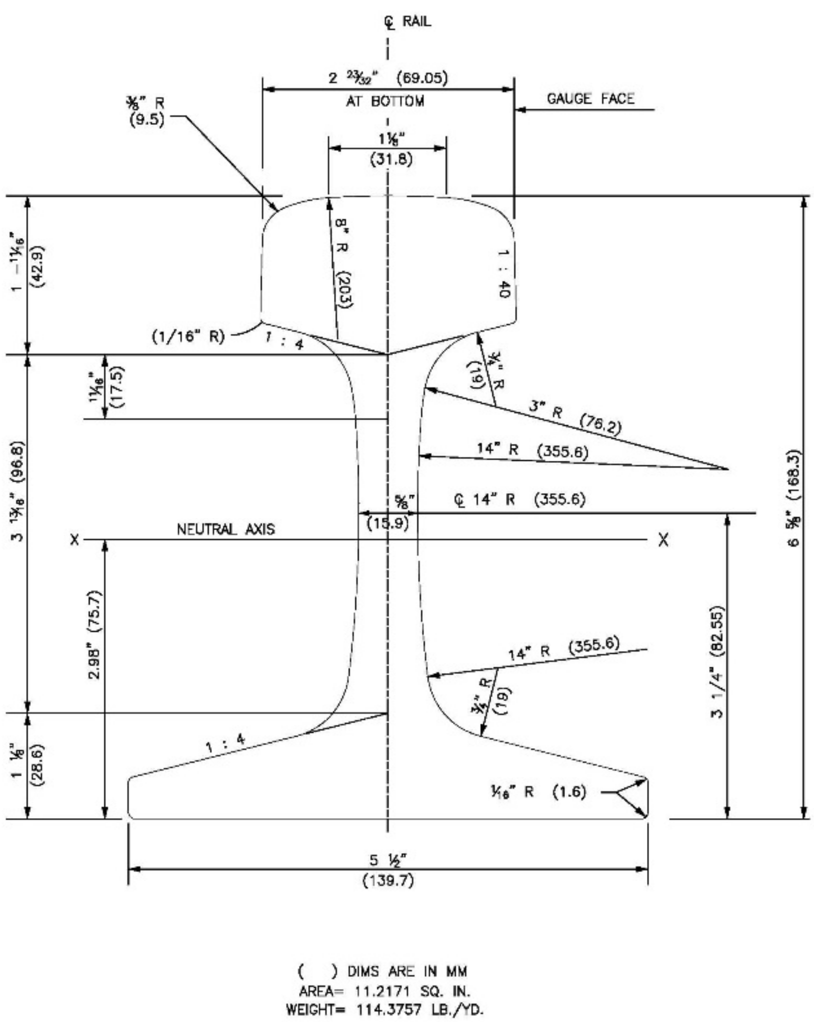


Figure 5-16 | 51R1 Girder Rail

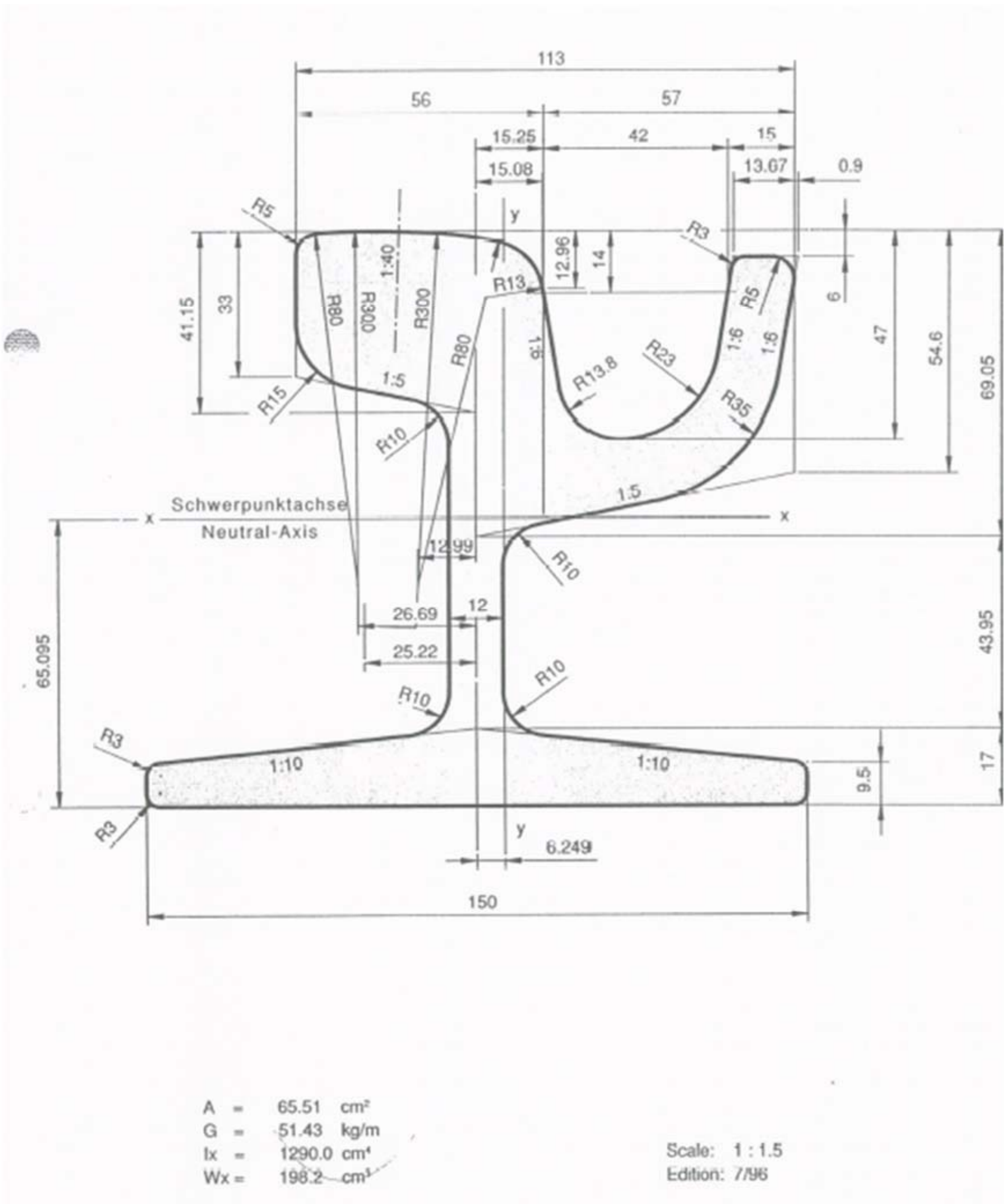


Figure 5-17 | 53R1 Girder Rail

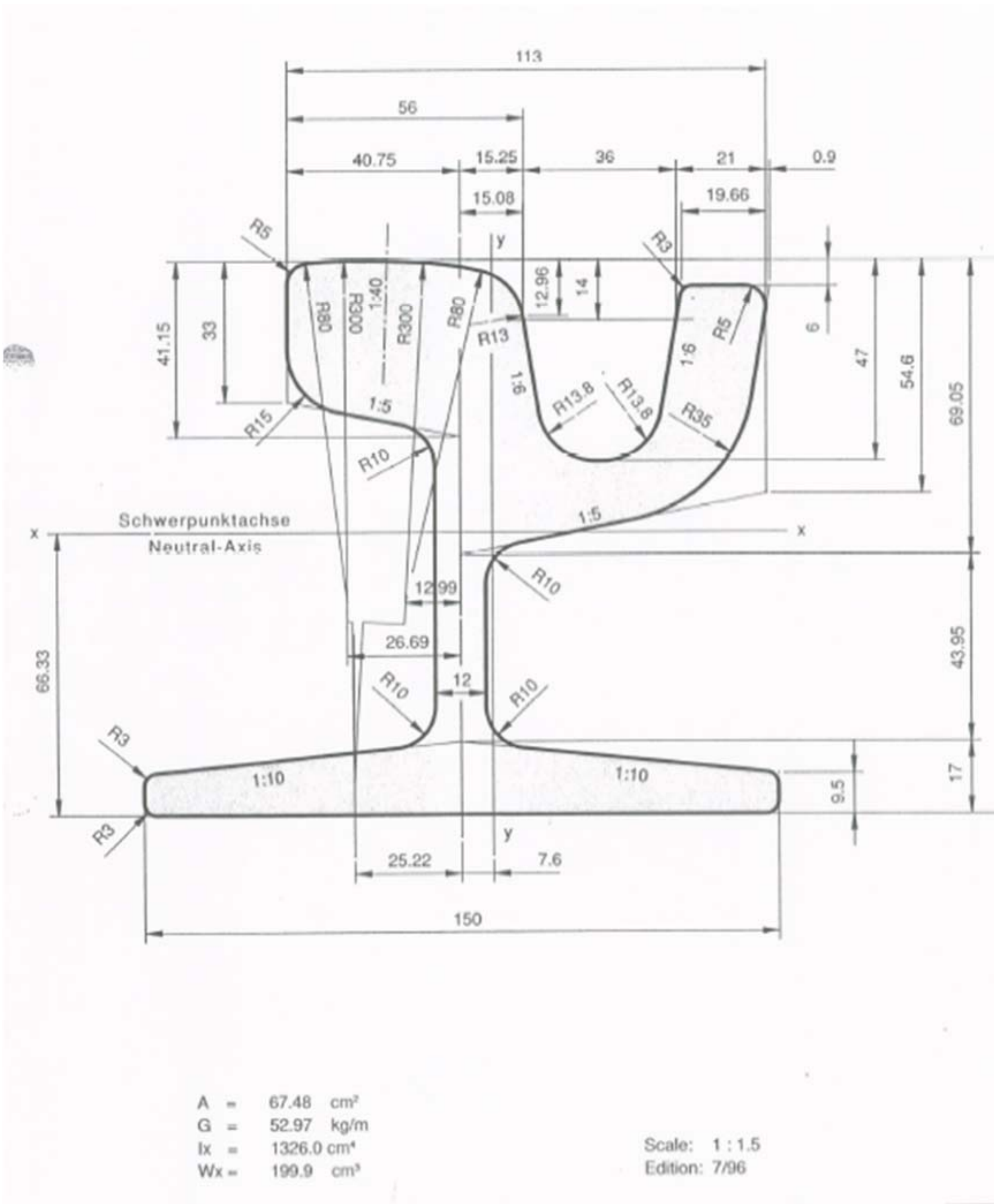
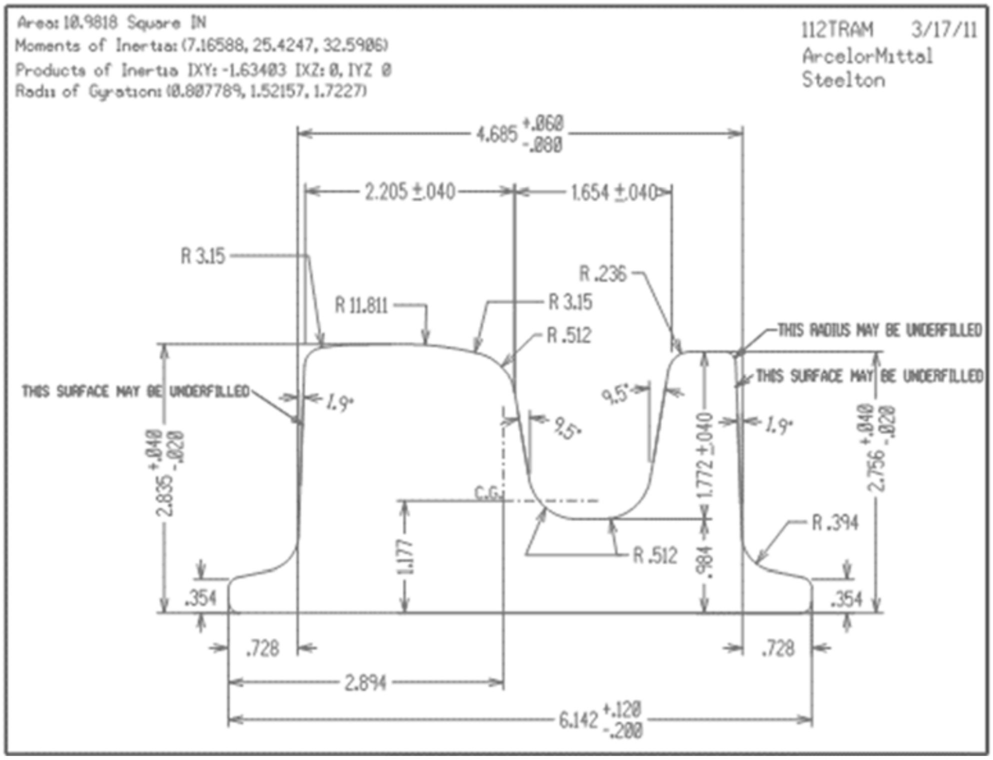


Figure 5-18 | LK1 Grooved Block Rail



5.5.3.4 Rail Fastenings and Rail Seats

Running rail shall be fastened to its support for each type of track construction. All rail fastenings and rail seats shall be in accordance with the current and applicable AREMA specifications.

5.5.4 Electrical Insulation

All tracks, regardless of the construction, shall be electrically isolated. Rails within the maintenance facility must be grounded for safety of maintenance crews.

5.5.4.1 Embedded Track

Embedded track rail shall be encased in an elastomeric material that meets the guidance specified in Chapter 6 and secured in place using tie bars/rail clips assembly or anchor plates/rail clips assembly. The preferred Elastomeric material shall be the pre-formed rubber boot but could be a poured in place grout if the track is embedded in concrete. The embedment material shall be set ¼ inches below the top of rail on the field side to prevent the wheel tread from damaging the pavement material.

Electrical testing of the embedded track will be required to demonstrate compliance with the corrosion control measures outlined in Chapter 6. The minimum resistance of the rail-to-earth will be a minimum of 200 ohms per 1000 ft.

During final design, alternative embedment methods for paved track shall be evaluated. If an alternate design for paved track proves to be advantageous, it may be substituted for the existing design with the approval of DDOT.

5.5.4.2 Ballasted Track

Ballasted tracks shall be constructed with concrete or wooden ties. The fastening system for the ties shall provide for electrical isolation to provide increased resistance to earth.

Electrical testing of the ballasted track will be required to demonstrate compliance with the corrosion control measures outlined in Chapter 6.

5.5.5 Special Trackwork

The term "special trackwork" designates the trackwork units necessary where tracks converge, diverge or cross one another. Special trackwork shall be located on constant profile grades and in tangent sections of track only. There shall be no superelevation in any special trackwork units.

5.5.5.1 Special Trackwork in Embedded Track

Turnouts, crossovers and crossing diamonds in the embedded streetcar track or embedded special trackwork units shall be constructed in a concrete tub track slab with rubberized spray-on liner to electrically isolate the special trackwork from ground. Special trackwork designs should conform to European design standards and as an alternative it can be embedded on elastometric grout. These turnouts are manufactured within the United States by various manufacturers. Turnouts shall have minimum 20m (65.617 feet) radius double-flexive tongue switches and flange-bearing mono-block curved frogs. Coordination with the vehicle manufacturer is required to ensure the vehicle can negotiate a 20m (65.617 feet) turnout.

- Efforts shall be made for embedded track turnouts to be located so that switch machines are not located in a pedestrian crosswalk and areas of shared use with vehicular traffic to enhance the safety of maintenance technicians.
- Embedded special trackwork shall be positioned so that switches, frogs and crossing diamonds are not located in designated pedestrian and bicycle paths to enhance the safety of both pedestrians and small-wheeled vehicles (e.g., wheelchairs) crossing the tracks.

Turnout and crossing diamond frogs shall be designed to accommodate the narrow tread streetcar wheel and hence shall be configured for flange bearing use. On curved streetcar crossing diamonds, consideration shall be given to making the outer rail of the crossing diamond fully flange-bearing and the portions along the inner rail tread-bearing to take advantage of the steering effects of the different rolling radii of the flange tip versus the tread.

Special drainage provisions shall be made in paved track turnouts to preclude standing water in flangeways, tongue areas, and in switch-throwing mechanisms.

Electrical testing of the embedded and ballasted track sections will be required to demonstrate compliance with the corrosion control measures outlined in Chapter 6.

Figure 5-19 | Embedded Turnout Tub

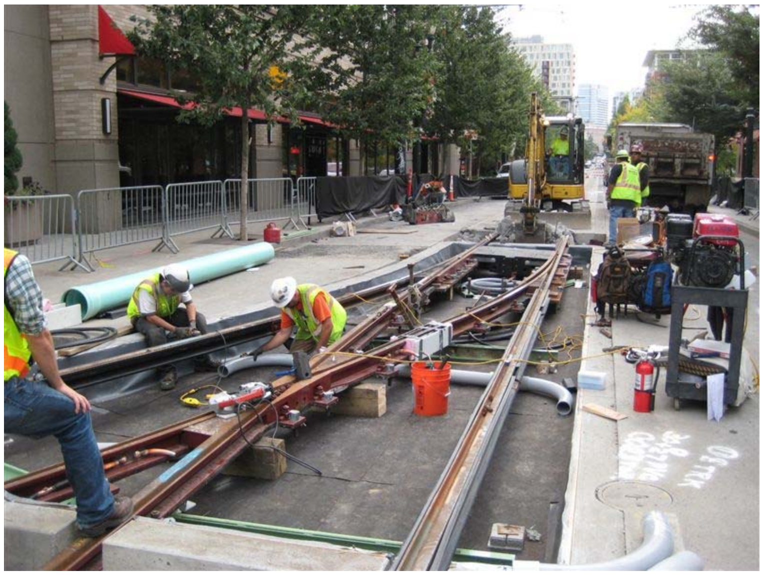


Figure 5-20 | Embedded Track Frog

Figure 5-21 | Embedded Track Diamond

Figure 5-22 | Embedded Track Switch

5.5.5.2 Special Trackwork in Ballasted Track

Where turnouts occur in ballasted track, the following desirable minimum and absolute minimum criteria shall apply:

- Yard tracks and main line tracks shall use #4 or 82-foot (25 m) turnouts.
- Tee rail switches shall be of the uniform riser design per AREMA and shall employ the AREMA detail 5100 undercut "Samson" switch point detail modified to lower the running surface of the stock rail opposite the point. [This modification is necessary to assure that wheels with worn flanges are intercepted and properly directed by the switch point. Flanges which have worn short can climb a 5100 detail used without the stock rail modification.]
- Where a pair of crossovers is required, they should be set as two single crossovers wherever possible. If this is not possible, a double crossover may be used with the approval of DDOT.
- Number 4 AREMA style turnouts should be used in any Maintenance and Storage Facility (MSF) yard. Turnouts can be installed in blasted track or installed on a concrete slab and direct fixation (DF). To avoid costly isolation measures, infill concrete is not required for turnouts installed with direct fixation on a slab. The rail will be exposed and isolated from the ground with the DF plates.
- The rail section leading up to an MSF should be 80 to 115lb CWR tee rail. Number 5 ballast, a walkable ballast specifically designed for use in maintenance facilities shall be used.

5.5.5.3 Switch Machines

Switch machines shall comply with the following as well as with Chapter 6 within this guidance:

- Powered switch machines shall provide both point detection and point locking
- Hand thrown manual switch machines shall generally be of the spring or toggle-type and will not normally require point detection or point locking
- Powered switch machine earth box for embedded turnout switches shall be designed to be installed between switch rails (in-board) and anchored on or in concrete inside the special trackwork insulated concrete tub
- Switch heaters are optional, but can be provided at the discretion of DDOT

Table 5-5 | Turnout Speed Table

TURNOUT OPERATING SPEED (MPH)			
TURNOUT RADIUS or NUMBER	MAX SPEED (U=3")	NORMAL SPEED (U=1 1/2")	Description
65.62 FT RADIUS (20 m)	7 MPH (11.265 km/h)	5 MPH (8.047 km/h)	American Public Transportation Association (APTA)
82.02 FT RADIUS (25 m)	8 MPH (12.874 km/h)	6 MPH (9.656 km/h)	American Public Transportation Association (APTA)

5.6 STRUCTURAL

5.6.1 General

This chapter defines the structural guidance and standards for the DC Streetcar System. Anticipated structures include catenary bridges, existing roadway bridges modified to accommodate streetcar guideways, underground structures and other miscellaneous structures.

5.6.2 Applicable Codes and Standards

The following are some of the codes, manuals, and specifications that 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
- DDOT Design and Engineering Manual
- DC Streetcar Utilities Standard of Practice
- AREMA Manual for Railway Engineering hereinafter referred to as the AREMA Manual
- American Concrete Institute (ACI) ACI 318 Building Code Requirements for Structural 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
- WMATA Adjacent Construction Project Manual
- District of Columbia Building Codes and all references and standards cited therein
- NFPA 101 and 130
- District of Columbia Accessibility Code (and the Americans with Disabilities Act)
- District of Columbia Department of Transportation (DDOT) requirements
- International Code Council (ICC)
- Relevant ASHRAE, ASPE, ANSI, NFPA, ASTM, and AWW Standards
- National Electrical Safety Code (NESC)
- National Electric Code (NEC)
- TCRP Report 155 – Track Design Handbook for Light Rail Transit, Chapter 7 – Structures and Bridges

Agencies or entities listed below publish or author codes, standards, and other requirements that may be applicable to the system. The following is a partial list and it is the designer's legal, contractual and professional duty to design in accordance with all the applicable requirements, whether or not referenced herein.

- American Association of State Highway and Transportation Officials (AASHTO)
- Americans With Disabilities Act (ADA)
- American Concrete Institute (ACI)
- American Society for Testing Materials (ASTM)
- American Institute of Steel Construction (AISC)
- American National Standards Institute (ANSI)
- American Society of Civil Engineers (ASCE)
- American Society of Mechanical Engineers (ASME)
- American Welding Society (AWS)
- Concrete Reinforcing Steel Institute (CRSI)
- Concrete Specifications Institute (CSI)
- District of Columbia Accessibility Code
- District of Columbia Building Codes
- District Department of Transportation (DDOT)
- District of Columbia Water and Sewer Authority (DCWATER)
- District Department of Energy and Environment (DOEE)
- International Codes (I-Codes)
- National Fire Protection Association (NFPA)
- National Electric Code (NEC)
- National Electrical Manufactures Association (NEMA)
- Occupational Safety & Health Administration (OSHA)
- Pre-stressed Concrete Institute (PCI)
- Underwriters Laboratory (UL)
- Transportation Research Board (TRB)
- Washington Metropolitan Area Transit Authority (WMATA)

For additional codes, standards, manuals and requirements, please refer to Chapter 2.

5.6.3 Loads and Forces

5.6.3.1 Dead Loads

The dead load shall consist of the calculated weight of the basic structure and the weight of all non-structural elements permanently supported by the structure such as: trackwork, electrification, railings, barriers, utilities, walkways, canopies, walls, and partitions.

5.6.3.2 Live Loads

Structures subject to streetcar loading shall be designed for the vehicle loading F, with an impact factor of 1.30.

Structures subject to railroad freight train loading shall be designed for Cooper E-80 railroad loading.

New structures subject to highway loading shall be designed for HL-93 truckloads.

Modified or rehabilitated structures subject to highway loading shall be designed for HS-20 truckloads.

Structures subject to pedestrian loading shall be designed for a load of 80 pounds per square foot.

5.6.3.3 Other Loads and Forces

Other loads and forces (e.g., wind, thermal, longitudinal, centrifugal, shrinkage) on structures shall be in accordance with Chapter 2 and the following guidance:

- New structures subject to streetcar and highway loading: AASHTO LRFD Specifications and DDOT Design and Engineering Manual
- Modified or rehabilitated structures subject to streetcar and highway loading: AASHTO LFD Specifications and DDOT Design and Engineering Manual
- Structures subject to railroad loading: AREMA Manual
- Other structures: District of Columbia Building Codes
- Structures constructed in the sidewalk shall be designed in accordance with the DDOT Design and Engineering Manual

5.6.4 Soils

The soils in the DC area vary widely. Soil and geologic data for the preliminary design of structures shall be site specific. The designer must comply with all stormwater management procedures and obtain all necessary approvals from the Department of Energy and Environment (DOEE).

5.6.5 Reinforced and Prestressed Concrete

Reinforced and pre-stressed concrete structures shall be designed in accordance with Chapter 2 and the following guidance:

- New structures subject to highway and streetcar loading: AASHTO LRFD Specifications, ACI 318 and CRSI Manual
- Modified or rehabilitated structures subject to streetcar and highway loading: AASHTO LFD Specifications, DDOT and CRSI Manual
- Structures subject to railroad loading: AREMA and CRSI Manual
- Buildings and other structures: District of Columbia Building Code, ACI 318 and CRSI Manual

5.6.6 Structural Steel

Structural Steel structures shall be designed in accordance with the following guidelines:

- Structures subject to streetcar loading: AASHTO and AISC
- Structures subject to railroad loading: AREMA Manual
- Structures subject to highway loading: AASHTO and DDOT Standards
- Buildings and other structures: District of Columbia Building Code and AISC Specifications

5.6.7 Foundations

Foundations for structures shall be designed in accordance with the site-specific soil and geological data, Chapter 2, and DDOT Design and Engineering Manual:

- New structures subject to streetcar and highway loading
- Structures subject to railroad loading: AREMA Manual
- Modified or rehabilitated structures subject to streetcar and highway loading

5.6.8 Support of Excavation Structures

When planning for structures requiring excavation support, spatial, and physical constraints (adjacent structures, utilities, etc.) shall be considered. Support of excavation structures shall generally be designed by the contractor in accordance with Chapter 2.

5.6.9 Streetcar Tracks on Bridges

Tracks on bridges may be embedded (shared with other vehicles), direct fixation, or ballasted. Where thermal forces in the rail cannot be restrained and rail expansion and contraction must be accommodated, rail expansion joints shall be provided. Refer to TCRP Report 155 – Track Design Handbook for Light Rail Transit, Chapter 7 – Structures and Bridges.

5.7 UTILITIES

The guidance in this section shall govern planning, maintenance, support, restoration, abandonment, reconstruction, removal, and construction of utilities encountered or impacted by construction of the streetcar system. The design guidance for utility design shall be coordinated, and in compliance with, the requirements of utility owners, and the applicable codes, regulations, and policies as established by the District of Columbia Building Code, District Department of Transportation (DDOT) *DC Streetcar Utilities Standard of Practice*, and all other codes and standards referenced in Chapter 2. Efforts shall be made to design the streetcar alignment and ancillary elements such that they minimize impacts to existing utilities without jeopardizing the functionality of the streetcar system. DDOT recommends that an experienced utility coordinator serve as an integral part of the designer's team to facilitate and coordinate efforts between all stakeholders. The utility coordinator shall work closely with the utility companies sharing conceptual designs and final design elements to limit conflicts, errors, and liability. This exchange of plans and data will directly correlate to significant cost-saving for the District.

Due to the utility coordination and phased plans submission (e.g., 30%, 65%, and 90% drawings) the permit process will have greater efficiencies. Critical design issues should be addressed during the plan design review process, allowing for significant cost savings for the District of Columbia.

The following list is not exhaustive, but includes some of the major public and private utility companies and organizations whose infrastructure would be affected by the construction of the DC Streetcar System:

- DC Water
- Potomac Electric and Power Company (PEPCO)
- Verizon Communications
- Washington Gas
- Comcast

5.7.1 Preconstruction

5.7.1.1 Purpose

The objective of preconstruction activities is to ensure that pertinent utility information is obtained, properly incorporated into the design process, and shown on construction plans. Information shall include owner, type, size, material, location, and existing ROW and easements of all existing and proposed utility facilities impacted by DC Streetcar construction, and the disposition of existing and proposed facilities within the area of any ROW or easement to be acquired by the DDOT.

It is anticipated that DC Streetcar track facilities will conflict with underground and overhead utilities at several locations along most proposed routes. Access to utilities that require constant inspections and maintenance should not be located within the streetcar zone of influence (as defined in the *DC Streetcar Utilities Standard of Practice*). The suspension of streetcar revenue service while utilities are excavated and repaired, in some instances, is not an acceptable option. Therefore, wherever utility relocations are physically or economically feasible, they shall be modified or relocated to locations outside the streetcar zone of influence.

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

- Utilities supported and maintained during construction and continued in service following construction of the DC Streetcar system
- Utilities reconstructed, relocated, supported and maintained-in-place
- Utilities temporarily relocated and maintained, then restored in original location 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
- Existing utility ROW and properties to be acquired for their relocation, if any
- Locations of utility casings crossing the track slab
- Utilities not to be removed

DDOT Public Space Division will monitor, through the TOPS online system, any applications for accessing public space in the identified streetcar area as to not adversely impact pre-construction schedules

Existing utility service shall not be interrupted and, if temporarily relocated, shall be restored upon completion of work. Replacements for existing sewers or water mains shall be designed to provide service equal to that offered by the existing installations. Designers shall submit any proposal for betterment to the attention of DDOT in the early stages of design. For the purposes of this design criterion, “utility betterment” shall be defined as the incremental additional cost of a utility relocation or replacement over and above the cost of a standard in-kind utility replacement (e.g., increase in pipe capacity, upgrade from copper telecommunications cable to fiber optic, etc.). No betterments shall be included in the design unless specifically approved by the utility owner or public agencies, and DDOT.

5.7.1.2 Procedure

The horizontal and vertical rail alignments, ROW and property lines adjacent to the ROW, construction easements, and affected roadways shall be indicated in the final contract documents. As the design is developed, the impacted utility companies shall be provided with plans at the 30%, 65%, 90% design stages. However, coordination should begin during the conceptual design stage after a corridor has been selected. Utility impacts should be researched thoroughly and considered during planning to select the most feasible final alignment configuration.

Design drawings prepared by utility companies shall be reviewed and approved by DDOT and the design consultants. The review shall consider space reservations for utility work to be completed during final streetcar construction. The utilities shall be responsible for obtaining all necessary permits to perform the proposed work.

Utility company design drawings shall be consistent with the work authorization estimate and compatible with the work of other utility agencies. Pertinent utility elevations and locations shall be required to be checked via field survey by the contractor. 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 the start of construction and that they will be compatible with the streetcar system.

New construction and support, maintenance, restoration, rearrangement, and relocation of utilities shall be in strict conformance with the latest technical specification and practices of the governing private utilities or public agencies. DDOT recommends that prior to the submission of plans to the governing agencies; a stakeholder review be conducted with the design team, DDOT, and the utilities prior to the submission of plans to the governing agencies. A permit schedule shall be developed by the design team and provided to DDOT prior to the submission of any plans. If applicable, any and all code modifications shall be submitted with the plans at time of submission to the governing agencies.

Standard specifications and standard utility drawings for the various utilities shall be referenced or incorporated into the contract documents as required. If there are no standards, final design shall be in accordance with the current design guidance and engineering practices for the particular utility involved. Satisfactory completion of the work and its acceptance shall be signified through signature approval by the responsible utility or agency.

5.7.2 Gas Lines

Permanently relocated gas lines shall be designed, installed and tested in accordance with the current standards of Washington Gas or other utility companies, as well as, the applicable codes and standards referenced in Chapter 2.

Construction of temporary or permanent gas mains and replacement of mains shall be performed in accordance with the Master Utility Relocation Agreement between the utility company and DDOT. The designer shall consider and recommend the most efficient of these options for the particular project. The support and maintenance in place of lines shall be defined as the responsibility of the construction contractor, and the work shall be required to be performed in accordance with contract documents and utility company procedures.

Pipe installed within the limits of the streetcar zone of influence shall be designed to support the dead loads imposed by earth, sub-base, embedded track section, and vehicular loads (automobile and streetcar) when the pipe is operated under a range of pressure from maximum internal to zero.

Steel carrier pipe shall be protectively coated and provided with a corrosion 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", the current standards of the utility company, and Chapter 6.

New utilities crossing the zone of influence shall have a casing, and existing lines shall have a split casing a minimum of 3 feet beyond the track slab edge, where appropriate, to minimize utility maintenance and operations. Stray current and corrosion control for casing shall be in accordance with Chapter 6.

5.7.3 Sanitary Sewers, Storm Sewers, and Water Mains

5.7.3.1 Sanitary Sewers

Designs for the relocation, replacement or extension of existing sanitary sewer systems serving other than the streetcar facilities shall comply with all federal, state and local standards and codes and standards referenced in Chapter 2; and shall be approved by DC Water & Sewer Authority (DC Water), the Department of Energy and Environment (DOEE), and all governing agencies. Sanitary sewers shall be designed to the criteria of the governing district or agencies and shall conform to the following:

- Pipe installed under the streetcar zone of influence shall be designed to support the dead loads imposed by earth, sub-base, pavement, embedded track structures, and vehicular loads (automobile and streetcar).
- 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 in accordance with the Master Utility Relocation Agreement between the Utility Company and DDOT.

5.7.3.2 Storm Sewers

Design of replacement, relocation or the extension of existing storm sewers shall follow the design criteria for computing runoff quantities as indicated in Section 5.3.3 of this chapter. Surface drains from adjoining areas shall not be connected to the streetcar system’s track drains.

5.7.3.3 Water Mains

Relocation and replacement of existing water mains impacted by the streetcar zone of influence shall comply with applicable Federal, State, local and DC Water and Sewer Authority standards, the standards of ANSI, AWWA, regulations of the governing municipality or agency, and codes and standards referenced in Chapter 2. It shall be designed to the criteria of the governing municipality and utility owner and consider future maintenance by DDOT and DC Water. . In addition, it shall also conform to the following guidance (taken from the *DC Streetcar Utilities Standard of Practice*):

- Pipe installed within the streetcar zone of influence shall be designed to support the dead loads imposed by earth, sub-base, pavement, embedded track, structures, and vehicular loads (automobile and streetcar) thereon when the pipe is operated under ranges of pressure from maximum internal to zero.
- Water mains removed from service shall be replaced with pipes of equal size, except that the diameter of pipe shall meet engineering requirements and comply with governing municipality's latest design criteria and standards.
- Maintenance, relocation, restoration, and construction of water mains and appurtenances shall be in strict conformance with the current specifications and practices of the utility owner.
- Construction of water services to abutting properties shall comply with applicable plumbing codes of the District of Columbia and DC Water.
- Necessary replacement of existing water mains and appurtenances shall provide services equivalent to those of existing facilities or meet current standards of the utility owner.
- Service to adjoining properties shall be maintained by supporting in place, by providing alternate temporary facilities or by diverting to other points.
- Water mains or fire hydrants shall not be taken out of service without prior approval of DC Water.
- Construction of permanent relocation and temporarily relocated and restored water lines requiring support and maintenance in place shall be in accordance with the Master Utility Relocation Agreement between DC Water and DDOT.
- New utilities crossing below the zone of influence shall have a casing, and existing lines shall have a split casing a minimum of 3 feet beyond the track slab edge, where appropriate, to minimize utility maintenance and operations. Stray current and corrosion control for the casing shall be in accordance with Chapter 6.

5.7.4 Electrical Power Facilities

All support, maintenance, relocation, and restoration of existing underground electric lines throughout the streetcar system shall be in strict conformance with current practices of the Potomac Electric Power Company (PEPCO), the requirements of the Electrical Code of the District of Columbia, the National

Electric Safety Code, *DC Streetcar Utilities Standards of Practice* and codes and standards referenced in Chapter 2.

Design shall be based on the following:

- Electric facilities shall be maintained in-place providing that the support system can satisfactorily retain the line and grade of the facility, and that the retention of duct structures is practical within the limitations contained herein.
- As dictated by space limitations or cost, electric facilities shall be relocated outside of the streetcar zone of influence.
- Electric facilities shall be temporarily supported while being maintained in service until replacement facilities shall be provided, either within or beyond the limits of the streetcar's construction excavation. Temporary conduits and manholes shall be provided to serve the same utility function as existing facilities with respect to accessibility, manhole size, required number of ducts, and structure protection for equipment, cable and service personnel. The number of temporary ducts shall be minimized by coordination with the utility company to assure utilization of maximum temporary capacity and exclusion of unnecessary spare ducts.
- Construction of permanent relocation, and temporarily relocated and restored ductbanks and electrical lines requiring support and maintenance in place shall be in accordance with the Master Utility Relocation Agreement between the utility company and DDOT.

The construction contractor for DC Streetcar project shall be required to:

- Maintain and support existing ductbanks, manholes, vaults and other surface features, where required
- Install and support temporary ducts, manholes and vaults when existing facilities cannot be maintained, where required
- Construct new ducts (including split duct to be retained), manholes and vaults, where required
- Exercise caution when working in the vicinity of, and installing support systems for, pipe-type cables. The supporting system shall be designed to mechanically support these pipes, and to protect the coating around the pipes from puncture and vibratory damage.
- Where required, provide special backfill and concrete encasement around pipe conduit carrying high voltage cable

5.7.5 Communications: Telephone, Fiber Optic, and Cable TV Facilities

Maintenance, relocation and support of existing telephone, fiber optic and cable TV lines during construction of the streetcar shall be in conformance with the current standards and practices of the applicable utility owner. The design shall clearly indicate:

- Lines to be maintained complete in place;

- Abandoned lines and cables or those to be abandoned or removed;
- Ducts to be removed
- Cables maintained and supported, and upon completion of streetcar's work, replaced by a new system of split ducts or new ducts; and
- Replacement cable and any relocation or new line construction.

Construction of permanent relocations, and temporarily relocated and restored ductbanks and lines requiring support and maintenance in place shall be in accordance with the Master Utility Relocation Agreement between the utility companies and DDOT.

Design shall be based on the following:

- Underground telecommunication facilities shall be maintained-in-place providing that the support system can satisfactorily retain the line and grade of the facility, and that the retention of the duct structures is practical within the limitations contained herein.
- As dictated by space limitations or cost, facilities shall be relocated outside of the streetcar zone of influence.
- Underground facilities shall be temporarily supported while being maintained in service until replacement facilities shall be provided, either within or beyond the limits of the streetcar's construction. Temporary split duct systems and manholes shall be provided to serve the same utility function as existing facilities with respect to accessibility, manhole size, required number of ducts, and structural protection for equipment, cable and service personnel. The number of temporary ducts shall be minimized by coordination with the utility to assure utilization of maximum temporary capacity and exclusion of unnecessary spare duct.
- Conduits carrying fiber optic cables shall be supported during construction. Upon completion of work, ducts shall be permanently supported on undisturbed material, or well-compacted backfill and surrounded by concrete encasement.
- Additional factors to be considered shall include limitations that may be imposed by streetcar system structures and excavation support systems.

5.7.6 Street Lights and Traffic Signals

All relocations, temporary or permanent, and maintenance of municipal streetlights and traffic signal equipment (including loop detectors and interconnect cables) shall be in accordance with the requirements of DDOT.

Where appropriate, consideration shall be given to shared poles for street lighting and the streetcar OCS.

The contractor shall be required to install, maintain, and remove conduits and pedestal supports for temporary traffic signals, which may be required as a result of streetcar system construction operations.

5.7.7 Parking Meters and Pay & Display Kiosks

DDOT will remove and store the existing parking meter heads with assistance from the contractor. The contractor shall be required to install a new parking kiosk in sidewalk locations as indicated and in accordance with the details shown on the plans and specifications as directed or approved by DDOT during the completion of streetcar construction.

Where existing standalone parking kiosks are encountered, work to remove and reinstall the equipment shall be coordinated with DDOT.

5.7.8 Vaults and Basement Encroachments

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

5.7.9 Overhead Utility Lines

Abandonment, relocation, restoration, maintenance, and extension of existing overhead utility lines, poles and appurtenances, including service lines to adjoining properties, shall be performed in accordance with the Master Utility Relocation Agreement between the Utility Companies and DDOT, with laws and regulations of the appropriate jurisdiction, utility owners' standards, the National Electrical Safety Code, and the affected utility companies.

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

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

The designers shall coordinate their efforts with those of the utility owners to assure that designs are mutually acceptable to the utility owners and DDOT.

Plans shall denote the general type of service provided by the overhead lines in accordance with the symbols of Utility Standard Drawings, including utility standard abbreviations symbols and general notes, as required by the utility company or DDOT.

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

Clearances shall be in accordance with the standards adopted by the utilities involved, and those specified in the National Electrical Safety Code (NESC) shall be considered the minimum requirements with respect to the DC Streetcar overhead contact system (OCS) and structures.

The designer shall evaluate the need for the 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 Contract Documents.

Construction of permanent relocations and temporarily relocated and restored overhead lines requiring support and maintenance in place shall be in accordance with the Master Utility Relocation Agreement between the Utility Companies and DDOT.

5.7.10 Utility Design Drawings

Composite utility drawings for coordination with utility companies or agencies shall be prepared by the designer at 1 inch = 20 feet scale with sufficient existing planimetric data as background to show the street and property patterns of the area. The drawings shall include:

- Proposed Streetcar system structure outline and horizontal alignment
- Proposed facilities related to the streetcar system, such as stops, maintenance and operations facility, OCS poles, other ancillary structures, and roadway and sidewalk modifications
- All existing utilities within the streetcar limit of disturbance
- All proposed or relocated utilities that may be affected by the streetcar construction
- Overhead lines that may be affected by construction
- ROW, curb and sidewalk lines
- Public and private skywalks and bridges
- Basement encroachments and cellar doors within the public sidewalk
- ROW lines, public easements, private Easements, when known
- Streetlights and traffic signals (poles, wires and booms)
- Parking meters and sign poles
- Trees and other landscaped areas
- Green Infrastructure (considered a utility), such as pervious pavement, rain gardens, bio-swales, BMP facilities, etc.

- Cross sections and utility profiles
- Location of any affected ADA facilities

Separate detailed utility plans and profiles shall be prepared for proposed utility relocations of the following:

- Water mains
- Sanitary sewers
- Storm drainage facilities

Separate detailed utility plans shall be prepared by the affected utility owner for proposed utility relocations of the following:

- Gas
- Electric
- Telephone and Communication Facilities

In the interests of clarity, and if impractical to do otherwise, separate plans shall be prepared for the following:

- Fire and police alarm systems
- Detailed street lighting and traffic signals
- Detailed parking meter and curb control signage
- Communication, protection systems, and cable television systems

During the preparation of composite and separate utility drawings, the designer shall review the Streetcar Master Utility Drawings and conduct a field survey to locate all visible utilities, which shall, among other things, determine the following insofar as it may affect the streetcar project design:

- Location of all manholes, valve boxes, vaults, street and traffic lights and appurtenances, trees, and other improvements
- Size and invert elevations of all pipes in sewer and storm drain manholes
- Size, internal dimensions, cover, and headroom of all manholes on duct lines belonging to electric, telephone and telegraph companies and governmental agencies. Covers shall not be removed or manholes entered without prior approval of the utility owner and shall be accompanied by the owner's representative
- Overall dimensions and configuration of all duct in manholes for electric, telephone and similar facilities. Depth, position in walls of manholes and the location of cables in manholes shall be determined for all affected ducts
- The ownership of all cables, which may exist in jointly used utility structures

- Interior dimensions, depth, cover, elevations, and type of material of private vaults

The designers shall coordinate with the appropriate utilities and governmental agencies at all stages of planning and design, and shall reach agreement(s) with the respective owners before detailing drawings. Where designs are prepared by utility owners, the designer shall ascertain that work is compatible with the streetcar project and shall include the work on the DC streetcar plans, appropriately labeled. The designers shall cooperate with all utility owners to assure that the utilities are coordinated during installation. The utilities, where applicable, should identify person(s) designated to review streetcar related drawings to maintain continuity and consistency in the permit review process.

It is the responsibility of the designers to submit plans and specifications at various stages of completion for review to the respective utility owners, including government agencies, and to secure and file with DDOT letters of acceptance and approval by the utility owners. Upon completing the design, the designers shall submit a list of betterments and shall secure from each affected utility owner a firm estimate of work to be undertaken by the utility. Betterments include the replacement, relocation, and upsizing of existing utilities in location not directly affected by the streetcar design, but which may be cost effective to replace such utilities in construction zones since excavation and maintenance of traffic will exist.

During design, consultants shall consider the various methods in which utilities may be relocated or replaced and the effect of these alternatives on the overall costs or other aspects of the streetcar project construction.

The type, manufacturer and details shall be provided for all manhole and utility access castings to be installed in the ROW.

In lightly developed areas, where utilities are spaced intermittently along the streetcar route , drawings shall include a key map showing areas where the utilities are located along the route and an index of composite and detail drawings in such areas.

To the fullest extent practicable and economical, existing utilities shall be maintained complete in place. All facilities maintained in place, restored and new are to be supported on undisturbed material or well-compacted backfill, as required by utility agency standards.

In addition to the buildings, curb lines, miscellaneous structures, vaults, and trees, plan sheets shall only show pipes, ducts and facilities pertaining to the particular utility relocation. Profiles shall show all utilities and interferences, as well as structures owned by the District of Columbia. Profiles should also show the depth of cover and the top and bottom envelope or cross section of all utilities drawn to scale.

In non-congested utility areas, profiles for water and gas mains may be replaced by a note stipulating the depth at which the lines are to be relocated.

When work shown on the drawings is to be done by others, the plans shall indicate if it is to be executed before, during or after streetcar project construction, and if the work is to be supported during excavation.

The contractor will be required to excavate certain abandoned utilities and to protect and support other lines. This work shall be indicated on the drawings prepared by the utility owner, on separate drawings prepared by the designer, or in the contract specifications, whichever is most efficient.

5.7.10.1 Utilities Composite Plan

Information to be shown on the composite utility plan includes:

- All utilities, abandoned (when of record), to be abandoned, existing, maintained in place, supported during excavation, restored, relocated, or proposed by others
- Structure outline, building lines, concrete pavements, sidewalks, curbs, trees, poles, public and private utility vaults, pipelines, tunnels, other surface and subsurface features
- Detailed dimensions and elevations of roofs and floors of vaults affected by construction shall be shown on an appropriate utility plan

Service lines between utilities and adjoining properties must be investigated for maintenance of service but need not be indicated on the drawings. It should be noted on the drawings that service connections must be maintained by the contractor.

The drawings shall not include utility work beyond the immediate limits of construction. Major utility work beyond the limits of construction, unless otherwise directed by DDOT, shall be the responsibility of the affected utility company.

5.7.10.2 Water Mains, Sewers, Electrical Ductbanks and Conduits, Chilled Water Lines and Drainage Facilities

Information to be shown includes:

- Plan, profile, and cross sections indicating water mains, sewers, conduits and ductbanks, stormwater drainage pipes, catch basins, and appurtenances affected by construction including the disposition of facilities to be maintained, relocated, proposed by others, and abandoned. The plan and profile for new work shall be on split plan and profile sheets.
- Details of non-standard manholes or other facilities
- Any related work to be designed and constructed by others

5.7.10.3 Gas

The utility owner shall prepare final design drawings for abandonment of gas mains, construction of proposed or temporary mains and services, and any connection or reconnection of gas mains and service as a result of streetcar project construction. All construction shall be normally performed by the utility owner's contractor. However, temporary relocation work may be performed by DDOT's contractor upon specific agreement with the utility owner. Designs prepared by utility owner and shown on the composite plans shall be marked as proposed by others.

Plans shall indicate staging of construction and indicate which utilities shall be maintained complete in place during streetcar construction.

The designer shall coordinate, as required, with the utility owner to ensure that the proposed facilities are compatible with other existing and proposed utilities and transit system installations.

The contractor will be required to excavate certain abandoned gas mains and to protect and support other lines during excavation. This work may be indicated on the drawings prepared by the utility owner, on separate drawings prepared by the designer, or in the contract specifications, whichever is most efficient.

5.7.10.4 Electric

The utility owner will prepare final design drawings for abandonment of ducts, manholes, vaults structures, and any overhead lines as a result of streetcar project construction. All such construction will normally be performed by the utility owner. However, temporary relocation work may be performed by the contractor upon specific agreement with the utility owner. Installation and connection of cables will always be performed by the utility owner. Designs prepared by utility owner and shown on the composite plans shall be marked proposed by others.

Plan, profile and cross sections shall clearly indicate electric conduits, high voltage lines, manholes, and transformer vaults and manholes affected by construction. Plans shall indicate facilities to be maintained-in-place, abandoned and manholes to be removed, and special backfill for high voltage pipe-type cable.

Work by the utility owner, such as proposed and relocated ductbanks and manholes, removal of ducts and manholes on energized electric lines, or transfer of cables to temporary troughs shall be indicated.

Details of non-standard manholes shall be included on plan drawings or on separate sheets. Each plan sheet shall include a schedule of information concerning existing manholes and ducts (manhole number, size and depth; number of cables and voltage, number of ducts, type, and number of vacant ducts).

Plans shall indicate facilities to be constructed by the utility owner that will be completed prior to streetcar's construction as well as those to be installed at other designated stages of construction.

Work involving street lighting and traffic lights and appurtenances may be included on these drawings; however, all changes to street lighting, traffic signals or interconnect cable must be on separate plans for review and approval by DDOT.

5.7.10.5 Telephone

The utility owner will prepare final design drawings for abandonment of impacted telephone lines, utility poles, and manholes. All such construction will normally be performed by the utility owner. However, some temporary relocation work may be performed by the contractor upon specific agreement with the utility owner. Installation and connection of cables will always be performed by the utility owner. Designs prepared by utility owner and shown on the composite plans shall be marked proposed by others.

Plan, profile and cross sections shall clearly indicate telephone lines affected by the streetcar's construction and indicate facilities to be maintained, relocated, proposed, or abandoned.

Details of non-standard manholes or other facilities shall be included on these drawings or on separate sheets.

Related work to be performed by others shall be indicated.

Each plan sheet shall include a schedule of information addressing existing manholes and ductbanks which includes manhole number, size, depth, number of cable pairs, number of ducts, type, and number of vacant ducts.

Where new ducts are installed, cable will be installed and splices made by the utility company.

Indicate which ductbanks may be maintained in place during construction and then permanently supported by compacted backfill, or those temporarily supported in troughs during construction, then restored and permanently supported on compacted backfill. The method of construction shall be chosen by the contractor.

Designers shall ascertain if cables owned by AT&T, Sprint, Verizon Business (MCI), Comcast or other communications and cable carriers, after consultation with each utility owner, shall be included in the proposed streetcar utility design. Designers shall also ascertain if fiber optic cables are affected.

5.7.10.6 Fire and Police Alarm Systems

Information to be shown includes:

- Location of existing alarm and call boxes, as applicable, and cable runs
- Facilities to be removed, temporarily relocated and restored, and cables to be supported

- Information concerning existing manholes and ducts, manhole number, size, depth, number of cables, number of ducts, type, and number of vacant ducts

Construction work affecting fire alarm cable shall be performed by the District's police, EMS and fire alarm contractors unless otherwise indicated on the plans and specifications. Construction work affecting police call and fire alarm cables shall be the responsibility of the appropriate owner.

Affected infrastructure may be indicated on the telephone drawings or on separate sheets, with the notation that the specific work item is to be performed by others.

5.7.10.7 Street Lights and Traffic Signals

Plans shall show all street lights, traffic signals, signal equipment and loop detectors in the affected area. Notes shall clearly identify equipment to be continued in service, equipment to be temporarily relocated and restored; any temporary installations; proposed new installations; new cable and duct runs; and new control appurtenances.

Generally, all pole removals and replacements, associated light and signal installations shall be required to be performed by the construction contractor. Timing and operation shall be implemented by DDOT. The contractor shall be responsible for coordination of all work with the DDOT Traffic Operations Department. The construction contractor shall be responsible for the protection and maintenance in-service of existing traffic signals and street lighting throughout construction operations.

5.7.10.8 Parking Meters

Drawings shall indicate parking meters affected by the streetcar's construction, and disposition to be made by DDOT. The contractor shall be required to remove, store and reinstall posts; the single space meter heads will be removed and replaced by the DC Department of Public Works.

5.7.10.9 Communications, Security and Cable Television Systems

Plan, profile and cross sections shall clearly indicate the Communication, Security, and Cable Television Systems affected by the streetcar's construction, and indicate facilities to be maintained, relocated, proposed, or abandoned.

Details of non-standard manholes or other facilities shall be included on these drawings or on separate sheets.

Each plan sheet shall include information concerning existing manholes and ducts, overhead poles, manhole number, size, depth, number of cables, number of ducts, type, and number of vacant ducts.

Affected facilities may be indicated on Telephone drawings or on separate sheets, with the notation that the specific work item is to be performed by others.

5.7.10.10 Temporary Support of Track Slab for Utility Maintenance and Replacement

When planning for structures requiring excavation support (e.g., adjacent structures or utilities), spatial and physical constraints shall be considered. Support of excavation structures shall generally be designed by the contractor in accordance with the *Utilities Standard of Practice* and Chapter 2.

5.7.10.11 Applicable Streetcar Standard Drawings:

- T-12 Utility Impact Zones

5.8 TRAFFIC

This section establishes the basis for engineering guidance to be used in the design of the DC Streetcar system. It includes requirements for traffic control devices and guidance for the design of the traffic signal systems, signing and pavement marking, and traffic control through work zones as they apply to interfacing the streetcar lines with the street and highway network.

5.8.1 Applicable Codes

Vehicle and pedestrian signals, traffic signs, pavement markings and traffic devices shall be in accordance with the guidance provided in Chapter 2, the Manual on Uniform Traffic Control Devices (MUTCD) and the DDOT Engineering and Design Manual. Materials and equipment used in each installation or modification of traffic signal systems, signing, and paving markings shall conform to the latest specifications contained in the DDOT standards.

5.8.2 General Design Guidance

Delineation shall be provided by a combination of pavement markings and other channelizing devices. The width of the guideway shall include a buffer zone beyond the dynamic envelope of the streetcar suitable to the specific location. Generally, streetcar vehicles require an 11’-0” marked travel lane to accommodate the streetcar buffer zone, but may increase on curves to accommodate the vehicle dynamic envelope. This lane width may be reduced to closer approximate the vehicle’s dynamic envelope as approved by DDOT.

Turning movements across the tracks from a parallel traffic lane shall be avoided wherever possible. At locations where such turns across the tracks must be allowed, special traffic signal phasing, including any appropriate special signals and signing, pavement marking, and roadway geometry shall be provided to control conflicting movements. Where turn movements are necessary, limitations on vehicle type permitted to turn should be considered, subject to DDOT agreement

Guideways and streetcar stops shall be designed so as not to create any unnecessary interference with pedestrian movements. Where pedestrians must cross streetcar tracks, appropriate control devices shall be provided. Where a pedestrian crossing is part of a signalized street intersection, control shall be provided by means of standard vehicle and pedestrian traffic signals.

Sidewalks may also serve as stops provided that the needs of both the streetcar passengers and those pedestrians not utilizing the streetcar service are reasonably accommodated.

5.8.3 Control of Streetcar Interface with Roadway Traffic

Where streetcars require a left or right hand turn at intersections, special signals may be required to control streetcar movements. These streetcar signals shall be physically separated from the roadway traffic signals. They shall be designed to display indications that are distinctive in themselves and do not resemble those displayed by conventional traffic signals. For more detail regarding streetcar signals, refer to Chapter 6.

The streetcar signal system shall provide indication detection of streetcar approach, arrival at intersection stop bar, and clearance of the intersection by the rear of the vehicle to the traffic signal control equipment. The traffic signal control equipment shall operate the streetcar signals and have the capability of adding at any point in the cycle a separate phase for streetcar movement on a pre-timed basis. It shall also have the capability of deleting such phases when not required. The equipment shall also be capable of coordinating signal operation at each intersection with any network of which it is a part.

The streetcar signal design should determine the type, location, phasing, and timing of the traffic signals; the methods of detecting vehicle traffic, pedestrians and streetcars; and the interfacing the control at each location with existing traffic signal systems.

5.8.4 Sign Design

Traffic signs related to streetcar operations shall be installed in accordance with DDOT requirements and the MUTCD. In situations where sign requirements are not addressed by the existing standards, special signing shall be developed by the design consultant and approved by DDOT and FHWA through the MUTCD interim approvals process.

5.8.5 Pavement Marking Design

Pavement markings related to streetcar operation shall be installed in accordance with the Streetcar Standard Drawings and codes and standards as listed in Chapter 2. Where marking requirements are not addressed by these standards, appropriate designs shall be developed by the consultant in coordination with DDOT. Pavement striping parallel to tracks shall be provided to denote the dynamic clearance envelope of the streetcars.

5.8.6 General Operations

Where streetcars operate in mixed traffic or adjacent thereto without an intervening barrier or curb, they shall travel no faster than the parallel roadway posted speed limit. However, the maximum operating speed of the vehicles shall not exceed 30 mph.

At signalized intersections, streetcars shall approach at speeds that will permit them to stop short of the point of conflict if the roadway is already occupied and, in no case at a speed higher than the posted speed limit.

5.8.7 Traffic Control through Work Zones

Traffic control plans are required for the execution of traffic control and maintenance of traffic in work zones. The plans shall include temporary signage that provides warnings of upcoming construction, and temporary pavement markings, channelization devices, and temporary traffic control to redirect traffic. In addition to vehicular traffic, the traffic control plans shall include provisions for pedestrian and bicycle traffic during construction. Plans shall also include any necessary lane closures, detours and street and sidewalk closures required to construct the streetcar. The time and duration of street and lane closure shall be provided. Access to driveways, business, and residences shall be maintained and only interrupted for short durations when required, provided with sufficient warning. Traffic control plans shall be approved by DDOT. Proper permits shall be obtained. “No Parking” signs shall be displayed where applicable.

5.8.8 Applicable Streetcar Standard Drawings

- C-01 Streetcar Typical Pavement Marking with Dedicated Bike Lane
- C-02 Streetcar Typical Traffic Signing with Dedicated Bike Lane
- C-03 Streetcar Typical Pavement Marking with Shared Bike Lane (2 Travel Lanes)
- C-04 Streetcar Typical Traffic Signing with Shared Bike Lane (2 Travel Lanes)
- C-05 Streetcar Typical Pavement Marking with Shared Bike Lane (3 Travel Lanes)
- C-06 Streetcar Typical Traffic Signing with Shared Bike Lane (3 Travel Lanes)

District Department of Transportation

Chapter 6

Systems

Content

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6.1 TRACTION POWER SYSTEM

6.1.1 Overarching Traction Power Distribution Considerations

Minimizing (and when possible eliminating) negative visual impacts of all elements of streetcar infrastructure is one of the goals of the DC Streetcar system and the design guidance in this document.

Streetcar propulsion and power distribution technologies are rapidly changing. As DDOT expands and rehabilitates its streetcar system, consideration would be given to alternatives to traditional and proven overhead catenary (or contact) system (OCS) technologies, including alternate technologies that are emerging on the market. Environmental and aesthetic factors influencing selection of an off-wire power source are detailed in Chapter 1, while technical factors are addressed herein.

On-board energy storage solutions, including advances in battery and capacitor systems, are currently being integrated into streetcar operations as part of hybrid systems that also utilize traditional traction power distribution via OCS. Such hybrid systems operate both on- and off-wire depending upon the project's specific requirements and the limits of existing technology. Advances in battery, capacitor and charging technologies have introduced the potential for non-continuous overhead charging systems that are less visually intrusive than traditional OCS.

Ground level power supply systems provide an additional area of potential solutions. Whether utilized as a continuous source of traction power distribution (various "third rail" technologies) or as a non-continuous recharging solution, ground level power supply has the potential to be the least visually intrusive option. However, ground level systems are typically proprietary in nature, complicated to a greater extent than overhead systems by pedestrian safety issues and climate, and may carry a higher cost.

It is important to note that all of the above technologies are currently in limited use or in some cases, still in the prototype stage.

Given the context of evolving technology this document does not proscribe a specific technological solution to streetcar propulsion or traction power distribution. Such solutions are more appropriately determined during a more detailed phase of planning, engineering, and design and environmental review associated with a specific line or lines. By setting performance and reliability requirements of any operating line in the District as well as the rapidly changing technologies for traction power supply and distribution make it imprudent to specify a particular solution when any such solution may be proven infeasible or may be superseded by a superior solution in the near future. By not specifying any single technology for the elimination of OCS, DDOT will help ensure that the District utilizes the safest, the most reliable and efficient, and the proven technology available at the time of implementation, while also eliminating or minimizing negative visual impacts of streetcar infrastructure to the greatest extent possible. As individual lines advance through the planning and design process, this section will be updated to reflect the technology direction that is identified for the line as the system or technology that provides the highest levels of safety and reliability with minimal levels of visual impact.

Minimizing (and when possible eliminating) negative visual impacts of all elements of streetcar infrastructure is one of the goals of the DC Streetcar system and the design guidance provided in this document. To the extent that safe and reliable service can feasibly be provided, the design and installation of infrastructure elements shall reinforce the goal of minimizing negative visual impacts associated with any element of streetcar infrastructure. Specifically as it pertains to traction power distribution, restrictions on the use of OCS up to and including the elimination of such elements may be required in certain areas of the District. Additionally, specific guidance for the technical and design solution for traction power distribution may be provided by the environmental planning and review process for a given streetcar line. The final guidance associated with any environmental review or action shall be consulted as part of the design process for all traction power distribution elements.

6.1.2 Baseline Traction Power Technology

This section includes functional and design requirements for the supply and distribution of the traction power supply system to transmit electric energy from its source to the vehicles. DDOT continues to evaluate and explore alternative propulsion technology for off-wire vehicles. If alternative vehicles are procured in the future, the Design Criteria will need to be updated to reflect any changes to the distribution of the traction power supply system. The location and design of these facilities should be closely coordinated with the State Historic Preservation Office (SHPO) early in the process.

The streetcar vehicles are propelled by electric traction motors. Energy to drive these motors is supplied to the vehicles by substations located along the wayside through a system of distribution cables, switches and an overhead contact system (OCS) installed above each track. A pantograph will be mounted on each vehicle to serve as the interface between the vehicle and the OCS and be the collector of electrical current for the vehicles. The running rails of each track, bonds, and cabling complete the path of electrical current back to the substation.

As OCS remains the proven propulsion technology with broad utility for nearly all streetcar applications in the U.S. and overseas, DDOT has been exploring alternative propulsion technologies without using OCS, which is most suitable for a dense, multimodal, mixed-flow urban environment with the climate of D.C. Those alternatives include batteries, supercapacities, flywheels, fuel cells in the on-board category, and some proprietary technologies in ground-level category. Those alternative propulsion technologies would require a different power distribution system from OCS.

The design of the traction power distribution system shall be such that it will provide an adequate, reliable source of electrical power to the vehicles under all operating conditions. The engineers and designers shall include as part of the design goals, the safe and efficient operation of the system under many specific conditions. Further, design shall ensure that the traction power substations (TPSS) will be operating in conjunction with adjacent TPSSs and be designed to carry sufficient streetcar loads to maintain normal operation in the event of a TPSS shutdown.

The specific subsystems of the traction power system are the utility service, service feeders, switchgear and metering, the transformer/rectifier units to convert alternating current (ac) power to direct current (dc) power, the dc switchgear and distribution system, relay controls, alarms, supervisory control and data acquisition (SCADA), the overhead contact wire and negative return systems, as well as other necessary supporting systems. The designer shall coordinate with the utility or local supplier of primary power, as well as designers of other project systems or elements, such as the vehicles, signals and traffic control, communications, civil and architectural works (including ADA facilities) to ensure compatibility with the traction power system.

6.1.3 Traction Power System Elements

The following sections describe the primary elements that shall be included in the design of the traction power system.

6.1.3.1 Traction Power Substation Siting

Depending on specific context, substations may be located in underground vaults, as pre-fabricated units or within a building or custom enclosure. Specific designs should take into consideration context-sensitive approaches and should be closely coordinated with the SHPO.

Special architectural treatments shall be required for substations located in view of the public. The treatments shall consist of context-appropriate materials to screen a pre-packaged substation or a custom-designed building into which the substation equipment is field installed. The architectural treatments shall screen all exterior mounted equipment from the view of a pedestrian and blend with the surrounding neighborhood. Generally, during the planning phase, TPSS sites are considered within the NEPA process to avoid unnecessary environmental impacts. Substation site plans and exterior elevations shall be submitted for DDOT and community review and approval.

Another consideration when siting a TPSS is the availability of adequate electrical service. Streetcar power needs are generally serviced from the utility low or medium voltage grids which are typically available in most areas considering streetcar service. Coordination with the local Utility regarding power availability should occur during the siting phase as extending utility infrastructure to service a substation site can add considerable cost.

Each TPSS shall be located as close as practicable to the wayside tracks but, where feasible, away from the public ROW.

6.1.3.2 Traction Power Substations

Each TPSS is the interface between the utility provided ac power and the dc traction power system. The substation controls and rectifies the utility supplied ac power to the dc power required for operation of the vehicles. The substation components should be standardized in size and configuration wherever possible to minimize the inventory of parts, to allow for full compatibility and interchangeability of equipment between substations, and to facilitate the training of operations and maintenance personnel. Each substation shall include the connections from the utility ac supply to the ac switchgear through an underground ductbank system; metering equipment; ac switchgear, ground and test device; transformer/rectifier units with primary and secondary connecting cabling and buses; dc switchgear; positive and negative buses; connections to the dc distribution system; grounding system; protective relay system; station batteries and battery charger; substation control system as well as other equipment required for a complete, safe, maintainable and efficient rectifier substation. Where required, the substation shall include a power source and feeders for the communications and signal systems and other wayside equipment.

6.1.3.3 Direct Current Distribution System

The dc distribution system consists of terminations, cabling, and switching equipment to connect the traction power substation to the OCS and negative distribution systems. The positive dc feeders originate from the load side of the dc switchgear and continue from the substation to the point of connection to the OCS at a disconnect switch mounted on an OCS pole. The positive dc feeder system includes any parallel cabling necessary to maintain the minimum voltage at the pantograph with any one adjacent substation out of service or as required to maintain the distribution system continuity across sections of track without OCS installed. The negative return includes cabling from the traction power substation return bus to the running rails and negative return cabling installed to maintain the continuity of the negative returns across sections of track without an OCS installed.

All feeder system cabling shall be installed underground in conduits, ductbanks to the nearest OCS pole to their point of connection with the OCS. Power system conduits shall be 4” diameter, organized into ductbanks and encased in red-dyed concrete, and shall incorporate a metallic tracer wire. Aerial feeders or surface-mounted conduit shall not be permitted except as approved by DDOT for specific locations such as a parallel feeder on a bridge structure.

6.1.3.4 Overhead Contact System (OCS)

The OCS is defined as all electrical, mechanical and structural equipment between the vehicle power collector and the dc positive feeder system. This includes the contact wire, all supporting structures (except where mounted on traffic signal or street lighting poles) and their foundations and guying systems (where necessary), overhead feeders, ancillary wires, hangers, insulators, conductor supports, tensioning devices (where required), cantilever arms, sectionalizing equipment, pole-mounted disconnect switches, pole-mounted lightning arresters, and other items necessary for a complete system.

6.1.3.5 Sectionalization

The system sectionalizing will be designed to enable the electrical protective relays to disconnect faulted sections, permit performance of planned maintenance, and achieve flexible operation during system emergencies.

There will be electrical continuity along the OCS system from end-to-end along the right-of-way with sectionalizing at the substations to provide isolation of each electrical section. The sectionalizing scheme will be consistent with the location of the substations, the track layout, the signalization scheme, and proposed vehicle operations. Sectionalizing also should be considered at crossovers, other special trackwork locations, and the storage yard, for maintenance and emergency purposes.

Sectionalizing of the OCS adjacent to substations, will be performed by means of insulated overlaps on mainlines. Where overlaps cannot be located adjacent to the substations, section insulators will be used. Section insulators will also be used for sectionalizing at crossovers and turnouts.

The primary connection and isolation of the system sections will be performed by the substation dc feeder circuit breakers. At locations along the route, connections and isolation of the system sections will be accomplished by manual disconnect switches.

6.1.3.6 Traction Power Distribution Design Environment

The traction power distribution system shall be designed to operate continuously and satisfactorily under the environmental conditions described in Chapter 2. The traction power system must be considered and designed as a single coordinated system. The basis for this consideration is a traction power load flow simulation that models the streetcar system operation. The power system shall be analyzed early in the project to allow consideration of alternative substation sites.

6.1.3.7 Codes and Standards for Traction Power Equipment

All materials; apparatus and equipment; and installation methods shall conform to the requirements of the latest edition of applicable AASHTO, ACI, ANSI, AREMA, ASTM, EIA, ICEA, IEC, IEEE, NEC, NEMA, NESC, PUC, UBC, UL, and other local and state codes as defined in Chapter 2, as applicable. The designer shall consult these documents and provide a design in accordance with the most stringent code and applicable industry practice. This document is intended to be as indication of minimum requirements.

6.1.4 Traction Power Substations

6.1.4.1 General Guidance

The dc traction power shall be supplied to the OCS by traction power substations (TPSS) with a rated output of 750 Volts nominal at full load. The TPSS shall be located as close as practicable to the wayside tracks. The equipment shall be rated for Extra Heavy Duty traction service as defined by IEEE 1653.2. At rated input voltage, the maximum output voltage at 1 percent of full load at the substation bus shall not exceed 795 Volts.

6.1.4.2 System Operating Requirements

The following ratings are the criteria upon which the design of the traction power distribution system shall be based:

• Nominal OCS Voltage	750 Vdc
• Maximum OCS Voltage	925 Vdc
• Vehicle Operating Voltage (Minimum)	525 Vdc*
• Maximum Rail to Ground Voltage	50 Vdc normal operation 70 Vdc single TPSS outage

*Vehicle minimum operating voltage should be verified against Chapter 4.

The TPSS shall comply with IEEE 519 and not inject objectionable harmonics back into the utility supply system.

Streetcar vehicles are equipped with regenerative braking. The traction power system shall be designed for natural receptivity only. Additional means of accepting regenerative power or of feeding regenerative power to the Utility may be considered, subject to discussion with the Utility.

6.1.4.3 Substation Location, Rating, and Spacing

Traction power substations should be located at or near streetcar stops, whenever possible. Locations should be optimized with respect to safety, efficiency, access, availability of land or existing structures, stray current control, and minimum life-cycle costs.

The designer shall provide computer simulation and modeling of the traction power system. This is recommended to be performed during preliminary engineering and design activities. The simulation shall model Streetcar movement over the entire system, considering vehicle propulsion system capabilities and civil alignment parameters such as passenger stops, grade, curves, and speed limits. Model dwell time at each passenger stop shall be 30 seconds. The simulation shall also provide network analysis of the wayside traction power system, considering the impedances and resistances of the transformer/rectifier units, dc feeders, running rails, rail voltages along the alignment and touch potentials at stops. The model shall address wear conditions of the OCS contact wire and the running rail.

During peak period operation, adequate power shall be supplied to the Streetcar system for maintaining all Streetcar pantograph voltages above 525 Vdc with the required headway and loading. This level of operation shall be modeled using the computer simulation described above. The results of the computer simulation shall provide verification of the following design constraints:

- In peak period (2 hour) operation, normal operation, rms thermal loading on the rectifier transformers and rectifiers shall not exceed 100% of the equipment nameplate rating.
- In peak period (2 hour) operation, normal operation, rms thermal loading on dc breakers and buswork shall not exceed 100 percent of the breaker and buswork continuous rating.
- In peak period (2 hour) operation, single adjacent substation outage, rms thermal loading on the rectifier transformers and rectifiers shall not exceed 150% of the equipment nameplate rating.
- In peak period (2 hour) operation, normal operation and single adjacent substation outage, rms thermal loading on conductors shall not exceed OCS conductor ampacity. Conductor ampacity shall be determined per IEEE 738, based on ambient air temperature of 105 °F, maximum conductor temperature of 167 °F, wind speed of 2 ft/sec, coefficient of emissivity of 0.5, and coefficient of solar absorption of 0.5.
- In peak period operation, rail-to-ground voltages shall not exceed the allowable maximum rail-to-ground voltage in Chapter 6**, section 6.1.3**.

With any one substation out-of-service, one Streetcar at an adjacent passenger stop shall be capable of normal rate acceleration from a start. A second Streetcar at the same passenger stop may perform at a reduced operating level if starting simultaneously with the first Streetcar.

6.1.4.4 Substation Primary Power

The local electric power vendor will supply 3-phase, 60 Hz power supply as primary service to the Streetcar system. Methods of primary power distribution to the traction power substations should be evaluated to determine the most cost-effective capital investment and the lowest annual operating cost that can provide adequate and reliable service.

A single utility company power feeder source shall not supply power to two adjacent traction power substations. The system should be designed so that if one power feeder source is out of service, then a back-up source can continue to supply traction power. The service cables from the utility company source will be extended to the traction power substation. Metering, switchgear, communications equipment, service feeders, protective lightning arresters and other elements necessary for electric service should be installed in accordance with the utility company's regulations and standards.

6.1.4.5 Substation Equipment

Substations shall consist of pre-fabricated units or equipment installed in previously constructed enclosures or rooms. Equipment shall include ac switchgear, auxiliary power supply, surge arresters, transformer-rectifier units, dc power switchgear, and ventilation equipment, as appropriate. The substations shall be designed to operate unattended, but should be equipped with local control switches for operation of all ac and dc switchgear.

6.1.4.6 Transformer – Rectifier Units

Transformers

- Type and rating: Indoor dry-type, self-cooled, designed for traction service with kVA rating suitable for the specified rectifier.
- Tap Changer dry-type transformer: No-load full capacity, on the high voltage winding. There will be a total of six taps above and below the rated kVA (3 above at 2.5 percent each and 3 below at -2.5 percent each. Taps shall be changed by removable links on a tap board with taps and connections identified. The tap board shall be accessible through a door key interlocked with transformer feeder breaker to prevent access to the tap board when transformer is energized.
- Bushings: In accordance with ANSI and NEMA standards for indoor interchangeable bushings. Silver plated terminal pads.
- Low Voltage Connection: Bus connections for bolted connection to ac multi-phase bus designed to align, match, connect and be compatible with the flange and busbar connections of the ac bus duct specified. Bonding strap for bonding bus enclosure to transformer case.
- Monitoring and Protective devices for dry type transformers. All contacts electrically separate. All devices shall be industrial type.
- Winding temperature indicator, with maximum reading pointer to detect transformer winding over temperature, and with factory-set two-stage contact device. The first stage provided with a contact which opens on temperature increase to initiate annunciation. The second higher temperature stage shall be provided with two contacts; one opening on temperature increase to initiate annunciation and one closing on temperature increase to actuate the rectifier-transformer ac feeder breaker lock-out relay. Settings as recommended by the manufacturer (Devices 49T1 & 49T2)

Rectifier Units

- Rectifiers shall be natural, convection-cooled rectifier, with 12-pulse rectification (6-Phase input) in accordance with Circuit No. 31 as defined in ANSI C34.2 suitable for indoor service and for the duty cycle indicated.
- Each rectifier shall be a complete self-contained unit, including bus, connections and hardware from the rectifier transformer output flange to the flange for connection of the bus to the dc switchgear. Each rectifier shall be a complete, operative assembly, consisting of silicon diodes. The rectifier shall comply with and be tested to IEEE 1653.
- Physical electrical isolation and insulation shall be provided between the rectifier enclosure and the rectifier-transformer enclosure. Connect the rectifier positive terminals to dc switchgear with bus.
- Provide separate compartments to isolate control and auxiliary circuits and functions from the 750 Vdc buses and diodes.

- Equip the rectifier unit with voltage surge suppressors to limit the reverse voltage across the silicon diodes within the peak reverse voltage rating of the diode, irrespective of whether the voltage transient appears in the alternating current or direct current power circuits.
- The current shall be balanced between diode strings to within 10%.
- Each diode shall be protected by a current limiting fuse.
- Mount the rectifier enclosure on rigid self-supporting structural steel framework, insulated from ground and have principal members of its structure bonded together. Furnish enclosure with protected openings to provide necessary ventilation for the components.
- Provide each rectifier with suitable protective devices to protect the overall equipment and assure continuity of operation. Provide devices to prevent damage to individual parts of equipment due to short circuit, loss of cooling, high temperature, transient voltage conditions, and overloads.
- The no-load voltage shall be limited to the value indicated in section 6.1.3.
- Provide a suitably rated negative disconnect switch. Switch shall be electrically operated with ability for manual operation in case of power failure.
- Provide suitably sized and rated negative and drainage buses.

6.1.4.7 Auxiliary Equipment

Equipment shall include lightning and surge protection, interconnecting ac and dc bus work, 125 Vdc control-power battery, UPS and charger, auxiliary transformer for communication equipment and SCADA, fire protection panel power, intrusion alarm system power and housekeeping power. Equipment shall include an exterior blue light that would illuminate to indicate that the substation is offline.

Substation control power battery system and UPS shall each be capable of supporting operation of the substation for 8 hours after the utility service has failed. The substation power battery system shall be expected to perform 8 trip/open/charge operations in this period.

Interior lighting shall be provided to sufficiently illuminate the vertical faces of interior equipment such as switchgear and transformer-rectifier units. Lighting fixtures will be positioned to avoid interference with overhead wiring and shall not be located directly above switchgear, transformers, and rectifiers. The level of illumination shall be in accordance with local and national codes and standards.

Exterior lighting shall be provided to sufficiently illuminate the substation enclosure and ingress/egress paths. The illumination levels shall be in accordance with local codes for outdoor lighting.

Emergency lighting consisting of rechargeable batteries and battery chargers shall be provided. A relaying device will be used to energize the emergency lamps automatically upon failure of the ac power when interior lighting is off. The battery will have the capacity to supply rated load for a minimum of 1½ hours at not less than 87.5 percent nominal battery voltage.

Duplex convenience power outlets will be located around the interior walls of the housing and in the rear of each circuit breaker cubicle. One duplex outlet is to be located near the switchgear and rectifier, on a separate circuit and rated to permit the use of a heavy-duty vacuum cleaner or a portable air compressor.

6.1.4.8 Emergency Trip Stations

An Emergency Trip Station (ETS) shall be located in a locked box on the exterior of each TPSS. The ETS shall be incorporated in the substation transfer trip scheme. The ETS shall be used during an emergency to de-energize the entire substation by tripping the associated ac and dc feeder breakers and de-energize the feeder dc circuit breakers, located in the adjacent substations, feeding the area.

6.1.4.9 Substation Grounding

The design of the grounding system shall preclude any unsafe condition for the equipment, maintenance personnel, passengers, and the general public. Each substation will be equipped with a minimum of two connection to the copper ground bus and redundant cable connections to a substation exterior grounding grid. The grounding grid will consist of driven rods and conductors embedded in the earth. Grid conductors shall have hard drawn copper wire and connecting materials shall be resistant to corrosion by the surrounding earth. The incoming ac service ground and facility ground will utilize the same substation grounding system. Non-current carrying enclosures or parts of alternating current equipment, including ac apparatus and rectifier-transformers, shall be securely connected to the grounding grid.

Enclosures for traction power rectifiers, dc switchgear, and dc busways should be insulated from ground and connected to the substation ground grid through a ground fault detection system. This system should be designed to detect enclosure energization ("hot structure") and grounding ("grounded structure") conditions. The dc system should normally operate without grounding. The traction power rectifier dc negative bus and dc switchgear also isolates from ground.

All disconnect switches and surge arresters will be grounded. Maximum rail potential rise, step-and-touch ac and dc voltages shall not exceed the allowable values defined in the IEEE standards for ac systems and the IEC standard for dc systems.

The ground resistance of each ground grid shall be tested after installation and each ground bus when connected to ground grid, using approved test procedure. Ground mat resistance shall comply with IEEE 80 and not exceed the design requirements. To meet resistance requirements, install additional ground rods as necessary.

6.1.4.10 Substation Enclosure

Traction power substations shall meet all local requirements for occupancy of this nature. They shall be designed to be as small as possible and still meet AISC specifications to withstand live roof loading, ice and snow loading, wind loading, and seismic.

Prefabricated enclosures shall withstand the stresses caused during loading, transportation, and installation with doors, walls, and roof panels reinforced by braces, stiffeners, and structural members to provide a rigid module. The enclosures shall meet the following requirements:

- Emergency egress requirements and interior working spaces and clearances shall comply with NFPA 70, Article 110, both in size and arrangement. Rear access to equipment from the exterior of the enclosure shall require approval by DDOT and be limited to low maintenance components such as bus bar.
- Redundant heating, ventilation, and air conditioning shall be provided. Ventilation louvers shall prevent the entry of leaves and paper. Inlet air filters shall be installed to minimize dust accumulation within the TPSS. Roof-mounted vents shall be a low-profile, and of an aesthetically acceptable type approved by DDOT.
- HVAC system design and materials shall comply with NFPA 90A.
- The enclosure shall have provisions for temperature control. The maximum air temperature within the substation shall not exceed the design value, under maximum ambient conditions and TPSS operation at full designed capacity.
- Doors, joints, walls, roof, floor, vents, and louvers shall be rainproof under wind, rain, and snow conditions
- Metal components of the enclosure shall be grounded.
- The substation transformer shall have a maximum sound pressure level per the manufacturer's specifications. Acoustical insulation, vibration isolation, and structural design techniques shall be used to minimize the continuous noise level of the assembled TPSS.

6.1.4.11 Direct Current Switchgear

The positive dc output of the rectifier shall be distributed via a dc switchgear lineup. The dc switchgear assembly shall be in the form of a lineup of dead-front, metal-enclosed, freestanding enclosures suitable for indoor service. Use the switchgear to serve as the control and protective equipment for the distribution of dc power to the streetcar vehicles. Include in the switchgear assembly draw out, single pole, dc circuit breakers, dc positive buses and bus connections, positive feeder cable terminal connectors, indicating lights, terminal blocks, protective and auxiliary relays, control circuitry, wiring, and other devices necessary to make a complete and operable assembly. Provide switchgear conforming to ANSI C37.14, ANSI C37.16, ANSI C37.17, and ANSI C37.20.2.

The design engineer will determine the number of dc circuit breakers and their function. Circuit breakers will be installed to provide isolation of designated OCS sections and all feeders at the substations. Breakers will be equipped with direct acting instantaneous over-current, “rate-of-rise”, and automatic re-closure relaying. The protection features shall result in tripping and holding tripped of all breakers feeding a faulted circuit without the need for a transfer trip between substations.

Circuit breakers shall be single-pole, single throw, air break, draw out type, with electrically controlled tripping, mechanically and electrically trip-free, complying with applicable parameters in Table 11 of ANSI C37.16a. The racking mechanism shall have connected, test and disconnected positions; manually operated closed-door mechanism by preventing over travel, guides for alignment of breaker with stationary unit and an indicator to show breaker position within the compartment. Feeder breaker shall have a series trip device, direct acting, direct release, forward and reverse (bi-directional), series trip device adjustable between 200 percent and 400 percent of circuit breaker continuous current rating. The circuit breaker shall have control switch on each circuit breaker for electrical closing and tripping of the breaker.

6.1.4.12 Interconnecting Buses

Interconnecting buses shall be sized per ANSI standards and shall be supported to withstand available short-circuit current at the appropriate bus-voltage level. Buses shall be constructed of ASTM B187, 98 percent conductivity copper with a maximum current density of 800 amperes per square inch.

The buses shall be capable of withstanding mechanical stresses and heat due to maximum short-circuit current. Bare buses shall be mounted on barrier type insulation or post type insulators of sufficient strength to withstand without damage or permanent distortion all stresses produced by short-circuit current equal to the interrupting rating of the circuit breakers.

Bus contact surfaces shall be silver-plated or tin-plated at connections. Each joint shall have an impedance of not more than that of a bus bar of the same length, clamped to maintain that impedance throughout the life of the equipment and treated to prevent corrosion. All connections to bus made with cadmium plated, galvanized or similarly coated, high strength steel bolts of sufficient number and size to provide solidly bolted connections.

6.1.4.13 Feeder Supports

Traction power positive cables from the dc feeder breaker connections and negative cables from the negative bus connections shall be installed in separate raceways. Raceways shall be non-metallic and have adequate cross-sectional area per the cables without crossing and twisting. The feeder supports shall be designed in accordance with NEC requirements.

6.1.5 Direct Current Distribution System

6.1.5.1 Overview of DC Distribution System

The dc distribution system shall consist of the cables and conduit necessary to distribute dc power from the TPSS to the OCS and the return from the running rails. The distribution system shall be divided into two sections, the positive and negative feeder system. Feeder systems shall consist of insulated copper conductors conforming to ASTM and ICEA standards, and the conduit, ductbank and raceway system, consisting of ducts and manholes, shall conform to NEC requirements.

6.1.5.2 Positive Feeders

The positive feeder system is the cable that connects the dc feeder breaker to the interface point with the OCS.

6.1.5.3 Negative Feeders

The negative feeder system is the dc feeder cable from the rails to the negative bus in the substation.

6.1.5.4 Cables

Traction power feeder cables shall be standardized with 2 kV insulation and be based on a single conductor size which shall accept normal, maximum overload and short-circuit currents not exceeding the safe insulation design limits of the cable. Multiple cables shall be used to meet different current requirements. The feeders' size shall be such that voltage drops in the feeders do not affect the required traction power voltage levels under normal and overload conditions and to operate at the rated insulation temperature during normal operating conditions.

Where cables are installed in exposed locations, a means shall be provided to support and protect the cables adequately. Lightning protection shall be provided at points where cables enter or leave underground conduit systems.

6.1.5.5 Conduit Systems

Feeder ductbanks shall consist of fiberglass reinforced epoxy duct or Schedule 40 PVC conduit encased in red-dyed concrete. Design requirements for the ductbanks, such as conduit size, maximum total turns (in angular degrees), and the minimum embedment depth below grade, the manhole spacing, and the duct gradient shall be in accordance with the NEC. All feeder ductbanks shall be identified by a detectable yellow warning tape six inches wide marked "Warning - High Voltage" laid in backfill 12 inches (300 mm) above the concrete encasement as required by applicable standards and codes.

Ductbanks shall be installed to run as directly as possible between terminations with care to avoid other ducts, pipelines, sewers, foundations, etc. Ductbanks shall also be run as gradual as possible in the horizontal and vertical planes to avoid deformation of the ducts. Manholes, pull-boxes and hand-holes, as required, shall be located to facilitate installation of the cables. The number of ducts installed shall have at least 20% spare capacity, with a minimum of one duct for future installation, where possible.

6.1.6 Overhead Contact System

6.1.6.1 Overview of OCS

The OCS 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, the environmental conditions discussed in Chapter 2.

The OCS consists of the conductors, including 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 OCS shall be coordinated with the vehicle dynamic performance characteristics and track geometry to develop a system where the pantograph maintains contact with the contact wire for proper current collection under all operating conditions; see Chapter 4.

The physical support system consists of foundations, poles or masts, guys, insulators, brackets, cantilevers, and other assemblies and components necessary to support the OCS so 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 shall be electrically continuous from substation to substation. At the TPSS, the OCS system continuity shall be sectionalized to isolate each electrical section. An arrangement providing continuity and flexibility for sectionalization of the OCS while any track is out of service shall be incorporated in the design. Sectionalization at switches or other special trackwork locations, as well as in the yard, is required to provide operations and maintenance flexibility.

At locations where insulated separation in the contact wire is required, such as at special trackwork, jumpers, switches and breakers will be employed to maintain electrical continuity. Where jumpers are used, they shall be sized to provide the same amp capacity as the contact system.

6.1.6.2 OCS Design Coordination

OCS designs shall be reviewed at each phase of the design and engineering process by the Core Team to ensure a coordinated design of the infrastructure with the project context and related improvements.

6.1.6.3 Overhead Contact System Configuration

<u>Mainline Sections</u>

The OCS in streets shall be supported and registered by means of cantilever assemblies. Cantilever arrangements may be required to reach over street parking lanes. Where cantilevers are not appropriate, support and registration shall be by means of span wires. Center poles should be used where the tracks are adjacent to center roadway median strips. In addition, the OCS style will consist of an auto-tensioned single contact wire, or a fixed-tension single contact wire located over each track.

The use of OCS poles along streets should be kept to a minimum. The OCS shall be designed to suit aesthetic requirements of the area. Where new street lighting is proposed, the design of joint use poles should be coordinated with street lighting designers. Wherever possible, to reduce clutter along streets, the OCS should be attached to existing structures, buildings, traffic signal poles, and street light poles, provided these supports are structurally suitable.

Wire termination or anchor poles should be designed without guy assemblies.

Mainline Tunnel or Roofed Sections

Within route sections covered by tunnel or roof, the OCS style will consist of a single contact wire located over each track, and where required, supplemented by along-track paralleling feeder cables. The single contact wire should be auto-tensioned where technically possible.

The OCS should be supported by a direct insulated attachment to the ceiling, to the soffit of the overhead structure or from adjacent wall structures. The contact wire should be registered by service-proven resilient support arms. Service proven conductor rail systems may be submitted for approval as an alternative design. Limited clearance conditions may require a close spacing of supports to minimize the depth of the attached system.

Vehicle Maintenance and Storage Facilities

A fixed termination single contact wire (FTSCW) style of OCS should be used for storage facility yard tracks. Poles supporting contact wire terminations should be designed to accommodate the variance in conductor tension due to climatic change.

The OCS in the storage areas shall be supported and registered by means of cantilever assemblies. Where cantilevers are not appropriate, support and registration will be by means of head span wires and steady span wires.

Where OCS wiring enters vehicle maintenance shops where it will be normal practice for staff to access vehicle roof equipment, permanent equipment will be required to safely isolate and ground each wired track individually. Such equipment will be designed to facilitate safety lockout and interlocking procedures used by the shop staff.

Non-bridging section insulators are required in contact wires entering vehicle maintenance buildings. Typically, these should be located outdoors, above the edge of the concrete apron surrounding the building. Specifically, they are required to be located above the midway point between any pairs of insulated rail joints cut into the track for ground system isolation purposes.

6.1.6.4 Design Parameters

The OCS shall be designed in accordance with the guidance in Chapters 4 and 5.

The OCS design should account for the following Operation Condition and Non-Operation Condition.

Operation Condition

Operating Condition is defined as the extreme combination of environmental values within which the OCS is to be available for normally operating rail vehicles. Two combinations are defined. Calculations should consider both and utilize the most onerous condition.

Operating Condition 1 is the concurrence of ¼ inch (6.35 mm) of radial ice cover, 40 mph (64.373 km/h) of wind, and temperature of -5 °F (-20.55°C).

Operation Condition 2 is the concurrence of no ice cover, 55 mph (88.514 km/h) wind, and temperature of -5 °F (-20.55 °C).

Non-Operation Condition

Non-Operating Conditions will be applied to design calculations for structural and strength purposes for equipment, conductors and parts. Unless covered by superior requirements of other relevant codes, OCS equipment and conductors will be designed to meet the structural and strength requirements of National Electrical Safety Code.

Safety Factors

Unless covered by superior requirements of relevant codes, the following minimum equipment and conductor strengths are to be applied to the design:

- Tensioned Conductors:

Operating Condition	2.0
Non-Operating Condition	1.6

- Structures, hardware and non-electrical wires:

Operating Condition, against breakage	2.5
Operating Condition, against slippage	2.5
Non-Operating Condition, against breakage	2.0
Non-Operating Condition, against slippage	2.0

Pantograph Data

The OCS will be designed to suit pantographs operating with the following dimensions:

- Minimum Collector Head Width from horn tip to horn tip 66.1 inches (1678.94 mm)
- Maximum Collector Head Width from horn tip to horn tip 73.0 inches (1854.2 mm)
- Minimum Length of Carbon Collector 40.6 inches (1031.24 mm)
- Maximum Collector Head Width 15.7 inches (398.78 mm)
- Maximum Unworn Carbon Collector Radius 26 feet (7.92 m)
- Maximum Pantograph Sway relative to vehicle body 1.5 inches (38.1 mm)

Pantograph Security

Minimum Pantograph Security (Residual Width) 3 inches (76.2 mm)

6.1.6.5 System Design Study

The design of the OCS should be based on an engineering study. The study will include calculations and development of the system design parameters. It will take into account all factors that contribute to displacement of the contact wire with respect to the pantograph, including:

- Climate condition
- Conductor data
- Pantograph security
- Conductor stagger
- Mast deflection due to static and live imposed loads
- Poles installation tolerances
- Vehicle roll and lateral displacement
- Sway of pantograph
- Track maintenance tolerances

The result of this study shall define and provide values for the following parameters, where they have not been specified herein:

- Maximum structure spacing as a function of track curvature and vertical profile
- Conductor blow-off, stagger effect and allowable static offset
- Maximum stagger on tangent track, and on curved track
- Conductor rise and fall under various climatic combinations
- Conductor along-track movement, and wire elongation
- Conductor tensions, sags and factors of safety under various climate conditions
- Contact wire stagger deviation due to movement of hinged cantilevers
- Conductor profile, hanger lengths and spacing

- Equipment vertical and radial loads
- Loss of conductor tension along the system

Clearances and Tolerances

The normal minimum and absolute minimum static and passing clearances will be maintained between live conductors, OCS equipment, including the pantograph and any grounded fixed structures, in accordance with AREMA Manual for Railway Engineering, Chapter 33, and Part 2 as applicable to Light Rail Transit Cars.

For vehicle related clearances, full allowance shall be included for the dynamic envelope of the vehicle under operating conditions, including track and other maintenance tolerances.

Absolute Minimum Passing or Static clearance values shall not be used for design purposes.

Pantograph Clearance Envelope

A pantograph clearance envelope shall be developed for applications on all tracks for worst case conditions. Erection tolerance components are to be included for all surfaces involved in each clearance summation.

Horizontal clearance components will include a full vehicle roll plus a 6 inch mechanical running clearance.

Vertical clearance component dimensions will include minimum static clearance or passing clearances plus dynamic uplift; whichever is more onerous and appropriate for that situation.

No equipment, except the OCS steady arm end attached to the in-running contact wire, shall intrude into the pantograph clearance envelope, when the contact wire is in its static position or dynamically uplifted position. The heel end of all steady arms will be outside the pantograph clearance envelope.

6.1.6.6 Single Contact Wire Auto Tensioned Style Wiring

The system on tangent track streets shall be supported and registered by means of single cross-span head span wires designed to accommodate along track movement or hinged cantilevers. At sharp curves and corners, wire pull off assemblies may be used. The contact wire shall be staggered.

The single contact wire auto tensioned style wiring shall consist of a number of tension sections. Each tension section shall be designed as long as possible considering the mechanical constraints of the system design, such as displacement of contact wire due to swinging cantilevers, tension loss along the system, balance weight travel and manufacturing limits of conductor length. Further, the tension section design shall take into account the electrical sectioning requirements.

Tension lengths shall be terminated at each end by auto-tensioning devices or fixed terminations. Where tension sections have an auto-tensioning device at both ends, the possibility of wire travel along track will be addressed in the design.

Where route sections are not divisible into full tension sections, or are over steeply graded sections of track, half tensions sections will be permissible in the design. Half tension sections are where one end of the wiring utilizes a fixed termination and the other end a balance weight anchor assembly. Where half tension sections are employed on steep grades, the fixed termination will be installed at the higher level.

6.1.6.7 Single Contact Wire Fixed Termination Style Wiring

At operations facilities and designated tracks junctions, single contact wire fixed termination style wiring shall be used.

The wiring shall be supported and registered by means of cantilevers or single cross-span head span wires. At sharp curves and corners, wire pull off assemblies may be used. The contact wire shall be staggered.

6.1.6.8 Adjacent Overhead Contact System Styles

Tension sections shall each be designed to be wholly of a single style. Where two tension lengths of different styles abut at an overlap or cross at a turnout, the equipment and fittings shall be designed for smooth operation of pantograph under the possible climatic variations

6.1.6.9 Tensioning Devices

Tensioning devices shall accommodate conductor expansion and contraction and shall be provided with broken wire restraint arrangements. All operating wires shall be of flexible, non-rotating stainless steel wire. Devices will have features that limit wire travel between two field-adjustable stops.

Balance weight anchors are the preferred auto-tensioning device. Balance weight anchor assemblies shall tension using cast iron, or steel balance weights.

In designated city streets, balance weight assemblies are to be installed inside tubular poles. The pole will have inspection holes with vandal resistant covers capable of removal for maintenance inspections of the weight position and internal moving parts. Poles and assemblies will be designed such that weights and other parts can be maintained or replaced with the pole in place.

Balance weights shall be positioned to be as unobtrusive as possible. In areas where external balance weights are permitted, and are frequented by passengers or pedestrians, the balance weight assembly shall be provided with a protective shield. The shield shall be vandal resistant, and be capable of removal or opening for maintenance inspections of the weight position and internal moving parts.

Spring tensioning devices may be used for very short tension sections servicing crossover or yard lead tracks, and where every span in the tension length is less than 80 feet long. Separate spring tensioners are required for each contact wire.

Pneumatic, hydraulic or gas tensioning devices shall not be used.

6.1.6.10 Contact Wire Height and Gradient

The design of the OCS shall include consideration of the pantograph lock-down height and the height of existing overhead obstructions. The contact wire at supports shall be designed to take into consideration the effect of wire sag due to temperature rise and installation tolerances, including track construction and maintenance tolerances.

Different conditions may exist along the route, for which applicable heights measured from top of the rail at maximum operating temperature and no wind, are required as shown below.

Table 6-1 | Contact Wire Height and Gradient

Condition	Minimum Permissible Contact Wire Height	Normal Contact Wire Height at Support
Exclusive right of way	16’ – 0”	19’ – 6”
Semi exclusive ROW (shared with other vehicles)	18’ – 0”	19’ – 6”
Maintenance Building	18’ – 0”	19’ – 6”
Storage tracks	18’ – 0”	19’ – 6”

Under no circumstances shall the contact wire height exceed 20.0 feet. Contact wire gradient shall not exceed 1.3%. Gradients up to 2.3% can be permitted in the yards.

6.1.6.11 Overhead Contact System Conductors

The contact wire shall be 350 kcmil solid grooved hard-drawn copper, conforming to ASTM Specification B47.

Wire size shall be confirmed by traction power simulation.

A 30% cross-sectional area of contact wire loss due to wear and the effect of temperature change on all conductors shall be considered in the design of conductor tension.

Full current jumpers shall be used to maintain electrical continuity at special trackwork locations and overlap spans where it is necessary to have a physical separation of conductors. All jumper wire shall be of stranding class G or higher. Jumper assemblies and methods shall have sufficient conductivity for the OCS circuit ampacity.

6.1.6.12 Registration Loads and Angles

Steady arm assemblies registering the contact wire shall have the following category names and limitations applied.

- Light Load: Radial load up to 200 lb pull or 80 lb direct push on a steady arm
- Medium Load: Radial load up to 500 lb pull on a steady arm
- Heavy Load: Radial load up to 1000 lb shared by a double medium load steady arm assembly

Direct push arrangements shall not be applied to in-running contact wires where push off radial load exceeds 80 lb.

The angle of deviation of the contact wire due to any one in-running steady arm shall not exceed 14 degrees.

6.1.6.13 Overlaps, Crossovers and Turnouts

Overlaps shall be used between adjacent tension sections to provide mechanical continuity of the OCS and to permit smooth passage of the Streetcar pantograph from one tension segment to another. One span overlaps are preferred. Un-insulated one span overlaps shall be designed to permit future installation of insulation. Two span un-insulated overlaps may be located on circular curves. Overlaps shall not be built over spiral transition curves in trackwork.

Crossovers and turnouts shall be used at track special work locations where the Streetcars change tracks and yard leads where they leave or enter the mainline. Crossover or turnout wire shall be arranged to cross with the mainline contact wire underneath. Assemblies shall be designed to restrict the relative vertical movement of the two contact wires, yet permit along track movement. Full current jumpers shall connect the two wires within the crossing span.

The overlap, crossover, and turnout arrangements shall be designed considering the electrical and mechanical properties of the OCS. The designs shall enable a uniform uplift of the contact wires of each system with no hard spots. A smooth pantograph passage and good current collection without arcing shall be achieved under all operating conditions.

Sufficient electrical and mechanical clearances shall be maintained between adjacent cantilevers and between the cantilever frames and adjacent conductors. In auto-tensioned segments the clearances shall allow for the cantilevers attached to adjacent sections to move in opposite directions as the temperature changes without infringing clearances or causing misalignment of the system.

The overlap, crossover, and turnout arrangements shall be designed using single poles with twin cantilevers. Only where this arrangement is not possible two poles with one cantilever each may be used.

In areas where center poles are used, the overlaps shall be staggered along the track to reduce pole loading.

6.1.6.14 Poles and Foundations

All poles shall be manufactured from steel and be designed as free standing, except guyed termination poles may be used in specific locations with DDOT approval. The quantity of pole types shall be minimized.

All poles shall have a base plate drilled to fit the foundation bolt pattern and be dimensioned to prevent poles being installed on a lower strength foundation. Where a functionally equal pole style of equal strength exists within the DDOT standard range of poles, new pole designs shall be suitable for installation on foundations suitable for DDOT standard poles and anchored with double bolts.

Poles shall be designed so that under all operating conditions the across-track live load deflection of any structure shall be no more than one inch in either direction laterally at contact wire height. Pole designs shall account for the impacts of track center and clearance calculations.

All poles shall have provision for grounding or bonding conductor connections.

The OCS designer and architects shall determine the elevation of the OCS foundation relative to the adjacent grade. OCS foundations shall be designed according to DC Streetcar design standard drawings.

On designated streets, poles may be required to be of an ornamental style, to provide for joint use with street lighting or traffic services, or be suitable for the internal installation of balance weight assemblies.

The design of foundations for support poles and guy anchors shall be based on the structure loading calculations and soil data. The supporting structure foundations shall be designed to accept bolted base poles and have provision for internal feeder conduits and pole grounding rods, wires, and fittings. Foundations shall be designed to match the maximum loads permitted for the attached type of pole or guy assembly.

6.1.6.15 OCS Grounding and Bonding

All OCS support structures and support assemblies shall be effectively grounded and bonded in accordance with NEC and in accordance with the requirements of Chapter 6.

6.1.7 Negative Return Path and Stray Current Control

Where it is necessary to have a bolted connection, the bolted joints shall be electrically bonded. Insulated joints shall be installed at the entrance to the shop buildings to prevent any connection between the traction power system in the shop and on the main line. In each track the pair of insulated rail joints shall be staggered so as not to be located at the same stationed locations. The OCS designer and architects shall determine the elevation of the OCS foundation relative to the adjacent grade. OCS foundations shall be designed according to DC Streetcar design standard drawings. The locations shall be staggered such that at least two axles of the Streetcar have a current return to each traction power circuit at the point where the Streetcar pantograph crosses the OCS section insulator. Such locations are to be valid for all types of rail vehicles in operation, and with these vehicles facing either direction.

The traction power distribution system designer, as well as other designers, shall employ designs that will mitigate stray currents and to provide means of monitoring any potential stray current conditions. As a minimum, the following measures shall be employed to mitigate stray current conditions. Running rails shall be isolated to the extent practical from ground. The mainline traction power system shall be isolated from the shop traction power systems. All traction power distribution system design shall be coordinated with Chapter 6.

6.1.8 Applicable Streetcar Standard Drawings:

- OCT-01 General Notes for OCS Drawings
- OCT-02 Abbreviations Used on OCS Drawings
- OCT-03 Vertical Electrical Clearance for non-OCS Wires
- OCT-04 Vertical Electrical Clearance Requirements
- OCT-05 Summary of Design Criteria, Tolerance, and Wire Heights
- OCT-06 Pantograph Collector Outline
- OCT-07 Simplified Pantograph Clearance
- OCT-08 Pantograph Clearance to Ground Items and Different Electrical Circuits
- OCT-09 Pantograph Clearance to Live OCS Fittings
- OCT-10 Steady Arm Clearances and Dimensions
- OCT-11 Conductor Particulars
- OCT-12 Auto and Fixed - Tensioned Single Contact Wire Span Length Chart
- OCT-13 Auto - Tensioned Single Contact Wire - Along Track Movement and Stagger Change
- OCT-14 Auto - Tensioned Single Contact Wire Radial and Wind Loads
- OCT-15 Fixed - Tensioned Single Contact Wire Radial and Wind Loads
- OCT-16 Swat And SWFT Erection Tensions
- OCP-01 Sample OCS Wiring Layout Plan

- OCP-02 Sample Pole and Foundation Schedule
- OCP-03 Sample Acceptance Measurement Requirements
- OCD-01 Typical Cantilever and Supported Pull-Off Structures - Swat
- OCD-02 Typical Headspan Structure - Swat
- OCD-03 Typical Cross Span Structure - Swat
- OCD-04 Typical Feeder Structures With Disconnect Switch
- OCD-05 Typical Section Insulator Suspension Structure - Swat
- OCD-06 Midpoint Anchors
- OCD-07 Insulated Overlap on Headspan Support Structures
- OCD-08 Insulated Overlap on Cantilever Support Structures
- OCD-09 Bracket Assemblies for Tubular Poles - Types BA, BB, BC, BD, BE, and BH
- OCD-10 Single Contact Wire Light/Medium Push-Off and Pull-Off, Cantilever Assemblies CA-01l/M and CA-02l/M
- OCD-11 Single Contact Wire Heavy Push-Off and Pull-Off, Cantilever Assemblies CA-01H and CA-02H
- OCD-12 Single Contact Wire Insulator Support, Cantilever Assembly CA-03
- OCD-13 Single Contact Wire Out-Of-Running, Cantilever Assembly CA-04
- OCD-14 Single Contact Wire Two Track Cantilever Assembly CA-05
- OCD-15 Single Contact Wire Push and Pull Cantilever Attached To Balance Weight Pole CA-06 and CA-07
- OCD-16 Bridle Wire Assemblies, Types BD-1, BD-2, and BD-3
- OCD-17 Medium and Heavy Pull Off Assemblies, POP-1M, POP-2M, and Pop-3H
- OCD-18 Headspan and Cross Span Support Assemblies - Type HS-1
- OCD-19 Head span Registration Assemblies - Type HR
- OCD-20 Midpoint Guy Assembly - Type MP-1
- OCD-21 Balance Weight Anchor Assembly - Type BW-01
- OCD-22 Fixed Termination Assemble - Type FA-1
- OCD-23 Jumper Assembly - Type JC, Cross Contact Assembly - Type CC
- OCD-24 Section Insulator Assembly - Type SI
- OCD-25 Cut-In Insulation Assemblies and Splice Types - IN2C, IN2G, IN3, and SP1
- OCD-26 Pole Mounted Disconnect Switch Assembly - Type DS-21 and DS-22
- OCD-27 Surge Arrester Assembly - Type SA
- OCD-28 Foundation and Pole Ground Connection Assembly - Type PG
- OCD-29 Shop Door Bridge Assembly - Type SD-1
- OCD-30 Shop Door Wire Termination Assemblies - Type SY-1 and SY-2
- OCD-31 Typical Shop Door Wire Termination Brackets

- OCD-32 Tapered Tubular Pole Assemblies - Type PS and PF
- OCD-33 Tapered Tubular Feeder Pole Assembly Type PF
- OCD-34 Tubular Balance Weight Anchor Pole Assembly Types PB4

6.2 STRAY CURRENT AND CORROSION CONTROL

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

6.2.1 Purpose

This guidance describes the design necessary to accomplish corrosion control measures for the entirety of the DC Streetcar system. Design factors to consider 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 shall be coordinated with all applicable engineering disciplines, and the standards and codes requirements referenced in Chapter 2.

6.2.2 Scope

6.2.2.1 General

Corrosion control design is separated into three areas, namely stray current corrosion control, soil corrosion control, and atmospheric corrosion control. The design guidance for each of these categories and its implementation shall 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

6.2.2.2 Stray Current Corrosion Control

Stray current control shall be based on the following principals:

- 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
- Developing a stray current baseline measurement along the propose line prior to streetcar construction commencing. Said benchmark to allow monitoring to determine corrosion control system efficacy.

Stray current control measures shall be installed on traction power and track systems to obtain minimal flow of dc stray current into the surrounding environment. Protection measures shall be applied to assure that stray earth currents are maintained within acceptable ranges to avoid deterioration of buried metallic structures. Data shall be obtained during Baseline Stray Current Survey to determine effects and magnitude of stray currents, if present, on existing utility installations, and to serve as a documented reference for future investigations.

6.2.2.3 Soil Corrosion Control

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

6.2.2.4 Atmospheric Corrosion Control

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

6.2.2.5 Grounding

Due to the natural difference between safety grounding and corrosion control requirements, care shall be taken where corrosion control appears to conflict with safety grounding. Grounding designs for traction power substations, passenger stops, shops and yards, aerial structures, and other wayside locations, shall be reviewed by corrosion control personnel to assure corrosion control designs are not compromised.

6.2.3 Interfaces

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

6.2.4 Applicability of Criteria

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

6.2.5 Expansion Capability

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

6.2.6 Standards and Codes

Standards, codes, and recommended practices for corrosion control shall include, but not be limited to the following publications and codes by:

- The National Association of Corrosion Engineers 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
- The Occupational Safety and Health Act
- National Electrical Code
- Military Specifications
- National Electrical Manufacturer's Association
- National Electrical Safety Code

Local and state codes may also apply, for additional requirements, see Chapter 2. Designers shall consult these publications and provide systems in accordance with the most stringent applicable code, or industry practice.

6.2.7 Special Design Provisions

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

6.2.8 Stray Current Corrosion Prevention

6.2.8.1 Purpose

The purpose of this section is to provide guidance 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 guidance, 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 shall be designed to minimize stray currents during normal revenue operations.

6.2.8.2 Scope

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

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

Designs shall be coordinated with the outside agencies through DDOT.

6.2.9 Stray Current Corrosion Prevention Systems

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

6.2.9.1 Traction Power Substations

The traction power distribution system shall be separated into two electrically isolated sections: the mainline and the Maintenance and Operations Facility shop. Traction power substations shall be spaced at intervals such that track-to-earth potentials along the mainline will be within safe operating levels.

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

Where feasible, substations should be equipped with a drainage bus suitable for connection to subsurface utilities.

Positive Distribution System

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

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

Negative Distribution System

1) **General**. The following industry-accepted standards shall 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 trackwork
    - Insulating pads and clips on concrete ties
    - Insulated rail fastening system for wood ties at a special track-work installation
    - Ballast on at-grade sections maintained a minimum of 25 mm (1 in.) below the bottom of the rail
    - Insulating direct fixation fasteners on concrete aerial structures
    - Insulating rail boots for embedded trackwork and at all roadway and pedestrian crossings
    - Cross-bonding cables installed between the rails to maintain equal potentials on all rails
    - Insulation of switch machines at the switch rods
    - Rail insulators to electrically isolate the main line rails from the maintenance shop return system
2) **Resistance-to-Earth**. The mainline running rails, including special trackwork and all ancillary system connections shall be designed to have the following desirable 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 - 250 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 may 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 shall be electrically insulated from the rails by use of dielectric materials.

Embedded track rails, regardless of embedment material (concrete or asphalt), shall be encased in an elastomeric material that meets the guidance specified in this chapter and secured in place by the use of tie bars/rail clips assembly or anchor plates/rail clips assembly. The preferred Elastomeric material shall be the pre-formed rubber boot. In special trackwork areas a poured in place elastomeric grout shall be used. The embedment material shall be set ¼ in below the top of rail on the field side to prevent the wheel tread from damaging the pavement material.

Electrical testing of the embedded track will be required to demonstrate compliance with the corrosion control measures outlined in ASTM G165 - 2005.

Grade Crossings, Embedded Track

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

Maintenance Shops

Shop traction power shall be provided by a separate dedicated dc power supply electrically segregated in both the positive and negative circuits from the mainline traction power system.

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

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

Water Drainage

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

6.2.9.2 Electrical Bonding

Bridge Structures

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

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

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

Structural deck members shall be electrically insulated from support piers and abutments.

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

Retaining Walls

All longitudinal bar overlaps in both faces of the wall, including the top and bottom bars of the footing, shall be tack welded to insure electrical continuity. Longitudinal bars in the footing shall be made electrically continuous to the longitudinal bars of the walls. Collector bars and bonding cables will be installed as stated in 14.9.2.1 above.

Utility Structures

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

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

Replaced, relocated, and maintained in placed utility structures, owned by others, if required, shall be provided with corrosion measures required by individual master agreements.

6.2.9.3 Drainage Facilities

The corrosion control design shall provide for stray current control at drainage facilities including conduits, manholes, junction boxes, drainage buses, cables, drainage panels and other associated equipment.

6.2.9.4 Test Facilities

Test facilities shall be required on all electrically bonded structures owned by the DC Streetcar System to measure and monitor stray currents. The corrosion control design shall provide test facilities for individual protected structures.

6.2.9.5 Quality Control

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

6.2.10 Soil Corrosion Control (Buried Structures)

6.2.10.1 General

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

1) Materials of Construction

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

2) 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.

6.2.10.2 Scope

The structures which may be affected by soil and water corrosion shall 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
- Hydraulic elevator cylinders
- Support pilings
- Underground storage tanks
- Other underground structures

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

6.2.11 Soil Corrosion Prevention Systems

6.2.11.1 General

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

6.2.11.2 Materials and Structures

Ferrous Pressure Piping:

All buried cast iron, ductile iron and steel pressure piping over 100 foot long, owned by DC Streetcar System, shall be cathodically protected. Designs shall include the following:

- Application of a protective coating to the external surfaces of the pipe (see Chapter 6)
- Electrical insulation from interconnecting piping, other structures, and segregation into discrete electrically insulated sections depending upon the total length of the piping (see Chapter 6)
- Electrical continuity through installation of insulated copper wires, across all mechanical joints other than intended insulators (see Chapter 6)
- Permanent test and access facilities, to allow for verification of continuity, effectiveness of insulators and coating, and evaluation of protection levels; shall be installed at all insulated connections and at intervals not greater than 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

Reinforced and Prestressed Concrete Pressure Pipe

Design and fabrication of reinforced concrete pipe and steel cylinder pre-stressed concrete pipe shall 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

Reinforced Concrete

Design shall 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 two-inch concrete cover on the soil side of all steel reinforcement when the concrete is poured within a form or a minimum three-inch cover when the concrete is poured directly against soils

Support Piles

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

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

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 shall consider the following characteristics of proposed materials:

- Manufacturer's recommendations
- Mechanical strength and internal pressure limitations
- Elasticity and expansion characteristics
- Comparative costs
- Expected life
- Failure modes
- Local codes
- Prior experiences with the proposed non-metallic material in similar applications

Hydraulic Elevator Cylinders

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

- External protective coating resistant to deterioration by petroleum products (hydraulic fluid)
- Outer concentric fiberglass-reinforced plastic (FRP) casing. Casing thickness, diameter and resistivity shall be designed to prevent moisture intrusion (including the bottom) and to minimize electrical insulation between the cylinder and earth
- Sand fill between the cylinder and FRP casing with a minimum resistivity of 25,000 Ohm-centimeters, a pH of between 6 and 8 and maximum chloride content of 200 ppm
- Cathodic protection through the use of sacrificial anodes installed in the sand fill or galvanic ribbon anode wrapped around cylinder
- Permanent test facilities installed on the cylinder, anodes and earth reference to permit evaluation, activation, and periodic retesting of the protection system
- A removable moisture-proof sealing lid installed on the top of the casing prior to installation of the cylinder. The top of the casing shall be permanently sealed against moisture intrusion after installation of the cylinder

Electrical Conduits

Buried metallic conduits shall 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 three 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

6.2.11.3 Coatings

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

6.2.11.4 Electrical Insulation

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

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

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

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

6.2.11.5 Electrical Continuity

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

- Use direct burial insulated, stranded copper wires with the minimum length necessary to span the device being bonded
- Wire size shall 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 shall be used per joint for redundancy

6.2.11.6 Cathodic Protection

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

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

- Cathodic current density (minimum 1.0 mA/sq ft of bare area)
- Current requirements
- Anticipated current output/anode
- Assumed percentage bare surface area (minimum 1 percent)
- 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 shall not be less than 50 years.

6.2.11.7 Testing and Test Facilities

Test stations consisting of two structure cables, one reference electrode, conduits, and termination boxes shall be designed to permit initial and periodic tests of cathodic protection levels, interference currents, and system components (anodes, insulated fittings, and continuity bonds). The corrosion control design shall specify the location and type of test facilities for each cathodic protection system.

6.2.11.8 Water Treatment

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

6.2.12 Atmospheric Corrosion Prevention

6.2.12.1 General

The purpose of this section is to provide guidance for a design that shall ensure the necessary function and appearance of structures exposed to the environment. Guidance for atmospheric corrosion control is based on prevention of appearance and reduction of maintenance costs. System wide guidance for all areas shall include the following:

- Materials selection: Materials shall have established performance records for the service intended

- Sealants: Sealants shall be used in crevices to prevent the accumulation of moisture
- Protective coatings: Barrier or sacrificial coatings shall be used on steel
- Design: Use of dissimilar metals and recesses or crevices that might trap moisture shall be avoided

6.2.12.2 Scope

The structures which may be affected by atmospheric corrosion shall 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

6.2.13 Atmospheric Corrosion Prevention Systems

6.2.13.1 Materials

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

<u>Steels and Ferrous Alloys</u>

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

<u>Aluminum Alloys</u>

- Use an anodized finish to provide the best weather resistant surface

<u>Copper Alloys</u>

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

Magnesium Alloys

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

Zinc Alloys

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

6.2.13.2 Coatings

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

Organic Coatings

Organic coating systems shall consist of a wash primer (if substrate requires), a primer, intermediate coat(s) and a finish coat. Acceptable organic coatings for use shall be determined on Baseline Corrosion Survey Report recommendations.

Metallic Coatings (for Carbon and Alloy Steel)

Acceptable coatings are as follows:

- Zinc Epoxy (organic or inorganic)
- Zinc (hot dip galvanizing)
- Aluminum
- Aluminum-zinc

6.2.14 Grounding

6.2.14.1 Purpose

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

6.2.14.2 Scope

Facilities addressed include the following:

- Traction Power Substations
- Aerial and Catenary Structures

6.2.15 Design and Coordination of Grounding Systems

6.2.15.1 Bridge and Catenary Structures

At each end of the structure, insulated cables shall be exothermically welded to the reinforcing steel and terminated in an appropriately sized and conveniently located weatherproof junction box or manhole. Support piers and abutments shall be insulated from the structural deck members.

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

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

6.2.15.2 Traction Power Substation

Corrosion control installations shall be coordinated with grounding electrodes, grounding standards, grounding requirements and IEEE Standards.

6.2.15.3 Applicable Streetcar Standard Drawings:

- T-12 Utility Impact Zones
- E-01 Low voltage Substation Typical Layout and Grounding Plan

6.3 SIGNAL AND ROUTE CONTROL

6.3.1 General

The DC Streetcar System shall be equipped with a train-to-wayside communications (TWC) system that performs the functions provided in this section.

6.3.1.1 Activate Special Traffic Signals

In areas of on-street running, special streetcar signals provided at specific intersections allow each streetcar vehicle to proceed through the intersection independent of other vehicular traffic. These signals are displayed by wayside traffic signal controllers when activated by the streetcar TWC system.

6.3.1.2 Routing

The train-to-wayside controller (TWC) provides for both the automatic and manual setting of pre-determined routes. The TWC activates and sets wayside powered track switch machines appropriate for the route. Manual switch control is also possible.

6.3.2 Applicable Codes and Standards

The operation of streetcars on public roads shall be controlled by signaling devices and pavement markings in accordance with the Manual on Uniform Traffic Control Devices (MUTCD) as published by the Federal Highway Administration. Additional requirements may apply as required by District of Columbia regulations.

Where the streetcar system crosses railroad facilities or otherwise affects railroad operations, the regulations of the Federal Railroad Administration (FRA) and the rail carrier shall apply. For additional requirements, refer to Chapter 2.

6.3.3 Functional Design Requirements

The streetcar vehicle TWC system shall use Phillips VETAG standard equipment and components to ensure compatibility between streetcars and wayside control equipment. The Phillips VETAG system shall provide for the transmission of 19-bit data messages from a streetcar-mounted transponder to a loop antenna and signal controllers along the wayside. The system shall not preclude future upgrades to a bi-directional system also based on the Phillips VETAG technology.

6.3.4 Operational Design Requirements

The streetcar TWC system shall interface with existing wayside traffic signal controllers, and shall be used for the activation of powered track switch machines where specified.

The TWC shall have provision for both the manual entry of codes and for entry of pre-determined routes. For pre-determined routes, the TWC system shall automatically activate and set wayside powered track switch machines and provide an indication of streetcar presence to the traffic controllers, as appropriate for the route. Individual manual switch control or override capability shall also be provided. Automatic operation of powered switches shall be interlocked to ensure two streetcars shall not occupy the same section of track resulting in unsafe situations.

Detector loops shall be provided between the rails at those locations where vehicle control of wayside devices or vehicle presence detection is required. These loops shall provide input to the train-to-wayside controllers that shall interpret vehicle commands and then perform designated wayside functions, such as throw switches, interface to auto traffic signal controllers, activate separate warning signs and signals, and interface to railroad crossing signal equipment. Railroad crossing signal interface will meet AREMA, FRA and rail carrier standards.

When using TWC for control of powered switches, devices such as mass detectors shall be used to prevent the actuation of a switch when a streetcar is passing through or occupying each powered switch. Mass detectors shall be chosen to operate effectively when installed between the running rails and to discriminate between streetcars and other vehicular traffic that may be present.

The TWC system shall be fully compatible for single unit streetcar, as well as multiple streetcar train set operations. In multiple streetcar operations, only the lead vehicle will have the ability to operate power switches and field devices.

6.3.5 Electromagnetic Interference

The train-to-wayside controller communications system shall be designed to operate in the electromagnetic environment of the dc system, while causing the minimum possible interference to other systems. The equipment shall be designed, selected and installed with consideration given to the electromagnetic environment, which includes the traction power supply, dc power distribution systems, vehicle propulsion systems, communication systems, adjacent railroads, industrial facilities, medical facilities, and electric utility lines.

All portions of the TWC system and its components shall be designed to operate in the electromagnetic environment that will exist in the vicinity at the time of construction and during final in service operation of the system. No portion of the streetcar signal system shall suffer from, or contribute to, harmful electromagnetic interference that is conducted, radiated, or induced.

6.3.6 Growth and Expansion

The TWC system shall be expandable for use on future routes or extensions with only minor modifications to both the field installed equipment and the streetcar vehicle born equipment.

6.3.7 Switch Machines

All track switches that are routinely used by streetcars in revenue passenger service or are used as part of streetcar routing between a Maintenance and Storage Facility (MSF) and the scheduled route shall be power operated. All powered switches within the yard shall be activated by the train-to-wayside system and equipped with occupancy, point locking, and point detection. Turn-around wyes or loops, sidings and other similar seldom-used switches may be manually operated and need not be equipped with point locking or point detection.

Streetcar vehicle specific signals similar to those found at controlled intersections shall be provided to indicate the route setting of the power switch. These signals shall be interlocked with the switch locking and point detection circuitry, such that they shall illuminate only when the switch is properly positioned and locked. These signals may be illuminated by the traffic signal controller when appropriate for streetcar vehicle movement, depending on location.

Where normal train movements are facing the switch points, indicators shall be provided for the train operators for each switch.

6.3.8 Traffic Signal Interface and Streetcar Signals

Where the streetcar vehicle operates in mixed traffic, streetcar movements shall be controlled by the automobile traffic signal system. Where switches need to be controlled for routing cars onto and off a particular streetcar route, the TWC based control system shall be provided.

Special signal indicators for use by the streetcar operator shall be provided for these areas. The special signal indicators shall be controlled and operated by the traffic signal controller. Special signal indications shall comply with the “Traffic Control for Railroad and Light Rail Transit Grade Crossings” portion of the latest version of the MUTCD to avoid confusion between rail and road traffic signals. Special signal phases shall be needed in the automobile traffic signal controllers.

To achieve this, these display indicators shall be conveyed by illuminated shapes. The illuminator shall be steady, except that the aspect will begin to flash 15 seconds prior to changing when used with traffic signal control. The illumination may be provided by LED technology or by incandescent lamps. The "Stop" indication shall be conveyed by a yellow rectangular bar in a horizontal position (0°). The "Proceed" indication shall have three aspects. “Proceed straight” shall be conveyed by a white rectangular bar in a vertical position (90°) for a straight move. “Proceed turn” shall be conveyed by a yellow slanted bar at a 45° angle for a turning move. For a left turn, the yellow bar shall be slanted such that the top of the bar is pointing to the left. For a right turn, the yellow bar shall be slanted such that the top of the bar is pointing to the right.

At intersections where the streetcar vehicle is passing through a track switch, the “proceed” signal shall be so interlocked with the track switch such that a proceed aspect shall not illuminate unless the switch is properly set and locked. When illuminated, the signal aspect shall indicate the direction for which the track switch is set.

6.3.8.1 Applicable Streetcar Standard Drawings:

- E-05 Train to Wayside Communication – Installation Details

6.4 COMMUNICATIONS

6.4.1 General

This section describes the guidance for the design of the communications system to be provided for the interfacing of the major subsystems for the DC Streetcar system.

The communications system shall provide the necessary functions to support the operational requirements of the streetcar system. The following systems are considered part of the minimum base communications system:

- Stop Platforms
- Vehicles
- Traction Power Substations

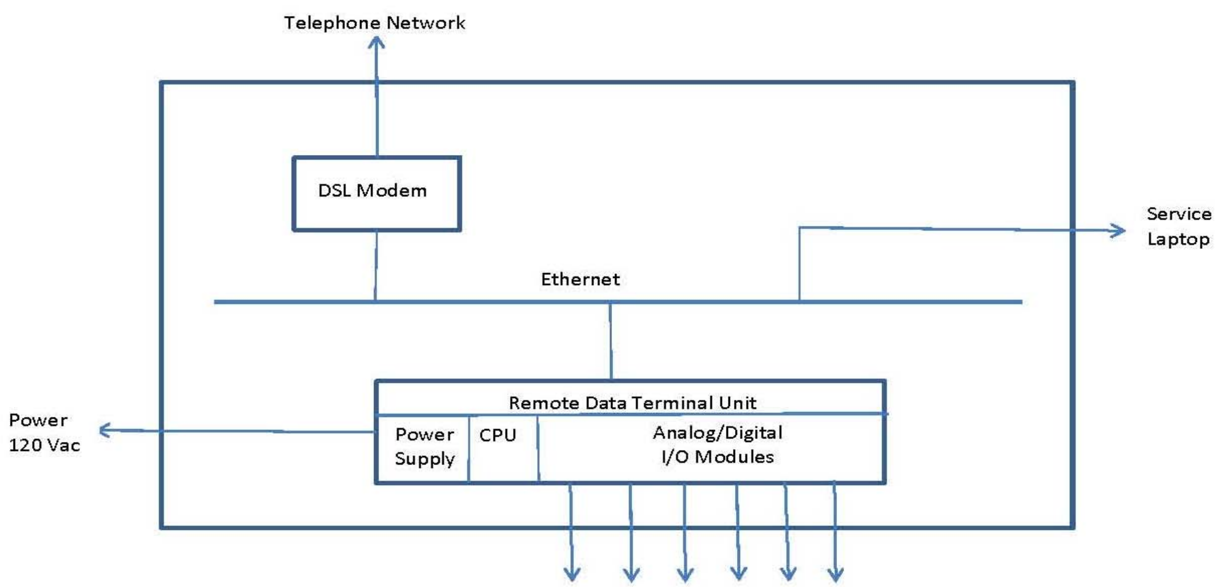
The above referenced systems shall communicate with the following location:

- Streetcar Control Center (SCC) located in the Car Barn Training Center (CBTC)

6.4.2 Supervisory Control and Data Acquisition

A Supervisory Control and Data Acquisition (SCADA) system shall be provided to enable the remote monitoring of train traffic, traction power substations, and passenger stop appurtenances. The SCADA system shall be located in cabinets at designated locations and communicate with monitoring consoles in the Operations Control Center (OCC) via telephone line. Each remote unit shall be interfaced to the telephone system using always-on DSL modems. **Figure 6-1** below shows a functional block diagram of a typical SCADA cabinet.

Figure 6-1 | SCADA Functional Block Diagram



6.4.3 Stop Platforms

Each stop platform shall be provided with a point of connection to provide the interface between the passenger stop appurtenances and the SCC. A point of connection may include, but not be limited to, pull boxes, hand holes, manholes, and cabinets. The passenger stops appurtenances include the passenger information system, video monitoring system, and fare collection equipment. At locations where TWC are required for signal or switch control, the SCADA and interface terminal equipment may be housed within the stop platform SCADA cabinet.

6.4.3.1 Passenger Information System

A wayside passenger information system (PIS) shall be provided to alert patrons as to when the next streetcar and the subsequent streetcar will be arriving. The PIS shall consist of an audio system and visual displays based on LED or LCD technology, and be suitable for operation over the ambient temperature ranges specified in Chapter 2.

A minimum of one display sign shall be provided at each passenger platform. The display shall be positioned to provide the information in a manner that meets the requirements of the ADA, including sign and message character size, color of character, and speed of preview of the message scroll. The PIS will have the capability of displaying multiple languages.

The primary components of the wayside PIS include:

- Visual displays mounted at each passenger stop to announce the arrival of the next train and route on which it is running
- Public address system at each passenger stop to enable the SCC to either activate pre-recorded announcements or initiate special announcements from the SCC
- PIS Application and Database Software operated at the SCC with provisions to manually override the message display. The manual override function shall permit the addition of additional messages to be inserted as an additional display alternating with arrival times or to replace the arrival information with new content such as "System Out-of-Service"
- Manual activated devices to announce the arrival and next train and route at each streetcar stop, to enable visually impaired customers to receive streetcar system management message. Such devices shall be equipped with braille.

6.4.3.2 Video Monitoring

A video monitoring and recording system shall be provided at each passenger platform. Each system shall be capable of recording and storing a minimum of four separate video channels. The systems shall be housed in the SCADA cabinet and include power distribution, camera control equipment including point, tilt, and zoom controls, camera power supplies, and digital video recorder (DVR) or equivalent storage device. The OCC shall be provided with the ability to control each individual camera and simultaneously display live video from two selected cameras.

The system shall be designed to store 10 days of video with 15 frames per second and 720x480 resolution. Cameras shall be capable of recording with ambient lighting levels as low as 1 foot candle. The DVR shall be provided with a removable storage media, such that the recordings can be removed and replaced with new media and continue recording while the removed media is analyzed off-site.

Provisions for copying the recorded media to a laptop computer without altering the original recording shall also be provided.

The number, style (hidden or noticeable), and locations of cameras shall be reviewed and approved by DDOT.

6.4.4 Streetcar Vehicles

6.4.4.1 Voice Radio System

A two-way radio system between streetcar personnel and the OCC shall be provided. The voice radio system shall include vehicle born mobile and portable radio sets.

The radios shall be fully compatible with all features operating as part of the District of Columbia's 800 MHz digitally trunked public safety radio system.

The following minimum channels shall be made available for all DC Streetcar radios:

- Streetcar Vehicle Operations
- Maintenance-of-Way Operations
- Maintenance Facility Operations
- Operations Control Center
- Other channels as determined necessary (Up to a maximum of four)

Specific requirements for talk groups shall be defined as necessary.

A voice radio base station shall be provided at the OCC. The base station shall be provided with the capability of recording all radio traffic on all channels of the system.

6.4.4.2 Automatic Vehicle Location System

An automatic vehicle location (AVL) shall be installed on the vehicle. The system shall be based on GPS location information supplemented by dead reckoning. The vehicles location shall be provided to the OCC either via cellular telephone or data radio communication.

6.4.5 Traction Power Substations

Each mainline substation shall be provided with a status and alarm system for transmission of substation status to the OCC through a SCADA cabinet installed in the substation.

The OCC shall be provided with a display for viewing of the status of each substation. The display may be a stand-alone unit or configured to operate on a personal computer.

At a minimum the following indications shall be provided:

- AC breaker open

- Feeder breaker 1 open
- Feeder breaker 2 open
- Over temperature alarm (prior to trip)
- Fire detected
- Intrusion detected

6.4.5.1 Applicable Streetcar Standard Drawings:

- E-01 Low Voltage Substation Typical Layout and Grounding Plan
- E-02 System wide Electrical - Typical Manhole Installation
- E-03 System wide Electrical - Conduit Installation Details
- E-04 System wide Electrical - Negative Connection to Rail
- E-05 Train to Wayside Communication - Installation Details

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District Department of Transportation

Chapter 7

Support Facilities, Yards, Shops, Administrative Buildings

Content

District Department of Transportation

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7.1 MAINTENANCE AND STORAGE FACILITIES

7.1.1 General

The DC Streetcar System includes a range of Maintenance and Storage Facilities (MSF), such as the Car Barn Training Center (CBTC) with full maintenance, and facilities with light maintenance of varying sizes - large, medium, small and micro. MSF will accommodate daily and routine inspections, maintenance, on-car repairs, and interior and exterior cleaning of the streetcars. Facilities will also serve as a storage and component change-out location. The location and design of these facilities should be closely coordinated with the State Historic Preservation Office (SHPO) early in the process. A pre-application meeting with the SHPO should be considered during the process.

Light maintenance facilities shall include minor component rebuild, truck overhaul and body repairs, vehicle parts painting, and off-vehicle wheel truing. Machine shop work and sheet metal work may be performed at another location, including potentially contracting with local shops with space and equipment to perform the work.

Dependent upon the location of the MSF and where practical, efforts shall be taken to design the building for mixed-use, or to allow for future vertical expansion to include other uses (parking, office, residential). MSF should be planned and designed to accommodate both the current vehicle fleet and potential future vehicles of different size, as may be available in the marketplace.

7.1.2 Applicable Codes and Standards

Design requirements for buildings, shop areas and yards shall comply with all federal and District 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. See Chapter 2 for additional information.

All new DDOT facilities over 10,000 square feet in area shall conform to the District Department of General Services (DGS) requirements. Refer to the DDOT "LEED Certification Guidebook" to assist making sound economic and environmental decisions for LEED projects. DDOT recommends that the designer work closely with the District Department of Consumer and Regulatory Affairs (DCRA) at the beginning of the MSF design process to address any potential design issues. The designer should request a Preliminary Design Review Meeting (PDRM). The PDRM affords the opportunity to provide an initial review of the building plans prior to filing. It is also recommended that pre-application meetings be scheduled with DC Department of Transportation, DC Water, and DC Department of Energy and Environment (DOEE). All new DDOT buildings, including any capital improvements within the property site limits, must comply with the 2010 ADA standards for Accessible Design, as well as with the Accessibility Codes of the ICC, whichever is more stringent.

7.1.3 Site Selection

The District Department of Transportation (DDOT) shall review MSF location alternatives provided by the Planning, Urban Design and Engineering Consultants, select appropriate sites, and if necessary, acquire property in accordance with the applicable Environmental Document. Facilities shall not negatively impact future development of adjacent areas. The location and design of MSF facilities should be closely coordinated with the SHPO early in the process.

7.1.4 Construction Materials

The exterior materials to be used on a facility should be selected based on durability, appearance and compliance with the requirements, codes and standards. The goal is to establish a facility that will provide not less than fifty years of low maintenance, while providing an appropriate appearance and fit into the District's plans for the local area, land use plans and urban design guidelines. Additionally, the development of the site shall be coordinated with other groups and agencies as required by DDOT or the project's Environmental Document.

The following Base Design Material Considerations shall be used for base planning and costing. Construction materials are subject to review and approval by the SHPO and CFA, as applicable.

Exterior Architectural Treatment – Materials such as brick, concrete block, pre-cast concrete and metal siding shall be used. Concrete wainscot panels, to 8-foot heights, are desirable and an advantage in terms of facility durability. They can also provide a more decorative outside appearance, avoiding the "warehouse" look. A veneer of brick or split face block may be desirable over the concrete.

Above the wainscot, steel siding placed over Z girts is acceptable to the facility operation. The standard metal building manufacturer's method of sandwiching insulation between siding and girts is not acceptable. An insulating vapor barrier and foam board with heavy 3 mil vinyl scrim is recommended. Flame-spread and smoke generation of the vinyl should be checked for conformance to local building code and fire marshal requirements. Siding may be any combination of decorative patterns.

Standing Seam Roofs (SSR) are practical in these applications. Roof materials may also be either a heavy gage corrugated steel or a built-up composite. Foam board insulation is again recommended.

Daylighting – Shop sky lighting is an advantage to daytime operation. Opacity factor must take into consideration solar gain in the District climate.

Concrete and Decking – General concrete should have a minimum concrete strength of 3000 psi (such as machine foundations and building footings).

The concrete on the main shop floor should be a minimum of 8” thick and 4000 psi. It is common to install new machinery, or add body hold down anchors at a future date. Generally, these devices require a minimum thickness of 8”.

A 4000-psi concrete strength may be used to minimize weight of concrete on steel columns. Typical thickness range is 4” to 6” above high point of rib of the Q-Deck. A 4” thickness is a practical minimum since moderately heavy loads may need to be rolled across the floor (for instance, rolling work stands for HVAC and Propulsion Inverter units, tool boxes). The HVAC, inverter, and other vehicle mounted equipment weights will be available. The designer must consider both point loads and distributed load (250/500 psf), whichever becomes worst case for the concrete design.

Interior Materials – Office areas should be metal stud and 5/8” gypsum-board construction. Floor and ceiling materials should be appropriate for the intended use. Sound insulation should be provided between adjacent office spaces.

Toilet and shower areas should have ceramic tile floor and wall finishes.

The central storeroom, adjacent offices and electrical room should be concrete block with a hollow core concrete plank roof, and a 2” concrete topping slab. Bar joists should not be used in this structure. The roof of this structure also provides a mezzanine for top-of-car access at approximately 10’-6” above grade. This height must be confirmed with DDOT. Use of the hollow core plank provides an interior ceiling height of approximately 9’6”, allowing for racks and shelving while maintaining space for lights and sprinklers. Roof should be rated at minimum 250 psf loading. Embedded load spreader plates will be used at locations where heavy point loads may be present.

Mezzanine Area Requirements

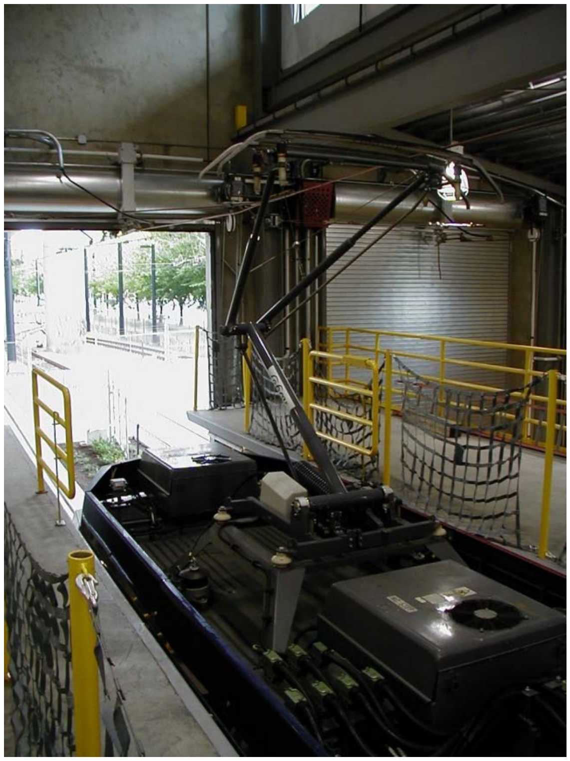
Technicians working in the streetcar workshop need the ability to remove, overhaul, and replace failed components on the cars. They must also make running adjustments on components, in place, on the cars. To accommodate these functions, the following features and requirements are necessary at the mezzanine:

OSHA compliant handrails and toe boards are required at all open sides of the platform. Handrail should be inset along the length of streetcar. Removable sections of handrail must be capable of accommodating different streetcar designs. At each end of car, fall gates must be designed to suit length and height of the cars being serviced.

The mezzanine surface should be concrete placed on formed pan (Q Deck, or similar). Surface should be a light broom finish. A white non-slip coating should be applied.

Mezzanine should be designed for a 250 psf floor loading; with point specific loadings in areas where work tables, work holding fixtures, storage cabinets and shelves are located.

Figure 7-1 | Mezzanine Access to Streetcar Roof



7.1.5 Structural

The following structural guidance shall be followed:

- The building shall be designed in accordance with the District of Columbia building codes and other codes and standards as referenced in Chapter 2.
- Soil bearing pressure shall be determined from the geotechnical report.
- The building structure shall be of concrete or steel fire resistant construction.

7.1.6 Facility Vehicle Interface

The facility designer should perform final functional layouts and define vehicle-facility interface based upon known information regarding the manufacturer and model of the streetcar vehicle. Where new vehicles are contemplated, or a mixed fleet may use the facility, interfaces shall be agreed with DDOT to accommodate the greatest number of car options. It will be up to the Design Build Contractor or designer to:

- Define height of mezzanine to suit height of car
- Define horizontal clearance between side of car and mezzanine

- Confirm width of pantograph carbon and OCS contact wire offset
- Verify locations of roof-mounted components and locations of gates and removable sections of handrail
- Design end of car fall gates. Fall gates must be interlocked with the OCS to prevent the car from exiting the building with the gate closed
- Provide an auxiliary power supply (”stinger”) for use when the OCS is off or pantograph is down. This device shall be located on the mezzanine, at a location suitable to the connection point on the car
- Verify location of car jack points so that local reinforcement of the floor can be made under the powered jacks
- Verify locations of doors on car to avoid any conflicts in building and structure
- Confirm weight of car for final structural design of track supports through the inspection pit
- Verify length of car and relationship to both pit and mezzanine
- Verify OCS location and bridge crane interlocking

7.1.7 Corrosion Control and Safety Grounding

Maintenance facilities shall have an equipotential grounding system for all conductive surfaces exposed to human contact, using a building perimeter ground. The perimeter ground shall be bonded to ground rods and to any metal structural elements of the building and reinforcement bars within the concrete. The reinforcing steel of the shop floor shall be bonded into a grid pattern and all shop conductive surfaces shall be bonded to the grid. Shop trackwork shall be continuous and bonded to the grid. The shop grid and perimeter ground shall be bonded to the shop substation ground mat. Insulated rail joints shall be provided at the ends of the concrete aprons, which define the extent of the shop grounding system and direct current (DC) electrical system.

DC stray currents are prevalent in the yard and shop area. Accordingly, ferrous pipe shall be coated with an electrical insulating material and tested prior to burial. The designer should evaluate use of plastic pipe for underground services (such as natural gas) where the code allows. Joints in piping will require bonding in some locations and insulated joints in others. Refer to Chapter 6 of the Design Criteria.

7.1.8 Acoustics

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

7.1.9 Maintenance

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

7.1.10 Mechanical Systems

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.

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.

Mechanical systems shall be designed to local codes and best practices used in the local area. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) guidelines shall be followed to establish HVAC loads for offices. The offices, dispatch room, break room, storeroom electrical rooms and the technical library room should be air conditioned.

Shop buildings should be heated to 65° F (18.33 °C) nominal, ±3° F, in the winter. This is a matter of employee comfort, workability of various car fluids, mechanical and electrical adjustments, and pliability of rubber parts (such things as changing window rubber seals become very difficult below 65° F, etc.). Strictly speaking, the shop does not require refrigerated air conditioning for any technical reasons involving the streetcar. At temperatures of 100° F employee comfort may suffer, but the streetcar is not a concern. OSHA does not have a standard regarding hot working environments. However, OSHA does state that it is the duty of the employer to protect workers from workplace hazards, which also includes heat-related hazards. OSHA recommends temperature control for commercial and industrial buildings in the range of 68°F to 76°F (20° C to 24.44° C). The designer shall explore the best options and life cycle costs with the owner before finalizing any cooling and ventilation methods for the shop building.

Other Utility Requirements:

A compressed air loop should encircle each shop, or sufficient size and capacity for the operation of the shop equipment and tools. All air drops shall come off the top of pipe. All compressed air pipes should be schedule 40, threaded joint, A-53 ERW. Planned air drops should be made on not less than every other building column. However, all threaded lengths of pipe shall be coupled, within maintenance pits and along mezzanines. Regularly placed tee connectors shall be included in the air loop, with the blanked off (plugged) left pointed vertically up. Maintenance pit and mezzanines require air drops on similar spacing.

Natural gas for shop and office heating should be A-53 ERW piping, all welded system except at the point of connection to the gas train at the appliance.

Potable water drops shall be located at each track door on the ground floor (total of six). Water drops shall have hose reel with 50 feet of ½" hose. Welding outlets shall be located on ground floor adjacent to car bays, at least two on each track end wall and two in center of facility (total of six)..

The architect will be given locations for all power, water and compressed air drops by the systems industrial engineer.

7.1.11 Access for People with Disabilities

All new facilities, including any capital improvements within the property site limits, must comply with the 2010 ADA standards for Accessible Design, as well as with the Accessibility Codes of the ICC, whichever is more stringent.

If any building or improvement on the property site under consideration is designated as historic under state or local law, or under the National Historic Preservation Act, then this building or improvement, or part thereof, shall comply with the ADA requirements to the maximum extent feasible.

If a portion of a building or site is altered or improved, then that portion must be brought into ADA compliance. For any alteration that affects or could affect the usability of or access to an area of a facility that contains a primary function then the design of that alteration shall ensure that, to the maximum extent feasible, the path of travel to the altered area and the facilities serving that altered area, are readily accessible to and usable by individuals with disabilities. The building shall be accessible to people with disabilities in compliance with the ADA.

7.1.12 Functional requirements

Any MSF shall house some or all of the following functions either in the building or on the facility's yard area, as directed by DDOT:

- Streetcar storage
- Train operator report area
- Operator and maintenance training
- Streetcar service and inspection
- Streetcar interior and exterior cleaning
- Streetcar air-conditioning, current collector and resistor unit repair
- Restrooms and Locker rooms
- Break rooms

- Fare collection (FC) equipment repair, storage and inspection
- Traction electrification system (TES) service and inspection
- Facilities maintenance
- System-wide parts storage
- Streetcar operations administration
- Streetcar maintenance administration
- Central Control
- Electronic component repair
- Communications equipment repair, storage and inspection
- Parking
- Storage of streetcar maintenance-of-way (MOW) materials
- Electrical substation for MSF and nearby catenary

7.1.13 Storage Yard

Sufficient storage tracks or space for storage tracks shall be provided to accommodate the ultimate fleet size to be stored and maintained at that facility. 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. Paved storage with embedded track or ballasted track shall be used.

Track centers shall typically be 14'-0" where no access aisle is required between tracks and 17'-0" where an access aisle is required. OCS and lighting poles shall be located between tracks with 14'-0" track centers.

The layout of storage yards 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. The location and design of storage yards should be coordinated directly and early with the SHPO.

7.1.14 Interior Cleaning Area

Cleaning of the interior of the streetcars should be accommodated within the shop on a flat (no pit) car positions or in a separate sheltered area. This track may also be used to perform daily and scheduled extraordinary interior cleaning of the streetcars.

7.1.15 Automobile Parking and On-site Roads

Automobile parking, including accessible parking spaces per code, shall be provided for visitors and employees that satisfies the codes and standards described in Chapter 2. Access for truck deliveries shall be provided. For any parking that is provided on the site, accessible parking spaces for people with disabilities will be established in proportion and in accordance to the standards set forth in the 2010 ADA Standards for Accessible Design.

Automobile parking should be minimized and should be balanced with current neighborhood availability and need. Employees should be encouraged to take public transportation (or modes other than the automobile) to and from work.

Adequate sheltered on-site bicycle parking shall be provided to accommodate and encourage bicycle ridership.

7.1.16 Outside Storage Areas

Outside storage space shall be provided, as necessary based on the purpose of the facility, for the storage of the following types of equipment and structures:

- OCS poles and large OCS hardware
- Lighting poles
- Running rail
- Ties
- Special trackwork (such as switches, switch stands, frogs, etc.) and other track materials (such as insulated joints, etc.) Locations of these types of storage areas are not generally critical and can be fit in, as the track layout is refined.

7.1.17 Fire Protection System

Fire protection utilities, such as hydrants, sprinklers in a 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.

7.1.18 Yard Lighting

Yards shall be illuminated to provide a safe working environment for 24-hour operation of the facility. The lights shall be as energy efficient as practically possible and shall be automatically controlled by a photoelectric cell. Yard lighting shall be provided to a level of 2 foot-candles average, 4:1 average to minimum and 9:1 maximum to minimum for the entire site. Lighting shall be shielded where practically possible so as not to spill on to neighboring properties. Lighting shall be shielded to meet Illuminating Engineering Society of North America (IESNA) certified cutoff or full-cutoff luminaries standard. Depending upon the location of the storage yard, the lighting and landscaping should be coordinated with SHPO.

7.1.19 Security

Operations facility security shall be achieved by walls and fencing at the periphery of the yard and by lighting. Walls should not be continuous but should be provided with visual openings (fencing and windows) to allow the operations of the facility to be viewed or shared with the surrounding neighborhood and visitors. Walls and fencing shall be provided, as needed, in accordance with Zoning and Historic District requirements. Gates shall be provided at all yard track and road accesses and shall provide for minimum interference to streetcar movement. Sliding (rolling) gates shall be used. Security lighting shall be placed as necessary to supplement the normal area outside work lighting. Lighting shall be shielded to meet Illuminating Engineering Society of North America (IESNA) certified cutoff or full-cutoff luminaries standard.

7.1.20 Refuse and Recycling Collection

Refuse and 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 shops and yard sites 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., and for disposal of industrial wastes.

7.1.21 Landscaping

Landscaping shall meet local zoning and green infrastructure requirements, as well as help to provide screening and buffering where needed, and to provide shade and cooling to the site and adjacent areas of public sidewalk. The amount and type shall be consistent with the local development requirements for the site, as directed by DDOT. Low maintenance ground cover material (gravel, mulch, etc.) may be provided on areas of the site not used for structures, track, access roads, walkways, curbside programs, services, or activities that are to be accessed by the public; however, the material shall not cause dust or other environmental hazard or nuisance by being in areas with heavy traffic. Areas receiving no traffic and not required for materials storage shall be landscaped.

7.1.22 Streetcar Shop Layout

The layout of a shop shall follow certain design guidelines relating to activities and functions in the yard or the facility; and shall take into consideration the following: the relative location of spaces to each other; areas of the spaces for the type of activity or function; utility requirements; special industrial equipment such as jacks and cranes; floor, pit and platform arrangement, etc. The potential variety of streetcar vehicles that may operate within these facilities should be considered during the planning and design phases. Guidance to be consider, as applicable, are as follows:

- Proximity to mainline and storage yard will minimize switching movements and accelerate emergency repairs
- A maximum of two linear car positions in the shop to preclude entrapment of a streetcar between others when maintenance and repairs are being performed
- Grouping related maintenance and servicing activities to simplify supervision and workflow, and to help minimize the floor space needed for circulation to and from the various interrelated spaces
- Proximity of support activities and proper industrial engineering shall be incorporated to maximize circulation efficiency. Buildings shall be accessible to the handicapped in compliance with ADA.
- Portable jacks shall be provided for lifting entire streetcar
- Bridge cranes shall be provided with adequate capacity to lift the heaviest streetcar component, an assembled motor truck. The bridge crane shall be so located as to allow removal and replacement of roof-mounted components and to allow a highway flatbed tractor-trailer to position itself under the crane for loading motor trucks and trailer trucks for shipment
- Turntables and transfer tracks shall be provided for exchange and movement of trucks
- Daily and routine maintenance pit(s) are to be provided and of a single-level design
- Services in the pit areas shall include; compressed air outlets at each support column, a 120 Vac duplex receptacle at each column, a welder receptacle, an emergency OCS shutdown, floor drains for pit wash down, exhaust ventilation, provisions for addition of grating at TOR level, approved railings or chains, stairway access, and provisions for vertical movement of tools and components between the shop floor level and the pit level, as well as platform level
- Eyewash provisions shall be provided in each maintenance pit
- Interlocks shall be provided to assure exclusive operation of the bridge crane or the OCS, but not both for each car position covered by the crane. Operation of the crane shall be allowed in a zone over the unit repair area
- Mezzanine platforms with gates shall be provided so that rooftop equipment can be serviced by maintenance personnel without requiring tie off and harness

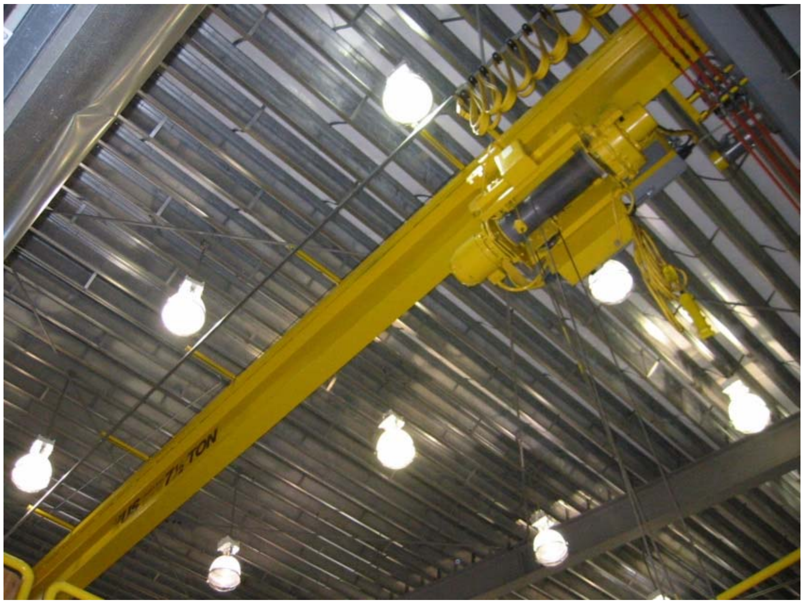
- An interlock on the gate system shall prevent cars from pulling out of the maintenance bay without the gates being secured open
- Services on the platforms shall include: compressed air outlets, 120 Vac receptacles, welder receptacle, approved railings and gates, under-platform lighting, exhaust ventilation system, and an emergency OCS shutdown
- Include a freight elevator if required
- An auxiliary power supply (APS) cord, plug and switch to safely provide streetcar auxiliary power to the cars when the shop OCS is not energized. APS provisions shall be provided at each rooftop access platform. APS shall be interlocked with the OCS to assure mutually exclusive operation
- Emergency shutdown pushbuttons for the OCS shall be located throughout the shop at convenient, well-traveled locations
- Suggested work areas are listed below:
    - Yard operations and central control
    - Training room
    - Janitor closet
    - Women's locker room and restroom with showers
    - Men's locker room and restroom with showers
    - Electrical room
    - Mechanical room
    - Lunch room and ready room
    - Conference room
    - Administration office
    - Shop substation
    - Telephone equipment room
    - Compressor room
    - Maintenance-of-way storage and repair areas
    - Foreman's office
    - Inspection pit
    - Rooftop level maintenance platform(s)
    - Spare parts storage
    - Fare collection equipment repair
    - Stairs, halls, lobby, and elevator
    - Exterior wash bay (manual wash of streetcar exterior)

Figure 7-2 | Wide Pit

7.1.23 Shop Functional Areas

Bridge cranes with adequate capacity to lift motor trucks shall be provided. Cranes shall be located to accommodate removal and replacement of major roof-mounted equipment. Cranes shall be interlocked with the OCS.

Figure 7-3 | Crane in Maintenance Facility



Areas shall be provided for secondary repair of streetcar heating, ventilating and air conditioning equipment and other minor equipment repairs.

Part of the storage area shall be designated for storage of pre-dried sand, purchased in plastic-lined bags.

A fire sprinkler system shall be provided throughout buildings in compliance with jurisdictional requirements. 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.

7.1.24 Support Areas for Shops

The following support facilities shall be provided:

- Locker room, shower, and restroom facilities for men and women
- Employee lunchroom, conference room and a training area
- Foreman's office, storeroom facilities, and general work areas. Loading and unloading of materials for the maintenance shop shall be accommodated by assuring the bridge crane spans a flat track in the shop
- Spare parts storage
- An interior inventory storage area for wheels, trucks and other large parts and component assemblies

7.1.25 Central Maintenance, Operations and Administrative Areas

Space shall be provided for the management of maintenance shops, operations facilities, and administration.

7.1.26 Exterior Streetcar Wash Facility

A car position exterior to a building shall be provided for washing the exterior of the streetcars. Infrastructure shall be provided to supply wash water and direct waste water to the sanitary sewer following recycling and pre-treatment, as described below. The wash bay shall be enclosed and heated as necessary to effectively function in sub-freezing climate conditions.

All wash and rinse water shall be collected, treated and then discharged in accordance with applicable codes, standards and laws. Rain and stormwater (on- or off-site) should be captured and stored for streetcar washing.

Equipment to recapture and treat wash water, including vehicle wash water recycling, and other fluids shall be provided. The recycling and reclamation system shall be capable of re-using 80 percent of the wash water. All wash water to be discharged shall be pre-treated to separate and remove oil products from the water and stored in a container system to be provided as part of the equipment.

7.1.27 Electrical Services

A separate substation shall be provided for each shop, with shop tracks electrically isolated from the yard and mainline tracks. Overhead wires in the yard and over individual shop car positions shall be sectionalized to allow the shutdown of power to each individual car position in the shop, and to each track 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.

Electrical system design guidance for yard and shop facilities are:

- The main electrical room shall be located on the ground floor. Service to this room shall start at an outdoor pad-mounted transformer where utility service voltage is dropped to 480v AC. Power to this facility is not expected to exceed 1500 amps at 480v.
- AC switchgear shall be located within an electrical room, to provide isolation disconnect from the transformer; isolation disconnect to the DC substation, and isolation disconnect to the facility power distribution system.
- All 3-phase, 60 Hz, 480Vac power to shop equipment should originate from a Motor Control Center located in the electrical room. All ground floor shop equipment must be fed through underground conduit.
- The DC power supply, including rectifier transformer, DC rectifier, and DC breakers and disconnects shall be installed in an electrical room, with suitable high and low voltage separations (the room may be divided by a sub-wall, if suitable to final equipment layout).
- Facility grounding is critical. Facilities shall be isolated from DC power of the mainline and DC power used in a storage yard, for safety reasons. Within a facility the DC system and the AC system shall be fully grounded. Bonding between rails, grounding of rails through the pit structure, and grounding of structures such as the mezzanine are critical. The local electrical engineer and the systems traction power engineer must collaborate on this design.

Electrical service design guidance for yard and shop facilities are:

- Electric motors 1 hp and up should be 3-phase, 60 Hz, 480Vac
- Motors fractional through ¾ hp may be single phase 115V or 240V. However, in some cases it may be advantageous to have motors ¾ hp, and under, on 480V, 3-phase. For example, the

trolley motor on the bridge crane may likely be ¾hp. The crane is 480V and the crane builder should keep all motors 3-phase, 60 Hz, 480Vac

- Welding Outlets: single phase, 60 Hz, 240Vac
- Machine Control Voltage: single phase, 60 Hz, 120Vac
- Lighting – Shop Areas: single phase, 60 Hz, 277Vac
- Lighting – Offices & Storeroom: single phase, 60 Hz, 120Vac
- Wall Heaters and Heating Strips: single phase, 60 Hz, 240Vac
- Convenience Outlets: single phase, 60 Hz, 120Vac
- An isolated/filtered computer 120V circuit(s) shall run in office areas and selected shop areas

Design guidance for lighting levels should adhere to the following limits, as measured in foot-candles:

Space Description	Minimum	Maximum	Preferred Lighting Type
Offices:	75	100	Fluorescent Strip
Mechanical Rooms:	50	75	Fluorescent Strip
Electrical Rooms:	50	75	Fluorescent Strip
Main Shop Floor:	75	100	Hi-Bay Metal Halide*
Above Mezzanine:	150	200	Metal Halide*
Below Mezzanine:	75	100	Fluorescent Strip
Pit Lighting:	50	100	Fluorescent Strip**

* Metal Halide Lighting should yield minimum Color Rendering Index of 90 and a Kelvin Temperature of 4200 or greater.

** Pit Lighting requires specialized fixtures designed to direct light upward, illuminating the bottom of the car.

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