WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

WMATA MANUAL OF DESIGN CRITERIA

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WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

Chief, Infrastructure Services

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PREFACE

The Chief Engineer is pleased to endorse this updated version of the Washington Metropolitan Area Transit Authority (WMATA), WMATA Manual of Design Criteria. This manual establishes the engineering design criteria for WMATA's Facilities and Systems.

Authorized:

Chief Engineer Infrastructure Services

R. Louis Viner, Jr. ______________________

RECOMMENDED FOR DEPUTY CHIEF ENGINEER APPROVAL			
Position	Name	Seal / Signature	Date
Deputy Chief Communication & Network Systems	Marshall S. Epler		
(Acting) Deputy Chief Power Systems Engineering	Moustapha Ouattara		
Deputy Chief Track Structures and Facilities	Thomas R. Robinson		

Deputy Chief Automatic Train Control	Eduard Popa		

Section	Description	Summary of Changes
1	Modification	A total restructure /rewrite of this section
2.3.13	Modification	Add fire protection service system for parking structure elevator
3	Modification	General: Section is rewritten and reformatted. Some new information added and old information deleted. Remove station graphics / signage discussion and reference Metro Rail System Signage Design Manual
3.1.1	Addition	Added regulatory requirements
3.1.2	Addition	Added security requirements
3.2.5.1	Addition	Added room grouping for reduced HVAC requirements
3.2.10	Modification	Reformat and reorder this section and all subsections
3.3	Modification	Reformat and update with additions and deletions
3.4.3.1.1	Modification	Reference Standard Drawings and delete shelter discussion
3.5	Addition	Add wayside facilities
3.2.9.1	Modification	Add two escalators between changes in elevation
3.2.20	Addition	Minimum size machine rooms
4	Modification	General: Section is rewritten and reformatted. Some new information added and old information deleted.

6.1.4	New Section	Add Bus Facility Maintainability and Constructability requirements
8.12.1.1	Deletion	Remove reference to UMTA metric conversion plan
8.12.2.1	Addition	Add Dulles Route
8.13.6	Addition	Add Communications and Cable TV
9.1.1	Modification	Update Policy
9.3.10	Addition	Add access easement definition
9.4.5	Modification	Updated Property Surveys in the District of Columbia sections
9.4.6	Modification	Updated Property Surveys in Maryland and Virginia sections
9.4.7	Modification	Updated Plat of Survey Requirements sections
9.5.5	Modification	Updated definition of lower limit
11.1.1	Addition	New section Minimum Criteria
11.2	Modification	Updated Survey Control sections
11.4	Modification / Addition	Updated and added new Horizontal Alignment sections
11.5	Modification / Addition	Updated and added new Curvature sections
11.6	Modification / Addition	Updated, rearranged and added new Superelevation sections
11.7	Modification	Updated Vertical Alignment section
11.8	Modification	Updated and added new Trackwork sections
11.10	Modification	Updated Contact Rail sections
11.11	Modification	Updated Clearances sections
12.1	Modification	Updated General section
12.4	Modification	Updated wetland mitigation section

12.5	Modification	Updated Flood Plains sections
12.6	Addition	Added Loudoun County Va.
12.8	Modification	Updated Tree Conservation & Sewers and Drainage sections
12.9	Addition	Added Stormwater Management requirement
12.11	Modification	Updated Water sections
12.13	Modification	Updated Elect subsections
12.14	Addition	Added Cable TV to Telephone
12.18	Addition	Added protective structure to Utilities Crossings of Metro section
12.19	Modification	Update Soil and Erosion and Sediment Control requirements
12.21	Modification	Update Design Criteria - General section
13	Summary	SECTION 13 of the Design Criteria was revised to address Auxiliary (AC) Power requirements. All references to Traction Power and SCADA related items were transferred to SECTION 23 and 28 of the Design Criteria respectively. SECTION 13 was also reorganized for better clarity and new areas added to address new technologies, new standards, and lesson learn from previous Contracts.
13.1	General	Revised section to add the need for design work to be safe, reliable, and energy efficient.
13.2	Responsibility	New section added to define responsibility.
13.3	Coordination	New section added to emphasize coordination between the various relevant disciplines.
13.4	General Illumination Levels	Replace all high pressure sodium lamps with metal halide.
13.6	Technical Specifications	New section added to clarify the relationship between specifications and the Design Criteria.

13.7	Design Drawings and Submission Requirements	New section added stating the requirements of submitted drawings.
13.8	CAD Standard	New section that references WMATA's CAD standard
13.9	Sequence of Electrical Drawings	New section added that states the design drawings sequencing.
13.10	Calculations	New section added requiring calculations in support of submitted design drawings.
13.13.3	Remote Monitoring	New section added
13.14.2.4.6	Breaker Operation	Corrected "LPC" to "PLC"
13.14.2.5	Digital Power Metering System	Revised to show digital power metering on the medium voltage switchgear as oppose to the low voltage switchgear.
13.14.2.6	Quick Connect System	Section was revised to reflect operations changes. Generator was changed from 100kW to 500kW and corresponding breaker was changed from 100A to 800A.
13.15.4	LED	New table added to incorporate LED lights
13.15.14	Load Classification	Section was revised to reflect operations changes. Generator was changed from 100kW to 500kW and corresponding breaker was changed from 100A to 800A.
13.15.19	Emergency Power System	Removed the provision for 50kVA UPS and added provisions for the use of 75kVA and 100kVA UPSs.
13.15.22.1	Material and Insulation	Revised section to clarify the acceptable use of low-smoke cables.
13.17.6.2	Interior Lighting	Revised section to add LEDs
13.18	Electric	New section added to address commercial/office building requirements.
14.2.4	Update	Plumbing design based on International Plumbing Code

14.3.1.1	Modification	Mods to subway tunnel ventilation system analysis
14.3.6.3	Modification	New tunnel fans to meet current version of NFPA 130
14.3.7	Modification	Mod to friction loss formula
14.3.8	Modification	Change location of air compressor and treat compressed air
14.3.12.6	Modification	Damper control
14.3.16	Update	Add SCADA requirement
14.4.1	Modification	Added room grouping for reduced HVAC requirements
14.4.2.1	Addition	Add PLC for fan control and add ventilation requirements
14.4.2.3	Modification	Battery Room ventilation based on concentration not room size
14.4.2.4	Modification	Heat loads based on equipment within room.
14.4.2.8	Modification	Add PLC for fan control and add ventilation requirements
14.4.2.9	Modification	Add PLC for fan control and add ventilation requirements
14.4.4	Delete	Remove and renumber remaining sections
14.5	Update	Heating requirements updated. Added room grouping for reduced HVAC requirements
14.6.7	Update	Specify chiller plant space requirements, room sizes, equipment and equipment clearance
14.6.7.3.1	New Section	Water meter remote monitoring
14.6.7.4 14.6.7.5 14.6.7.6	Delete	Remove and renumber remaining sections
14.6.13	Delete	Remove and renumber remaining sections
14.8.2	Update	Escalator and Elevator sump remote monitoring

14.8.6	Update	Provide velocity formula
14.8.9	Update	Update wet well and dry well requirements for pumping stations
14.11	Update	Escalators: update code requirements, number of escalators, class rise, class steps, clearance, controls, working temperature and pit access.
14.13	Update	Fire Protection standpipe system
14.14.7	Update	Sewage ejector system pumping / pneumatic
14.17	Update	Elevators:
14.18	Modification	Add access requirements
14.18.1	Modification	Add access requirements
14.18.2.1	Delete	Remove and renumber remaining sections
14.18.2.3	Addition	Add access requirements
14.18.2.5	Modification	Add clearance criteria
14.18.2.6	Modification	Add clearance criteria
14.18.2.7	Delete	Remove and renumber remaining sections
14.18.2.10	New Section	Add roof access requirements for mechanical equipment
14.20	Addition	Added Legacy DTS Control Functions
15.1, 15.2.1.1, 15.2.1.2, 15.2.1.7, 15.2.1.11, 15.2.2,15.2.2.1, 15.2.2.2, 15.3.2.7.1, 15.4, 15.20.2.4, 15.20.2.5,	Editorial Corrections	
15.1.4	New Section	To specify and be specific of WMATA requirement
15.2.1.3	IBC	To include local amendments

15.2.1.4.2	Addition	To specify and be specific of WMATA requirement
15.2.2.4	Addition	To specify and be specific of WMATA requirement
15.3.2.6.2	Modification	Revised and added for clarity
15.3.2.13	New Section	Added a minimum roof live load requirement
15.3.2.14	New Section	Specified the basic wind speed for consistency in the Design Criteria
15.3.7.1	Modification	To make a mandatory requirement and to clarify the application of loads
15.3.7.4	Addition	To specify and be specific of WMATA requirement
15.3.7.6	New Section	To specify and be specific of WMATA requirement
15.4.2.4.1	Modification	Revised and added to clarify
15.4.2.4.1.1	Modification	New/ Retaining wall shear key and waterproofing
15.4.2.4.2.4	Modification	Revised/ Retaining wall allowable soil pressure and settlement
15.5.1.1.2	Modification	Added to clarify
15.5.1.2.2.1	Modification	To correct the reference
15.5.1.2.3.1.1.1.1	Modification	Added to clarify
15.5.1.2.3.1.1.3	Delete	
15.5.1.2.7	Modification	Revised the wind velocity to 3-Second Gust equivalent basic wind speed
15.5.1.2.7.1.2	Modification	Revised/ Aerial structure transverse wind load
15.5.1.2.7.3	New Section	To specify the lower limit on the results of wind tunnel testing
15.5.1.2.9.1.1.5	New Section	3" max. allowable rail break

15.5.1.2.9.1.2.2	Modification	Clarification
15.5.1.2.9.1.2.3	Modification	Clarification
15.5.1.3.1	Modification	Revision for improving performance
15.5.1.4.1.3	New Section	Track box girder access
15.5.1.4.5.1.3	New Section	Concrete Rail Plinths
15.5.1.4.5.2	New Section	Track box girder access
15.5.1.4.7.3	Modification	Added to clarify
15.5.1.5.1	Delete	
15.5.1.5.4.1	Modification	Revision for improving performance
15.5.1.5.4.3	Modification	Revision for improving performance
15.5.1.7.3.2.3.3	New Section	Cassion foundation
15.5.1.7.3.3	New Section	Rammed aggregate pier foundation
15.5.1.8.6	New Section	Aerial structural bearing anchor bolt
15.5.1.8.7	New Section	Aerial structural bearing pad
15.5.1.9.1.4	Modification	Revision for improving performance
15.8.1.3.5	New Section	Structural steel design
15.9.3.3.2	New Section	Concrete Design
15.9.3.3.3	New Section	Concrete Design
15.9.3.3.1.2.1	Modification	Correct reference
15.9.3.3.1.2.3	Modification	Revision for improving performance
15.9.3.3.1.2.4	New Section	Allowable tensile stress
15.9.3.3.1.3.3	Delete	
15.18.1.3	New Section	Underground station wind load

15.20.1	Modification	To make a mandatory requirement and to clarify the application of locations
15.20.2.1	Modification	Underground facilities waterproofing
15.20.3	New Section	To specify and be specific of WMATA requirement
15.20.3.1	New Section	To specify and be specific of WMATA requirement
15.20.3.2	New Section	To specify and be specific of WMATA requirement
15.21.1.1.1.1	Modification	Revision for improving performance
15.21.1.1.2	Modification	Revision for improving performance
15.21.1.1.6.1	Modification	Adjusted for consistency
15.21.1.1.7.1	Modification	Added to clarify
15.21.1.1.7.2	Modification	Added to clarify
15.21.1.2.2	Modification	Revision
15.21.5.1	Modification	Revision for improving the performance
15.21.13	Delete	
15.21.16	New Section	Double Tees expansion joint
15.21.17	Modification	For clarification
16	Modification	All paragraphs except 16.1 have been renumbered and updated to reflect current criteria.
17.3	Modification	Address clearance issues for stub end storage tracks and bumping posts

23	General	Added negative rail potential limits Defined voltage drops for normal, abnormal, and emergency outage conditions Rail car data revised with addition of new rail car performance curve for simulation Clarified DC Switchgear insulation pad Removed cross-bonding at TBS coverage Removed 40w/lf rating of heat tape Added new section for Service and Inspection Yards
25.1.4.1.2	Modification	Train Control System functions DTS update
25.1.4.1.4.1	Modification	RTU Connection update
25.1.4.1.4.2.1	Modification	Communications System connection update. Delete
25.1.4.1.4.2.2	Delete	
25.1.4.1.4.3	Delete	Ancillary Facilities
25.1.4.1.4.5	Delete	DTS Junction Box Wiring Diagrams Section
25.1.4.4.2 25.1.4.4.2.1 25.1.4.4.2.2 25.1.4.4.2.3	Delete	Drawing Editor Systems Sections
25.1.4.5, 25.1.4.5.1, 25.1.4.5.2	Delete	TC Maintenance Telephone System Sections
25.1.5.3	Delete	Inclement Weather Operation
25.1.5.8	New	Added description for ATAWS
25.1.7	Delete	ATC Systems Integration
25.2.2.1.3.3	New	Added title for section “Special Trackwork Speed Command Transmission”

25.2.2.4 25.2.2.4.1 25.2.2.4.2 25.2.2.4.3 25.2.2.5 25.2.2.6 25.2.2.7 25.2.2.8 25.2.2.9 25.2.2.10 25.2.2.11	New	Added section entitled “Rail Operations Control Center (OCC) Overview” and subsections
25.5.2	Delete	Table II, Table IV and Table V
26.2.1	Modification	Update video interface
26.2.2.1.4	Modification	Update to reflect current use
26.2.3.3	Modification	Update to reflect current use
27	General	Reduce and renumber the section paragraphs
27.1.1	Modification	Revised note at end of section
27.1.3	Modification	Revised emergency panelboard
27.1.6	Deletion	Removed security provisions section
27.2.3	Modification	Updated Major System Components section
27.2.8	Modification	Added note to Intercoms section
27.3	New	Added Call-For-Aid System section
27.4	Modification	Updated the Information Display Systems sections
27.5	Modification	Updated the Fire Detection and Alarm System sections
27.6	Modification	Updated Access Control System sections
27.7	Modification	Updated Intrusion Detection and Alarm System sections
27.8	Modification	Updated Video Surveillance System sections
27.9	Modification	Updated Land Mobile Radio System sections

27.10	Modification	Undated Kiosk System sections
27.11	New	Added CNG Detection sections
27.12	Modification	Updated Operations Control Center Communications sections
28	SCADA	Added new section to address Supervisory Control and Data Acquisition (SCADA). SCADA systems provide control and monitoring of the electrical and mechanical equipment and systems serving the mission critical loads.

SECTION 1 - GENERAL

SECTION 2 - SITE DESIGN

SECTION 13 ELECTRICAL

SECTION 1 - GENERAL

1.1 PURPOSE

1.1.1 The primary function of this Manual is to establish criteria to be used in the design of the Washington Metropolitan Area Transit Authority's Facilities.

1.1.2 In order to protect WMATA's investment of public funds in Architectural Design and its legacy, any proposed work that is viewable by the public must be internally coordinated per the "Coordination" topic in this section.

1.2 SCOPE

1.2.1 The Design Criteria is derived from many sources, including organizational goals, Board resolutions, internal initiatives, and technical and regulatory requirements. Changes to the Design Criteria will be authorized in accordance with established internal procedures.

1.2.2 This version of the Design Criteria supersedes all the previously issued Design Criteria and all other standards, and relate to the following elements of design:

1.2.2.1 Architecture

1.2.2.2 Automatic Fare Collection

1.2.2.3 Automatic Train Control

1.2.2.4 Civil Engineering

1.2.2.5 Communications

1.2.2.6 Electrical Engineering

1.2.2.7 Elevators & Escalators

1.2.2.8 Environmental

1.2.2.9 Landscaping

1.2.2.10 Mechanical Engineering

1.2.2.11 Safety / Security

1.2.2.12 Structural

1.2.2.13 Track

1.2.2.14 Traction Power

1.2.2.15 Utilities

1.3 DESIGN REQUIREMENTS

1.3.1 In designing WMATA Facilities, the designer shall consider the following factors:

1.3.1.1 Maximum levels of perceived and actual safety for the public (passengers and non-passengers) and WMATA employees.

1.3.1.2 Maximum levels of service availability and reliability for passengers.

1.3.1.3 Maximum efficiency and sustainability in operation and maintenance.

1.3.1.4 High quality aesthetics and appearance as conveyed to and perceived by the public (passengers and non-passengers).

1.3.2 Regulatory:

1.3.3.1 In all cases, design(s) and proposed work shall comply with local, state and federal law.

1.3.3.2 The Designer shall meet or exceed the Authority's Standards and Design Criteria relevant for each element of the work, as these represent the minimum standards to be used for design and construction.

1.3.3.3 WMATA facility designs shall comply with:

1.3.2.3.1 National Highway Standards, Manual of Uniform Traffic Control Devices and other applicable traffic regulatory agencies' standards

1.3.2.3.2 Private and public utility companies and agencies' published standards; organizational reference standards and specifications including, but not limited to, the National Fire Protection Association (NFPA) Requirements

1.3.2.3.3 Current jurisdictional authorities' regulations, federal, state and local building, mechanical and electrical codes

1.3.2.3.4 All WMATA facilities must meet the ADA Standards for Transit Facilities and the ADA Standards for Accessible Design, and are subject to FTA assessment as actually built with regard to ADA regulations. The Designer shall secure the latest version of these regulations from the FTA

1.3.2.3.5 The ADA Design Compliance Certification Form attached at the end of standard WMATA specification section DESIGN REQUIREMENTS AND PROGRAM CRITERIA addresses design conformance with ADA regulations for relevant items reflected in each required level of design completion, and shall be certified by the Designer and accompany each design review submittal as specified in DESIGN AND CONSTRUCTION SUBMITTAL

PROCEDURES of the WMATA Standard Specifications

1.3.2.3.6 The ADA Facilities Accessibility Checklist Form attached at the end of DESIGN AND CONSTRUCTION SUBMITTAL PROCEDURES of the WMATA Standard Specifications shall also be completed concurrent with the design of relevant items and shall be submitted along with each required level of design completion review submittal as specified in DESIGN REQUIREMENTS AND PROGRAM CRITERIA

1.3.3 Sustainability:

1.3.3.1 All new WMATA facilities and substantially rehabilitated WMATA facilities (typically more than 50% of building value) shall be designed and constructed and commissioned using current best practices in cost effective sustainable design, pursuing target goals in WMATA's Sustainability Agenda.

1.3.3.1.1 Optimize energy performance over the facility lifetime

1.3.3.1.2 Reduce water and waste

1.3.3.1.3 Evaluate design alternative solutions. Include rationale for recommending the chosen alternative and costs over the life-cycle of the final project. Life-cycle cost alternatives should include a calculation of savings from a net-zero design.

1.3.3.1.4 Include monitoring, metering and management systems in utilities

1.3.3.1.5 Facilities shall be "solar ready"

1.3.3.1.6 Parking facilities shall be "electric vehicle ready" for 10 high speed chargers, minimum

1.3.3.1.7 Support and maximize ridership and access to alternate transportation including pedestrian, bicycle, transit and car sharing

1.3.3.2 **LEED:** All new facilities and substantially rehabilitated facilities shall be designed, constructed and commissioned with the minimum goal of achieving United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) Silver Certification.

1.3.3.3 Under Joint Development projects, developers are required to achieve at least the Silver level of either LEED for New Construction (LEED-NC) or LEED for Core and Shell (LEED-C+S), or their equivalent under a different rating system acceptable to WMATA. If the Joint Development project contains more than two buildings and consistency with the requirements of applicable local land use law allows it, a project is required to obtain a minimum standard of LEED for Neighborhood Development (LEED-ND) Silver, or equivalent under a different rating system acceptable to WMATA, for the Joint Development Site.

1.3.4 Renovation and Operations & Maintenance Projects:

1.3.4.1 Renovation and modification of all WMATA facilities, structures and systems are subject to these design criteria, whether the work is performed by WMATA personnel or by contractors.

1.3.4.2 The intent of renovation projects are to maintain and improve the existing structures and systems.

1.3.4.3 New work should not diminish the current aesthetics, capacity or safety of the existing structures and systems. Where possible, improvements are desired.

1.3.5 Durability:

1.3.5.1 It is the intent of the Authority that WMATA structures provide a minimum design life of 100 years. Exception: WMATA parking structures should provide a minimum design life of 50 years.

1.3.6 Maintainability and Reliability

1.3.6.1 Maintainability is determined by the characteristics of WMATA structures, finishes, fixtures and installed equipment which makes it possible to operate a safe and efficient system with the most economical expenditure of maintenance resources.

1.3.6.2 Resources include manpower, utilities, equipment, materials and support facilities. Emphasis shall be applied to those maintainability considerations which determine the frequency, rapidity and ease of maintenance operations or which affect utility consumption.

1.3.6.3 Maintenance operations consist of inspection, adjustment, cleaning, servicing, testing, monitoring, repair and replacement. Attention shall be given to providing remote asset control and monitoring, as well as accessibility for performance of maintenance and replacement and storage of consumables, (service hatches, stairs, ladders, lifting equipment, catwalks, structural openings, space and layout, fixture/equipment locations, etc.). Full consideration shall be given to economic factors, e.g., life cycle costs, in determining the extent to which maintainability is incorporated.

1.3.6.4 Where the principles of operational efficiency and reliability are in conflict with criteria in this Manual or any project documents, such conflicts, with recommended action, shall be brought to the attention of the Authority.

1.3.7 Coordination:

1.3.7.1 Any work, whether for new facilities or temporary or permanent modifications to existing facilities, which impacts the health, safety or welfare of the public or WMATA employees, must be submitted for review by WMATA Manager of Architecture.

1.3.7.2 Any temporary or permanent modification which will impact the appearance of a facility or a structure, and is located in public space or is otherwise viewable by the public, maybe subject to review by the U.S. Commission of Fine Arts, National Capitol Planning Commission, National Park Service, State Historic Preservation Offices, and/or various other local and federal entities. As such, it must be reviewed by the WMATA Manager of Architecture.

1.3.7.3 Enhancement or modification to lighting must be coordinated through WMATA Architecture Department, WMATA Electrical Department and the qualified professional lighting design consultant.

1.3.7.4 Coordination with other WMATA design disciplines, and other WMATA departments such as PLNT, Systems Maintenance, Safety and Metro Transit Police, is mandatory.

1.3.7.5 Design Documents: This manual is part of a set of documents known as the WMATA Standards and Criteria which consists of the following documents:

1.3.7.5.1 WMATA Manual of Design Criteria (this manual)

1.3.7.5.2 WMATA Standard Specifications

1.3.7.5.3 WMATA Standard Drawings

1.3.7.5.4 WMATA Directive Drawings

1.3.7.6 Information Documents:

1.3.7.6.1 WMATA Sustainability Agenda

1.3.7.6.2 WMATA Station Site and Access Planning Manual

1.3.7.6.3 WMATA Metrorail System Signage Design Manual

1.3.7.6.4 WMATA Tram/LRT Guideline Design Criteria

1.3.7.6.5 WMATA Adjacent Construction Project Manual

1.3.7.6.6 WMATA Safety & Security Certification Program Plan

1.3.7.6.7 WMATA Systems Safety Program Plan

1.3.7.6.8 WMATA Workplace Strategy

1.3.7.6.9 WMATA CAD Manual

1.3.8 Architectural Design

1.3.8.1 Harry Weese's award-winning original station architecture, with its distinctive, elegant and spacious underground stations, has established a standard for architectural design excellence. Above ground stations, while not as dramatic, are designed with just as much attention given to aesthetics, durability, functionality, and quality. This tradition of architectural design has made the system one of the most beautiful, and its stations considered by many to be "exemplary works of Modern Design."

1.3.8.2 The Washington, D.C., Metro rail transit system was selected for the 2014 AIA Twenty-five Year Award, praised for giving "…monumental civic space to the humble task of public transit…"and for having "…revolutionized public perceptions of mass transit in the mid-to-late 20th century. They (the original stations) are quintessentially modern while maintaining a certain grandeur befitting the nation's capital. The original Metro stations have become icons of Washington architecture, and the entire system…remains a point of pride for Washingtonians."

1.3.8.3 While not necessarily duplicating past designs, new station designs shall build upon the tradition of superior architectural design and continue to reinforce a unique Metro image that unifies the system as a whole. New station designs shall have the common range of materials and follow the design principles established by Harry Weese and as outlined in the following criteria.

1.3.8.4 In addition to station design, WMATA has a history of, and an expectation for, architectural design excellence for all its facilities, both public and non-public. Other public WMATA structures can include, but are not limited to, parking structures, pedestrian bridges, customer service facilities, aerial guideways, abutments, retaining walls, tunnel portals, bicycle storage facilities and office buildings. Non-public facilities can include, but are not limited to, industrial facilities (such as rail yard and bus maintenance shop buildings), administrative yard buildings, ancillary rail buildings and traction power substations.

1.3.8.5 WMATA's expectation of final design: the completed work shall be visually attractive, innovative, as well as functional, durable and sustainable. The overall architecture should impart a sense of pride within the local community, and provide a stimulating and attractive environment for the people who will see, work in, and use the new work on a daily basis.

1.3.8.6 Material & Color Palette

1.3.8.6.1 Historic WMATA stations are consistently designed around a set of materials, listed below:

1.3.8.6.1.1 Raw concrete: coffered vaults, walls passageways, etc.

1.3.8.6.1.2 Board-formed concrete: station end walls, other vertical surfaces

1.3.8.6.1.3 Dark polished bronze: handrails, outlets & fittings, exterior station pylon, escalator cladding

1.3.8.6.1.4 Porcelain enamel metal panel: kiosk, signage pylons, etc.

1.3.8.6.1.5 Unglazed quarry tile: hexagonal, typical size 8" nominal across flats, reddish brick color, "flashed"

1.3.8.6.1.6 Brown color: Federal Specification 595C, color number 20040

1.3.8.6.1.7 Metal ceiling panels: 30"x30" grid, or rectangular independent panels; warm white color

1.3.8.6.2 Modern Palette for new WMATA Rail Stations (in addition to the "historic" palette)

1.3.8.6.2.1 Stainless steel railings, escalator cladding, platform and mezzanine equipment cabinets, platform shelters, mesh and wire fabric enclosure

1.3.8.6.2.2 Low-E clear vision glazing at vertical applications

1.3.8.6.2.3 Fritted or tinted laminated heat-strengthened glass at roof or horizontal applications without screening

1.3.8.6.2.4 Warm light gray for exposed and clad metal structures

1.3.8.6.2.5 Precast concrete pavers for exterior station platforms

1.3.8.6.2.6 Porcelain tile for exterior station mezzanines and passageways

1.3.9 Design Requirements for All WMATA Facilities

1.3.9.1 Where public elevators are provided, a minimum of two elevators in close proximity or adjacent are required, for operational redundancy.

1.3.9.2 All walking surfaces intended for public use shall be slip-resistant and heel-proof.

1.3.9.3 WMATA requires all low-slope roofs to be white EPDM, provided in the manufacturer's highest available thickness.

1.3.9.4 Due to maintenance considerations, limit use of tamper proof screws and keyed equipment to locations where this manual deems they are necessary.

1.3.9.5 Exterior facilities and structures must be carefully examined for bird and pest proofing measures required to protect the public and reduce maintenance.

1.3.9.6 All occupied WMATA facilities shall be fully sprinklered. Storage and equipment rooms and/or facilities may have alternate fire suppression systems as specified by WMATA.

1.3.9.7 Glazing size shall be limited to four feet by eight feet, maximum.

1.3.9.8 Roof Design Criteria:

1.3.9.8.1 The Authority requires white EPDM membrane roofing on new facilities; exceptions for alternates can be granted by WMATA Manager of Architecture.

1.3.9.8.2 Membrane systems for new facilities shall either be protected by a paver and pedestal system, approved green roof system, or shall be fully adhered.

1.3.9.8.3 For reroofing, membrane roofing is preferred for replacing most flat roofing types, including BUR; standing seam metal may be replaced in kind or with a membrane with applied batten strips provided by the manufacturer to simulate standing seams.

1.3.9.8.4 Membrane roofing must be able to withstand all applicable wind loads and resist UV exposure, thermal forces, and chemical and biological contaminant exposure.

1.3.9.8.5 The selected membrane system shall be of the maximum thickness provided by the manufacturer.

1.3.9.8.6 Membranes must be recyclable, and may contain recyclable content if appropriate.

1.3.9.8.7 Prefabricated flashings, boots, walking surfaces and other accessories must be obtained from or certified as compatible by the membrane manufacturer.

1.3.9.8.8 Albedo and SRI ratings must meet or exceed "cool roof" Energy Star / DOE criteria.

1.3.9.8.9 Life cycle cost analysis shall be provided by manufacturer to WMATA to support selection of membrane system.

1.4 PROCEDURES

1.4.1 The Designer shall meet or exceed the Authority's Design Criteria and Standards relevant for each element of the work, as these represent the minimum standards to be used for design and construction.

1.4.2 WMATA's Safety and Security Certification Program Plan (SSCP) will be followed when new Metrorail extensions are added, and/or new Metrorail and Metrobus facilities are incorporated into the inventory.

1.4.3 If any of the laws, codes, regulations and standards that also control the design and construction of the Project exceed the Authority requirements, then the more stringent shall govern. Deviations may be made to meet the requirements of a particular design problem; however, all deviations shall be referred to WMATA for consideration and approval. It must be emphasized that it is the responsibility of the Designer to justify any deviation from the Design Criteria established and to secure the necessary jurisdictional approvals as the work progresses.

1.5 GLOSSARY

1.5.1 Washington Metropolitan Area Transit Authority: An interstate compact created by Public Law 89-774, 80 Stat. 1324, Nov. 6, 1966, having the responsibility for constructing a rapid rail transit system to serve the National Capital Region. Hereinafter, the Washington Metropolitan Area Transit Authority is referred to as WMATA, or the Authority and recently as Metro.

END OF SECTION 1

SECTION 2 - SITE DESIGN

2.1 GENERAL

2.1.1 This section works in conjunction with WMATA's 'Station Site and Access Planning Manual' (SSAPM) which can be accessed using the following WMATA internal internet link: http://tsdv/ENGA/2005/PDF/SSAPMMay08.pdf.

2.1.2 The information presented below is not covered in the 'Station Site and Access Planning Manual'

2.2 SITE ELEMENTS

2.2.1 Landscape

2.2.1.1 Plants: To the greatest extent possible, use native, low-maintenance, drought resistant plant species at all WMATA sites.

2.2.1.1.1 Ground Cover

2.2.1.1.2 Trees and shurbs: Avoid the use of deciduous species within sidewalks and paved plazas.

2.2.1.1.3 Watering System(s)

2.2.1.2 Earthworks

2.2.2 Hardscape

2.2.2.1 Sidewalks and Plazas

2.2.2.2 Bicycle Paths

2.2.2.3 Roads and Parking

2.2.2.4 Fencing and Barriers

2.2.2.5 Structures

2.2.2.5.1 Shelters and Seating

2.2.2.5.2 Bicycle Storage

2.2.2.6 Other Elements

2.2.2.6.1 Trash Receptacles

2.3 SITE FACILITIES

2.3.1 SITE HIGH OCCUPANCY VEHICLES (HOV)

The High Occupancy Vehicle function is designated at specific stations with access to major traffic arteries or limited access highways. It consists of commuter bus/van pool spaces, and may be used to accommodate oversized vehicles such as RV.s. and campers.

- Drop-off lane (10' wide) for A.M. curbside drop-off.
- Storage bays: 12' x 40' for all day bus parking.
- Provide re-circulation path from storage bays to drop-off areas for P.M. curb side pickups.

2.3.2 PARK & RIDE SURFACE LOTS

2.3.2.1 Site Park & Ride Surface Lot Vehicular Circulation:

2.3.2.1.1 Provide an efficient, clearly defined and safe circulation system, with an emphasis on minimizing pedestrian/vehicular conflicts. Internal parking lot circulation shall encourage use of the entire lot, with a minimum of dead end parking areas. Park & Ride facilities shall be designed with 90º angle parking with two-way circulation. Parking may be designated adjacent to the cross aisles, except where provision of parking will interfere with pedestrian flow between the station entrance and the Park & Ride facility.

2.3.2.1.2 Limit the parking lots to areas no larger than 500 cars and orient driving aisles toward the station entrance.

2.3.2.2 Park & Ride Surface Lot Payment System:

2.3.2.2.1 The preferred payment system is a pay-on-exit system employing entrance and exit gates at each point of entry and exit. Gates may allow entry only, entry and exit, or exit only, depending on the parking structure design. The number of gates required is calculated as follows:

2.3.2.2.1.1 Minimum gate array for 2-way flow through a single access point is a 2-gate aisle for up to 400 parking stalls (entry and exit with middle gate reversible).

2.3.2.2.1.2 For facilities with more than 400 stalls, provide a minimum of 3-gate aisles, 1-gate aisle for reach 250 vehicles projected to peak one-hour period (assuming pay-on-exit). If the garage is designed to be a pay on-entry facility, provide a 2-gate aisle plus 1-gate aisle for each 250 vehicles projected to enter the facility during the AM peak hour. Where more than a 2-gate array is required, sufficient lane distance on either side of the gates shall be provided for traffic to merge and change lanes safely.

2.3.2.3 Park & Ride Surface Lot Landscaping:

2.3.2.3.1 Design landscaping of parking facilities to conform to local jurisdictional requirements and coordinated with WMATA design criteria.

2.3.2.3.2 In accordance with WMATA Board of Directors Resolution 1972-27 adopted November 16, 1972, Metro parking areas (for more than five vehicles) shall be effectively screened from surrounding development (on each side which adjoins or faces a residential zone or institutional premises) unless already effectively screened by a natural terrain feature, a railroad track on elevated ground, change in grade or other permanent natural or artificial screen, or (is separated therefrom by) a road whose width of right-of-way is 120 feet or more.

2.3.2.3.3 Parking lots (containing 500 or more parking spaces) shall be divided into parking areas of not more than 500 cars each and shall be separated by landscaping, changes of grades, buildings or other natural or artificial means. Not less than five percent of the total parking areas of any lot shall be devoted to (such) internal landscaping and interior parking separation areas.

2.3.2.3.4 Therefore, provide major landscape buffers of 50 feet minimum width between separate parking areas (with allowance for circulation between areas). See Resolution of the WMATA Board of Directors, November 16, 1972 (72-27).

2.3.2.3.5 Provide landscaping equal to 5% of the parking lot. 10-ft. wide landscape areas, located every second parking bay and bordered each side by concrete mowing strips, will satisfy this requirement. Use landscape strips to make grade adjustments in the site.

2.3.2.4 Park & Ride Surface Lot Pedestrian Circulation:

2.3.2.4.1 Accommodation of pedestrian movement within and adjacent to the parking lot shall be considered an essential part of the facility's design. Pedestrian route of travel shall be direct, well lit and clearly defined. Pedestrian safety and security shall be given highest priority. The Park & Ride lot shall be laid out according to pedestrian direction of travel, which is assumed to be parallel to car traffic in the driving aisles. In the absence of sidewalks, pedestrians shall be required to walk in the driving aisles.

2.3.2.4.2 Collector sidewalks leading to the station shall be located perpendicular to the driving aisles and sized to accommodate the areas they serve.

2.3.2.4.3 Landscaped areas shall not be used by pedestrians as part of their travel path. Landscaped areas adjacent to above ground stations shall not have gravel as a surface material.

2.3.2.4.4 Accessible spaces required by ADA shall be located in the parking lot as near the station entrance as possible and adjacent to a sidewalk. Where site stairs are required, they shall be located outside the accessible route. Stairs shall be the same width as the walkway, with 12" treads, 6" closed risers, a rounded tread nosing, and continuous handrails on both sides.

2.3.3 PARKING STRUCTURES

2.3.3.1 Parking Structure Design:

2.3.3.9.1 Parking structure design shall be user-friendly, secure, efficient, convenient to use, and designed for minimum maintenance. Interior parking circulation shall be clearly defined with minimum visual obstructions and without dead-end parking areas. Design facility for self-park operation with pay-on-exit revenue control system.

2.3.3.2 Parking Structure Access Roads and Entrance:

2.3.3.2.1 Coordinate with State and local authorities in providing dedicated routes from adjacent municipal roads.

2.3.3.2.2 Access drives and revenue access lanes shall be striped with painted lane lines and marked with traffic control signs, signal and control devices as necessary for MUTCD compliance. Provide access and revenue controls as indicated for Park & Ride surface lots.

2.3.3.2.3 Where the site allows, utilize the topography to provide multiple level access into the parking structure.

2.3.3.3 Parking Structure Circulation:

2.3.3.3.1 Unless constrained by site or access limitations, provide double threaded helix ramp system if the structure has more than three levels. Provide one set of double-helix ramps for every six bays of structure. Design facility for two-way traffic, with double-loaded aisles and ramps with 90Eparking for maximum efficiency. Layout parking aisles aligned in the same direction as the path to the station.

2.3.3.3.2 Parking ramps may not exceed 5% slope. Where parking ramps are not feasible due to the site or other constraints, speed ramps may be provided with 10%-maximum slope if weather protected or 8%-maximum slope if exposed to weather. Provide skid-resistant molded driving surface at all ramps with slopes greater than 5% and restrict from pedestrian traffic.

2.3.3.4 Parking Structure Spaces:

2.3.3.4.1 The Authority will provide the Parking Structure Program indicating the minimum number of parking spaces, cashier's booths and access lanes required. Provide minimum 8'-6" wide x 18'-0" long standard parking spaces with a 24-ft. minimum clear drive aisle between rows. Calculate accessible space count and van accessible space count requirements for the disabled in accordance with ADA Standards for Transportation Facilities and the governing building codes.

2.3.3.5 Parking Structure Pedestrian Circulation:

2.3.3.5.1 Within the structure, pedestrian movement shall be directed along the driving aisles to the primary vertical circulation element(s). Their route of travel shall be direct, clearly defined, and well lit. Where pedestrians must cross vehicular traffic (inside the structure or beyond), clearly defined crosswalks shall be provided, giving right of way to the pedestrians.

2.3.3.5.2 Provide an ADA-compliant accessible route from the accessible parking spaces to the elevator lobby. Assure direct access path via sidewalk network, with minimal travel distance across roadways for handicap accessible spaces. Provide a continuous covered walkway or covered pedestrian bridge from the parking structure to the station entrance.

2.3.3.6 Parking Structure Vertical Circulation:

2.3.3.6.1 Locate lobby for the elevators and the primary stairs at the nearest point from the parking structure to the station entrance. To facilitate patron use, design primary stair with the maximum width allowed without center rail. Provide minimum 18-footseparation in lobby from the primary stairs to the elevator entrances. Maintain unobstructed pedestrian access for full width of the opening at elevator lobbies and 5-foot minimum unobstructed access to egress stairs using striped markings on decks with properly spaced bollards.

2.3.3.6.2 Primary and additional egress stairs shall be designed and located as required by the governing building code. Construct stairs with precast concrete or cast-in-place concrete with aluminum nosing cast in treads. Stair towers and elevator lobbies are to be open to interior spaces and enclosed with glazed aluminum storefront on exposed sides, unless governing codes require rated enclosures. If rated enclosures are required, maintain full visibility of the elevator lobbies from adjacent parking area. Provide natural ventilation with louvers at the bottom and the top of stair towers.

2.3.3.6.3 Elevators shall meet ADA Standards for Transportation Facilities, local building code, and the WMATA Design Criteria requirements indicated in Section 14 (Mechanical) of this Manual. The requirement for the number of elevators serving a parking structure shall be calculated using the WMATA Elevator Traffic Analysis Guide. Calculating factors determining elevator counts include maximum wait time, capacity, speed, number of parking spaces, number of levels of parking, parking capacity fill rate and the level from which the access to the station is located. At a minimum, provide two traction elevators serving a parking structure with four or more levels or two hydraulic elevators if serving less than four parking levels. Provide emergency power generator, per Section 13 able to operate elevators to designated landing and all emergency lighting circuits and required equipment.

2.3.3.6.4 The back of the elevator cab and the back of the hoistway shall be fully glazed for visibility of riders. Orient glazed side of hoistway away from an eastern or western exposure to avoid excessive heat penetration from direct sunlight. Provide ventilation in accordance with Section 14.17.5.3.

2.3.3.6.5 Provide WMATA-approved bomb-resistant trash containers: two at each elevator lobby/main stairway entrance on each level and one at each stair entrance on each level. Provide one ash receptacle at each elevator lobby on each floor.

2.3.3.7 Parking Structure:

2.3.3.7.1 The parking structure shall be designed to meet local building codes with local jurisdictional amendments, FTA requirements as applicable, and to the requirements indicated in the Design Criteria Section 15 (Structural) of this Manual. The perimeter of the structure shall be open to the exterior to allow penetration of natural lighting and ventilation into the interior of the structure. Provide light wells to all perimeter areas of the parking structure that are located below grade using architectural cast-in-place or precast-concrete retaining walls.

2.3.3.7.2 Parking structures shall be designed for a minimum 50-year life span using the most stringent requirements of the ACI Code, the AASHTO Specifications and the Design Criteria Section 15 (Structural) of this Manual for the design. Generally, design parking structures using a precast, prestressed concrete system unless angled corners are necessary due to the constraints of the site and the schedule would permit using a cast-in-place system. To avoid erection problems during construction, precast, prestressed concrete structures are not permitted to have angled double-tee decks. However, small angles may be used due to site or space constraint, with the approval of the Authority, on a case-by-case basis.

2.3.3.7.3 Provide an 8'-2" clear minimum vertical clearance (plus vertical cure compensation, where applicable) inside the structure over all parking areas, drive aisles, and at transition slopes on ramps, without intrusions of any kind. Allow 12'-3" minimum floor-to-floor heights with a 48-inch minimum girder depth, and with an inch of construction tolerance. Provide 60-foot wide clear spans minimum for all parking bays with parking located on both sides. For a 60-foot clear span of parking bay, a column grid of approximately 62' long and 45' wide is recommended. However, end bays or bays of 47'width are recommended at the top and bottom of the ramps.

2.3.3.7.4 Design and construct parking structures to properly drain water from all surfaces on every parking level. Slope parking decks a minimum of 1.5% (2% is preferred), in all directions except at an ADA-accessible route and parking space. Provide drains at all deck low points, slightly oversized to prevent standing water on deck surfaces during storms. The water runoff shall be based on rain fall intensity of 3 inches per hour.

2.3.3.7.5 Locate expansion joints at the high point of deck where water is less likely to pass over the wash. Slope structure at lobbies to drain away from elevator door openings and stair landings.

2.3.3.7.6 For the precast pretensioned prestressed parking structures, the drainage catchment area shall not exceed 2,800 sq. ft. for the roof parking deck and 5,600 sq. ft. for all other level decks. These areas are based on the basic grid module of about 62' long and 45' wide. To achieve proper drainage at the roof level, use of 4-inch thick concrete overlay (see Section 15) shall be considered.

2.3.3.7.7 Separate elevator and stair towers from the parking structure with an expansion joint. However, on a case-by-case basis, the Authority may allow the use of attached stairs and elevator towers, based on the scheme of the structure.

2.3.3.8 Parking Structure Exterior Precast Spandrels and Panels:

2.3.3.15.1 To enhance the appearance of the exterior of the parking structure, fabricate spandrels using architectural precast concrete with finishes indicated or with finishes approved by WMATA. Provide a design for the structure’s exterior that compliments the character of the adjacent architecture. Match the finish of the adjacent structure, if the parking structure is an expansion of an existing parking facility. Minimize the depth of spandrels and size of exterior panels to provide a light and open appearance from the structure’s exterior and in interior spaces.

2.3.3.9 Parking Structure Railings and Guardrails:

2.3.3.9.1 Design railings and guardrail systems with minimum size steel members to reflect the light and open appearance desired, if they are visible from the structure's exterior. Do not use metal railings on top of spandrel panels.

2.3.3.9.2 Provide railings and guardrails with finish systems that are highly resistant to corrosion.

2.3.3.10 Parking Structure Security:

2.3.3.10.1 Provide parking structure design with passive security measures inside and outside the parking structure. Avoid dead end spaces and dark corners in parking areas. Access to parking structure shall be limited to principal users by restricting access to the interior of the structure from non-principal users with parapets, wire mesh partitions, and/or spiny landscaping materials.

2.3.3.10.2 Install Garage Emergency Telephone Systems (GETS) at all stair towers on all levels and at additional points in the structure to provide coverage of a minimum 200 feet of travel distance.

2.3.3.10.3 On the lower parking level of the structure, provide a room of area not less than 200 s.f. with a window for the Metropolitan Transit Police Department (MTPD). Finish room with painted walls, tiled floor and an acoustical panel ceiling. Locate MTPD room near a staff restroom. Furnish room with a WMATA phone system telephone, data terminal wired for WMATA-LAN access, heating and air-conditioning, and power for equipment.

2.3.3.10.4 Provide CCTV coverage of revenue collection areas and lane control signals, with CCTV images recorded on 4 channel recorders in the Operations Room. Provide CCTV coverage in each elevator cab with feed to station kiosk monitor with display rotation type service. Feed service to existing monitors that are in existing station kiosks.

2.3.3.11 Parking Structure Parking Access and Revenue Controls (PARC):

2.3.3.11.1 Provide an Operations Room of area not less than 250 s.f., with security window and located in the parking structure to house facility controller and other PARC equipment. Located room within 200 feet from cashier booths and adjacent to a staff uni-sex restroom. Assure direct and exclusive access to Operations Room door from the parking area. Finish room with painted walls, tiled floor and acoustical panel ceiling. Furnish room with a WMATA phone system telephone, data terminal wired for WMATA-LAN access, CCTV equipment, heating, ventilation and air-conditioning, and power for other equipment.

2.3.3.11.2 Furnish Smartrip processing at all revenue access equipment, with each lane separately tracked for all Smartrip activity. Provide ADA-compliant and ballistic-resistant cashier booths that are operated with a fee computer system capable of integrating Smartrip with the fee computer to track transactions by type and amount.

2.3.3.11.3 Provide MUTCD overhead lane control signals for all cashier arrays. Signals displays shall be in compliance with the MUTCD. Controls for the signals shall be in the principal cashier booth for each of the arrays.

2.3.3.12 Parking Structure Signage and Graphics:

2.3.3.12.1 Refer to WMATA Signage Manual.

2.3.3.13 Parking Structure Fire Protection/Plumbing:

2.3.3.13.1 All areas of the parking structure will shall be covered by dry fire department standpipe systems as per local building code and approved by the jurisdictional Fire Marshall.

2.3.3.13.2 Fire Protection service system shall be provided for the elevator machine room and elevator hoistway in compliance with the NFPA 72, NFPA 13 and ASME A17.1 Code requirements. Automatic sprinklers shall be installed in the elevator machine room and hoistway that contain combustible hydraulic fluids as required by NFPA 13.

2.3.3.14 Parking Structure Lighting:

2.3.3.14.1 For all parking areas and pedestrian areas including stairways and elevator towers, use solid state luminairies. Refer to Design Criteria Section 4 (Lighting) Table 4.5.3 of this Manual for "Exterior Spaces" for proper illumination level. Minimum to maximum lighting intensity ratios shall not exceed 1 to 10 measured horizontally and vertically 3 feet above the floor. Average to minimum lighting intensity shall be maintained as 4 to 1. Luminairies are to be specifically designed for parking structures and shall not cause glare for drivers. The luminairies design shall provide for the light source to be shielded from the driver's eye.

2.3.3.14.2 The lighting for the elevator and escalator entrances shall be not less as required by the ASME A17.1 Code.

2.3.3.14.3 20% of the lighting shall be on emergency circuits. Provide separate electrical closet on each floor to house the electrical panel for furnishing power to the luminaries on the same floor. The electrical closet shall not be installed near the contraction/expansion joint. Provide controls for luminaries in open glazed stairways to be off during daylight hours, but luminaries shall remain on where daylight does not reach to at least 50% intensity.

2.3.3.15 Parking Structure Landscaping:

2.3.3.15.1 Landscape the perimeter of the parking structure per local codes and WMATA requirements or as required by local jurisdictional Authority. Plant material types and placement shall consider security requirements and maintenance needs including impact of roof top snow removal. Landscape plant materials shall be provided with WMATA standard watering system.

2.3.3.16 Parking Structure Maintenance Considerations:

2.3.3.16.1 Provide Storage Room in every parking structure over 500 spaces with a 200 sf space for gasoline/ diesel powered snow removal equipment. Locate Storage Room to avoid loss of any parking spaces below the lowest ramp. Secure space with an electric-operated coiling grille door and concrete masonry walls on all sides. Storage room shall comply with local jurisdictional code.

2.3.3.16.2 Install traffic coating over occupied spaces and service rooms to extent required to prevent water penetrations through deck structure and joints in deck.

2.3.3.16.3 Design for Architectural, Structural, Electrical and Plumbing systems to eliminate ledges and shelves, as feasible, where birds may roost or nest. Provide angled metal inserts at structural elements that form shelves and other bird control measures or devices throughout the facility.

2.3.3.16.4 Provide steel corner guards at corners of columns where exposed to vehicular traffic and parking areas.

2.3.3.16.5 Locate plumbing risers tight to column and walls and protected from vehicular impact with steel guards.

2.3.3.17 Parking Structure Maximum Glass Panel Size:

2.3.3.17.1 The maximum glass panel size in stairways and elevator shafts shall not exceed 4 feet by 8 feet.

2.4 SITE AND RIGHT-OF-WAY SIGNAGE AND GRAPHICS

2.4.1 Site and Right-of-Way Signage and Graphics Design Principles:

2.4.1.1 For standard Site and Right-of-Way Signage and Graphics requirements, refer to the WMATA Metrorail System Signage Design Manual. All new Site and Right-of-way Signage and Graphics shall adhere to the following adopted basic principles of design:

2.4.1.2 Signs shall be durable and meet the latest standards, regulations and codes.

2.4.1.3 Traffic and restrictive signs shall conform to the shapes, layouts, colors, letter sizes and typeface as required by the local jurisdictions, National Highway Standards and other applicable traffic regulatory agencies.

2.4.1.4 Fixed signs located on the Metrorail right-of-way shall conform with the Metrorail Safety Rules and Procedures Handbook.

SECTION 3 - METRO RAIL FACILITY DESIGN

3.1 GENERAL DESIGN CONSIDERATIONS

3.1.1 Regulatory: WMATA requires all Metro Rail stations and facilities to meet or exceed the current NFPA 130 in addition to all other laws, codes and standards.

3.1.1.1 WMATA requires NFPA 130 egress calculations be performed using the following assumptions:

3.1.1.1.1 Trains: two in station, loaded to capacity

3.1.1.1.2 Platform(s): fully loaded, whether side or center

3.1.1.1.3 Mezzanine: "free" and "paid" sides loaded 50% each

3.1.1.1.4 Vertical Circulation: all entering elements - elevators, escalators, stairs at all levels - loaded 50% each

3.1.1.2 The above assumptions can only be modified or waived by WMATA's Fire Marshall.

3.1.2 Security: Any equipment, signage or cabinets accessible to the public shall comply with the following:

3.1.2.1 Tops shall slope 30-degrees to the front to prevent placement of unauthorized items; no flat-topped equipment or raised surfaces within reach shall be allowed.

3.1.2.2 Be located as close as possible to adjacent walls or other equipment to prevent customers from standing between equipment or place unattended objects.

3.2 RAIL STATIONS, GENERAL DESIGN CONSIDERATIONS

3.2.1 Station Vertical Circulation:

3.2.2.1 The Authority determines the program (i.e. quantity and location) for vertical circulation elements in the station facilities, including stairs, escalators, and elevators, as well as for fare collection equipment including faregates, farecard vendors, exit fare vendors and Trip Card Dispensers based on projected passenger demand. Established policy requires that platforms be capable of being cleared as follows:

Design Headway Time	Platform Exit Time

2-3 Minutes	1.5 Minutes
4-5 Minutes	2.0 Minutes
6-7 Minutes	3.0 Minutes

3.2.2 Station Emergency Exiting Requirements:

3.2.2.1 The program for vertical circulation elements and faregate aisles may be increased to satisfy emergency exiting requirements as specified by NFPA-130.

3.2.3 Station Plan and Profile:

3.2.3.1 The plan and profile of a station and its adjacent track work are determined by WMATA.

3.2.4 Station Utility Infrastructure:

3.2.4.1 Piping and conduits in areas visible to the public shall be concealed as much as possible.

3.2.5 Station Glazing Adjacent to the Trackway:

3.2.5.1 Glass in areas above or next to the trackway or major roadways must allow for glass replacement from inside the structure, bridge, or station area without having to access the trackway.

3.2.6 Station Entrance:

3.2.6.1 Station Entrance General Design Principles:

3.2.6.1.1 The entrance to a station, consisting of the stairs, escalators, elevators, and surrounding space, shall be integrated with its surroundings in such a way as to be compatible with the urban/suburban fabric. The following points shall be observed in its design:

3.2.6.1.1.1 Align the entrance parallel or perpendicular to the major adjacent street, being cognizant of historic and visual axes.
3.2.6.1.1.2 Provide a 20 ft. minimum queuing distance at escalator top and bottom.
3.2.6.1.1.3 Minimize taking of existing structures where their removal would constitute a disruption of the urban fabric.
3.2.6.1.1.4 Coordinate entrance to not preclude any future joint development, taking care not to preclude access to such development, including but not limited to knockout panels in walls and floors.
3.2.6.1.1.5 Anticipate need for future access points to the Metro Rail System
3.2.6.1.1.6 Provide an entrance pavilion to distinguish an entrance

landmark and provide Metro System information for both rail and bus.

3.2.7 Station Entrance Design Elements:

3.2.7.1 Two ADA accessible elevators between changes in elevation. At least two escalators between changes in elevation per location. One is running up direction and other is running down direction.

3.2.7.2 Each double escalator wellway shall have a stair plus the required amount of escalators, a minimum of 2 escalators and a stair 10'-0" wide between, from the surface. A straight run is preferred over a scissors type run. The number and combination of escalators and stairs shall be based on WMATA provided data for passenger circulation requirements or NFPA-130, whichever is greater.

3.2.7.3 A straight run is preferred over a scissors type run.

3.2.7.4 Use 97G-10 and 97G-15 luminaire, see Standard Drawings.

3.2.7.5 Provide a canopy over any exterior open escalator wellway. Typically the canopy is mounted on top of the surrounding granite parapet wall, and typically is the entrance to an underground station at the ground surface level. The form and materials of the canopy shall reflect the standard elements, finishes, luminaries, snow guards, and geometry of WMATA’s standard stainless steel and glass canopy as shown on WMATA’s design drawings.

3.2.7.6 Provide a granite parapet surrounding escalator way for an underground station.

3.2.7.7 Provide a granite apron surrounding the parapet for an underground station.

3.2.7.8 Provide a 3' x 3' concrete sidewalk grid for an underground station.

3.2.7.9 Each double escalator wellway for underground stations shall have a stair plus the required amount of escalators (a minimum of 2 escalators with a 10'-0" wide stair between them from the surface).

3.2.7.10 Provide at least two escalators between changes in elevation for an above ground station.

3.2.8 Station Mezzanine:

3.2.8.1 Station Mezzanine Design Principles:

3.2.8.1.1 The Authority establishes the program for both the initial and ultimate peak demands. The new or reconstructed mezzanine shall satisfy the ultimate demand.

3.2.8.1.2 The size and shape of the mezzanine is directly determined by the programmatic requirements for a station and the number of entrances required. This accounts for the wide diversity of mezzanines throughout the system.

3.2.8.1.3 The layout shall reflect the logical sequence that a new patron would follow when first learning to use the system. Circulation flow, leading from one area or function to the next, is the critical issue.

3.2.8.1.4 Information panels and fare vending equipment are located on the right of a patron entering the station mezzanine. After the fare vendors and Smartrip Card Dispensers, a telephone booth and map case are located. Next are the faregates.

3.2.8.1.5 Fare vendors and Smartrip Card Dispensers shall be first in the sequence, followed by map cases, then the faregates.

3.2.8.1.6 Vending and information area must be designed for maximum flexibility, given the changing nature of technology. WMATA favors a 4 foot on center modular metal panel system in which equipment of varying sizes can be accommodated by customized openings, in a flush condition and regular pattern. Panels will span from floor to ceiling, with a toe kick at the bottom and space for 42-inch displays at the top, above equipment. Depth of the system shall include a nominal 3 foot service space to the rear of the equipment from the face of the panel.

3.2.8.1.7 Adequate queuing distances are absolutely necessary.

3.2.8.1.8 Station Mezzanine Equipment and Queuing: The program of required equipment, prepared by WMATA, is based on ridership projections. Once the program is known, the minimum areas for queuing determine the size of the mezzanine. Passenger flow shall serve to plan the mezzanine spaces.

3.2.8.1.9 Provide a 25 ft. minimum queuing distance for faregates.

3.2.8.1.10 Queuing distances for terminal and temporary-terminal station shall be larger than those for a mid-route station. WMATA's projected patronage and recommended clearances to fare equipment shall be considered.

3.2.8.1.11 Visibility from the kiosk to the farecard vendors, Smartrip Card Dispensers and faregate equipment is essential. Center the kiosk on passageways and farecard vendor array and faregate equipment. Provide visibility to elevators and escalator ways.

3.2.8.1.12 Minimize the duplication of mezzanine fare equipment by locating it at a point common to all entries (either passageways or entrances).

3.2.8.1.13 In no case shall rain and direct sunlight reach the farecard vendors, the faregate displays and/or photo sensors, and the

Smartrip Card Dispensers, since rain and sunlight will impact the equipment performance and operation. The kiosk windows shall also not be exposed to direct sunlight where possible.

3.2.8.1.14 Public toilets are required on the paid sides of the fare gates only.

3.2.8.1.15 Employee washroom(s) may be on the paid side or free side. Paid side is preferred, adjacent to Break Room.

3.2.8.1.16 Employee Break Room shall include a kitchenette with sink & disposer, power for refrigerator & microwave(s), and be able to accommodate dining tables and chairs.

3.2.8.1.17 Provide a minimum of two ADA-accessible elevators from each platform to each mezzanine; center platform stations will have fewer units than a side platform station.

3.2.8.1.18 The minimum vertical clearance in the mezzanine shall be 13'-0".

3.2.8.1.19 Above ground station mezzanines shall be entirely protected by an entrance pavilion, overhead platform, or vaulted structure. Vertical transparent wind screens shall also be provided for additional protection as required. Design the overhead protection and wind screen so that the mezzanine is adequately protected from driving rain, sleet and snow. Assume a 65^0 angle from the vertical for roof overhangs. Canopies over mezzanines shall have a continuous linear glazed skylight. Faregates shall be completely protected from rain, sleet, snow, or other forms of moisture. Fairgates shall be shielded from any direct sunlight.

3.2.8.2 Station Mezzanine Design Elements[1]:

3.2.8.2.1 The size and shape of the mezzanine is directly determined by the programmatic requirements for a station and the number of entrances required. This accounts for the wide diversity of mezzanines throughout the system. However, each contains these elements:

3.2.8.2.1.1 **Kiosk:** Preferred location is centered between the train tracks and any passageways leading to the kiosk. Faregates shall be located on both sides of kiosk, with patron flow generally directed to the right.

3.2.8.2.1.2 **Service gate and railing:** Service gate and railing shall always be adjacent to the kiosk.

3.2.8.2.1.3 **Fare gates:**

3.2.8.2.1.3.1 **Station Mezzanine Faregate Aisle Queue:** The queue length is calculated if the number of standard faregate aisles is less than the program requirement. The calculation determines the maximum queue volume, and employs a peak queue factor and interpersonal spacing for Level of Service C pedestrian flow. If the number of standard faregate aisles satisfies the program requirement, then the minimum queue length may be applied.

3.2.8.2.1.3.2 **Station Mezzanine Faregate Aisles:** The required number of standard faregate aisles is calculated by dividing the projected faregate transactions of the peak minute by the average transactions per minute for one aisle. The calculation employs two important factors: peak load and platform clearance. The peak load concept, or peaking factor, accounts for the uneven distribution of disembarking passenger loads during the peak hour. With respect to platform clearance, it is WMATA policy that platforms be cleared in half the scheduled headway time of the peak train service. Clearance of the platform allows for headway fluctuations, which may occur during peak periods, and assures that the disembarking passenger load shall have unimpeded flow to and through the faregate aisles, without the danger of passenger back-up. The platform clearance factor is assigned only to the number of disembarking passengers.

3.2.8.2.1.3.3 Spare aisles, a service gate, and at least one ADA accessible faregate aisle are added to the number of standard faregate aisles to establish the total faregate aisle program.

3.2.8.2.1.3.4 Provide a 25 ft minimum queuing distance on each side of the faregates, measured from the face of the side assembly.

3.2.8.2.1.4 **Accessible fare gates:** shall be located closest to the kiosk, on the side of the kiosk that allows the shortest path from the entrance elevator to the platform elevator.

3.2.8.2.1.5 **Station Mezzanine Farecard Vendors:**

3.2.8.2.1.5.1 The required number of farecard vendors is calculated by dividing the projected farecard vendor transactions of the peak minute by the average transactions per minute for one vendor. The calculation employs two factors: peak load and a percentage factor for the number of peak-hour boarding passengers using the vendors. The peak load concept, or peaking factor, accounts for the uneven distribution of passenger loads during the peak hour. Spare vendors are added to the number of farecard vendors to establish the total farecard vendor program. One accessible farecard vendor and one accessible exit fare vendor are required.

3.2.8.2.1.5.2 The percentage factor varies among the stations, and is highest for those stations that serve passengers unfamiliar with the automatic fare collection system, e.g. tourists and convention attendees.

3.2.8.2.1.6 **Station Mezzanine Farecard Vendor Queue:** Calculate the queue length if the number of farecard vendors is less than the program requirement. The calculation determines the maximum queue volume, and employs a peak queue factor and interpersonal spacing for level of service C per pedestrian flow criteria. If the number of farecard vendors satisfies the program requirement, then the minimum queue length of 20 feet shall be used.

3.2.8.2.1.7 **Exitfare machines:** requirements similar to Fare Vendors

3.2.8.2.1.8 **Escalators and elevators:** The surface elevators to the mezzanine for the disabled shall be located on the main entrance passageway with minimum secondary passageway length. The WMATA elevator passageway minimum width 5'-0" clear, with continuous handrail on both sides. All elevator access shall be to the free area, so that access to the platform area shall be only through the faregate array.

3.2.8.2.1.9 **Map case:** see Standard Drawings. Locations shall be at regular intervals, as agreed to with WMATA.

3.2.8.2.1.10 **Smartrip Card Dispensers:** The number of Smartrip Card Dispensers shall be based upon the number of parking spaces in the station parking facility. For stations with fewer than 1,000 parking spaces, one Smartrip Card Dispenser shall be installed; between 1,000 and 2,999 parking spaces, two Smartrip Card Dispensers shall be installed; and more than 3,000 parking spaces, three Smartrip Dispensers shall be installed. The Smartrip Card Dispensers shall be located in the free area, and in the general area of the farecard vendors. The queue length minimum for the Smartrip Card Dispensers is equal to queue length calculated for the farecard vendors.

3.2.8.2.1.11 **Signage:** See the Metro Rail System Signage Design Manual.

3.2.8.2.1.12 **Station Mezzanine Public Information Display System (PIDS):** For each mezzanine, a minimum of one single-sided PIDS shall be installed near the farecard vendor with the PIDS screen in plain view of patrons purchasing farecards or approaching the faregates to enter the system.

3.2.8.2.1.13 **Tile floor:** slip-resistant, with narrow, heel-proof joints

3.2.8.2.1.14 Precast concrete or stainless steel and glazed parapet

3.2.8.2.1.15 **Lighting:** See Section 4

3.2.8.2.1.16 **WMATA-Approved Bomb-Resistant Trash Receptacles:** Provide WMATA-approved bomb-resistant trash receptacles in quantity and location as directed by the Authority.

3.2.8.3 STATION PLATFORM

3.2.8.3.1 Station Platform Design Principles:

3.2.8.3.1.1 Station Platform Width: Design in accordance with NFPA 130.

3.2.8.3.1.2 A clear, unobstructed view of all parts of the station platform, with the minimum number of columns, and equipment, blocking the view, shall be provided.

3.2.8.3.1.3 A center platform is preferred over side or twin platforms.

3.2.8.3.1.4 Where two station entrances are provided, each with its own mezzanine, access from the mezzanines to the platforms shall be located as close to the platform ends as possible, to insure optimum loading and safety.

3.2.8.3.1.5 All Metro platforms are a minimum of 600 feet long. This corresponds to the length of an 8-car train.

3.2.8.3.1.6 There shall be an egress stair at the end of each platform.

3.2.8.3.1.7 PIDS displays shall be spaced no more than 150 feet apart on any station platform.

3.2.8.3.1.8 Above ground station platforms shall be entirely covered. Design the canopy so that the platform is adequately protected from driving rain, sleet and snow. Assume a 65^{o} angle from the vertical for roof overhangs. Canopies over platforms shall have a continuous linear glazed skylight.

3.2.9 STATION PLATFORM TYPES

3.2.9.1 Platform Width at Center Platform Station:

3.2.9.1.1 The platform width shall be sufficient to accommodate the projected passenger load. However, the minimum platform width shall be 30'-0½" with a clear distance between the platform edge and the nearest obstruction (e.g. escalators) being a minimum of 9'-3" where possible. Area adjacent to trackway below platform over hang to remain open for emergency refuge.

3.2.9.2 Platform Width at Side Platform Station:

3.2.9.2.1 Minimum platform width shall be 15'-0" to the face of the parapet wall if vertical circulation elements are located within the limits of the platform, with a clear distance between the platform edge and the nearest obstruction (e.g. escalators) being a minimum of 9'-3" where possible. Minimum platform width may be reduced if vertical circulation elements are located outside the platform limits. Area adjacent to trackway below platform overhang to remain open for emergency refuge. Platforms and tracks may not be at the same level, as at Pentagon and Rosslyn stations.

3.2.9.3 Platform Width at Dual Chamber Station:

3.2.9.3.1 Minimum platform width shall be 13' 5-7/8" to the face of the parapet wall. The clear distance between the platform edge and the nearest obstruction (e.g. escalators) shall be a minimum of 9'-3" where possible. Employ where dual chambers are excavated for the station train room (e.g. Wheaton and Forest Glen Stations). Area adjacent to trackway below platform over hang to remain open for emergency refuge.

3.2.9.4 Twin Platform Width at Triple Track Station:

3.2.9.4.1 Minimum platform width shall be 24'-3". The clear distance between the platform edge and the nearest obstruction (e.g. escalators) shall be a minimum of 9'-3" where possible. Employ where center pocket track is located in the station (e.g. National Airport and West Falls Church Stations). Area adjacent to trackway below platform overhang to remain open for emergency refuge.

3.2.9.5 Station Track Stationing and Elevations:

3.2.9.5.1 The location of a station platform is precisely fixed by its "stationing" (the distance normally measured from Metro Center (or another base reference if necessary) in 100 feet lengths along the track alignment) and by its top of rail (T/R) elevations on the profile, denoted as follows (in this example, Anacostia Station):

Begin Platform	Sta. 82+37.00
(inbound end)	T/R EL.+2.57'
End Platform	Sta. 188+37.00
(outbound end)	T/R EL.+0.47'

3.2.9.5.2 The numerical difference between the beginning station at the inbound end of the platform and the end stations of the platform is always a minimum of 600 feet; the difference between T/R elevations may vary from 1.2 ft, which represents a 0.2% slope (the minimum for an at-grade station) to 2.1 ft, which represents a maximum slope of 0.35% required for underground and aerial stations and the maximum for at-grade stations. The platform and ancillary rooms slope correspondingly.

3.2.10 STATION ESCALATORS

3.2.10.1 Station Escalator Design Principles:

3.2.10.1.1 Information on the Design Criteria for escalators is contained in Section 14 (Mechanical) of this Manual.

3.2.10.2 Station Escalator Design Elements:

3.2.10.2.1 All escalators are designed on a standard 30º angle of inclination. "Working points" (upper and lower) are intersections of this line with the finish floor elevations of the two levels.

3.2.10.2.2 The quantity and location of escalator in each station are based in part on the policy program for vertical circulation but not less then 2 escalators per location.

3.2.10.2.3 Cladding panels on the outside of escalators shall have plumb vertical joints.

3.2.11 STATION ELEVATORS

3.2.11.1 Station Elevator Design Principles:

3.2.11.1.1 Information on the Design Criteria for elevators is contained in Section 14 (Mechanical) of this Manual.

3.2.11.2 Station Elevator Design Elements:

3.2.11.2.1 Elevator Types: The following types of elevators are used in the system:

- Hydraulic (types I-IV):
- Vertical rise up to 36'-0".
- Machine room may be remote from elevator if necessary.
- Traction (Types VI-VIII):
- Vertical rise over 36'-0".
- Machine room shall be above or adjacent to elevator hoistway.

- Dual street elevator access and dual center platform elevators shall be provided a minimum of two per station.

3.2.11.2.2 Elevator Hoistway and Cab Walls and Doors Glazing: Provide clear glazing for viewing into and out of the interior for safety and security on elevator hoistway walls and doors and on cab walls and doors. Glazing is to be laminated tempered safety glass. Where hoistway wall glazing is not possible, glazing is still required on the elevator hoistway doors and cab doors for unobstructed viewing into and out of the cab.

3.2.12 STATION SERVICE ROOMS:

3.2.12.1 The Service Room Schedule is a listing of all the required ancillary rooms for the station. The numbering system shall be consistent with this criteria; for example, room #8 always refers to the Fire Equipment Cabinet. The schedule is inserted into the plans and sections showing the service rooms and the corresponding numbers are placed in the room plans and sections.

3.2.13 Station Service Room Schedule:

1	Mechanical Equipment Room	15	Bus Drivers' Washroom
2	A.C. Switchboard Room	16	Dispatcher Room
3	Battery Room	17	Train Operators' Room (w/ potable water)
4	Communications Room	18	Train Operators' Washroom (2)
5	Train Control Room	19	Maintenance Room
6	Operations Room	20	Train Operators' Locker Room
7	Telephone Room	21	Transformer Room
8	Fire Equipment Cabinet	22	Elevator Machine Room
9	Cleaners' Room	23	Sewage Ejector Room
10	Cleaners' Room with Ejector	24	Cart Storage
11	Women's Washroom	25	Electrical Cabinet Room

12	Men's Washroom	26	Police Service Room
13	Water Service Room	27	Emergency Tunnel Evacuation Cart Storage Room
14	D.C. Tie Breaker Room	28	Escalator Control Room

3.2.14 Mechanical Rooms:

3.2.14.1 All mechanical rooms are denoted as #1, with their specific function labeled on the plans.

3.2.14.2 For room sizes and other dimensions, refer to the Design Directive & Standard Drawings.

3.2.14.3 Center Platform Stations

3.2.14.3.1 Two rooms, one located at each end of platform; or

3.2.14.3.2 Four rooms, two at each end of platform, stacked vertically.

3.2.14.4 Side Platform Stations

3.2.14.4.1 Four rooms, located at each end of both platforms; or

3.2.14.4.2 Eight rooms, stacked vertically at each end of both platforms.

3.2.14.4.3 The Mechanical Equipment Room provides air conditioning for platform area and under platform exhaust.

3.2.14.4.4 Each room needs 6'-0" x 8'-0" high double doors and a knockout panel adjacent to tracks for equipment access

3.2.14.4.5 Ductwork runs from these rooms under platform and under any service rooms located between the station end wall and the Mechanical Room; center ductwork under platforms.

3.2.14.4.6 Provide two means of egress, diagonally opposite from each other.

3.2.14.5 Fan Room (ventilates the A.C. Switchboard Room)

3.2.14.5.1 Locate adjacent to AC Switchboard Room

3.2.14.5.2 Fresh air intake and exhaust required

3.2.14.5.3 6' x 8' double doors

3.2.14.5.4 9'-0" minimum ceiling height

3.2.14.5.5 Access not through Electrical Room

3.2.14.6 Chiller Plant (for underground stations; may serve more than one station)

3.2.14.6.1 10' x 10' double door.

3.2.14.6.2 3' x 3' access hatch to cooling tower (unless cooling tower is remote).

3.2.14.7 Cooling Tower

3.2.14.7.1 Provide one for each Chiller.

3.2.14.7.2 May be remote from Chiller Plant, but chilled water lines connect the two rooms, to minimize distance

3.2.14.7.3 Needs exposure to fresh air.

3.2.14.8 Fan Room at Mezzanine (to ventilate and cool kiosk)

3.2.14.8.1 Room required unless fans can be placed above kiosk to exhaust at grade.

3.2.15 Station Electrical Rooms:

3.2.15.1 All electrical rooms are denoted as #2, #3, #14 and #25 with their specific function labeled on the plans.

3.2.15.1.1 #2 A.C. Switchboard Room

3.2.15.1.1.1 2 rooms - used where 2 entrances to the station are remote from each other, generating two sets of service rooms.

3.2.15.1.1.2 Combined - used when there is a centrally located mezzanine and all the service rooms are located together.

3.2.15.1.1.3 All AC rooms shall have 2 means of egress.

3.2.15.1.1.4 6' x 8' double door and access hatch for equipment.

3.2.15.1.2 #3 Battery Room

3.2.15.1.2.1 Requires adjacency to each A.C. Switchboard Room.

3.2.15.1.2.2 3' x 7' door on short side of room.

3.2.15.1.3 #25 Electrical Cabinet Room

3.2.15.1.3.1 Required when service rooms are remotely located from A.C. switchboard room; enables electrical service to be brought into service rooms.

3.2.15.1.4 #14 D.C. Tie Breaker Room

3.2.15.1.4.1 Required when there is no substation located at a crossover.

3.2.15.1.4.2 Door at platform level.

3.2.16 Station Systems Rooms:

3.2.16.1 All systems rooms are denoted as #4, #5, #6, #7, #8, #16, #17, #24, #26 and #25 with their specific function labeled on the plans.

3.2.16.1.1 #4 Communications Room:

3.2.16.1.1.1 This room is preferred to be located at the platform level.

3.2.16.1.1.2 One per kiosk minimum, within 300 feet cabling distance from kiosk center.

3.2.16.1.2 #5 Train Control Room

3.2.16.1.2.1 This room varies according to the track conditions. All Train Control Rooms shall have two means of egress.

3.2.16.1.2.2 Platform level is optimum.

3.2.16.1.2.3 All Train Control Rooms shall have two means of egress.

3.2.16.1.3 #6 Operations Room

3.2.16.1.3.1 Locate at platform level

3.2.16.1.3.2 Maybe combined with the train operator's room #17 to form one large room (see requirements for #17).

3.2.16.1.4 #7 Telecommunications Room

3.2.16.1.4.1 Located at mezzanine level or platform level

3.2.16.1.4.2 One at each end of station

3.2.16.1.5 #8 Fire Equipment Cabinet

3.2.16.1.5.1 Locate at each end of platform and in every mezzanine.

3.2.16.1.5.2 Platform cabinets shall be immediately adjacent to end of platform.

3.2.16.1.6 #16 Dispatcher/Terminal Supervisio’s Room

3.2.16.1.6.1 Located only at terminal or temporary-terminal stations, for dispatching of trains.

3.2.16.1.6.2 Located at inbound end of platform with a window for clear visibility of trains in the station.

3.2.16.1.7 #17 Train Operator's Room

3.2.16.1.7.1 Located next to dispatcher room with a Dutch door between the two rooms.

3.2.16.1.7.2 May be combined with the operations room #6.

3.2.16.1.7.3 Functions as a place for train operators to report to work, eat lunch, use toilet facilities, etc. Provide lockers.

3.2.16.1.8 #24 Cart Storage Room

3.2.16.1.8.1 Size may vary according to number of carts programmed per station.

3.2.16.1.8.2 The room shall be located at inbound end of platform (unless revenue collection is remote).

3.2.16.1.8.3 Provide easy access to elevator for transporting carts to/from mezzanine (2'-6" minimum corridor width).

3.2.16.1.9 #26 Police Service Room

3.2.16.1.9.1 Equipped with in-house telephone and data connectivity

3.2.16.1.9.2 Locate at mezzanine level, in a place where an injured or arrested person can be taken, where reports can be filed by Metro Police, and where VIPS can gather for a briefing.

3.2.16.1.10 #27 Emergency Tunnel Evacuation Cart Storage Room

3.2.16.1.10.1 Locate at inbound end of platform.

3.2.17 Station Plumbing and Maintenance Rooms:

3.2.17.1 All plumbing and maintenance rooms are denoted as #9, #11-12, #13, #18 and #19 with their specific function labeled on the plans.

3.2.17.2 #9 Cleaners' Room

3.2.17.2.1 For grade or above grade stations.

3.2.17.3 #11-#12 Women's and Men's Washrooms/Bus Drivers' Washrooms

3.2.17.3.1 Shall comply with ADAAG guidelines for accessible restrooms.

3.2.17.3.2 Provide men's and women's washrooms at each mezzanine and in terminal station operators' room on platform level.

3.2.17.3.3 Provide bus drivers' washrooms as required by WMATA.

3.2.17.4 #13 Water Service Room

3.2.17.4.1 Located at mezzanine level near existing utility service.

3.2.17.5 #18 Train Operators' Washrooms

3.2.17.5.1 Men's and women's shall comply with ADAAG guidelines for accessible restrooms and be adjacent to the Train Operators' room (#17).

3.2.17.6 #19 Maintenance Room

3.2.17.6.1 One per station, usually at platform level, shall have minimum **dimensions of 12' X 12'.**

3.2.18 Station Elevator Machine Room and Escalator Control Rooms:

3.2.18.1 **#22 Elevator Machine Room** shall be 224 sq.ft. (14'-0" x 16'-0") minimum for single elevator. Machine Room must be air conditioned and heated. The air conditioner shall be Split System.

3.2.18.2 **#28 Escalator Control Room** shall be 168 sq.ft. (12'-0"x14'-0") minimum for single escalator. Control Room must be air conditioned and heated. The air conditioner shall be Split System.

3.2.19 STATION PLATFORM AND TRAINROOM ELEMENTS

3.2.19.1 Station Platform and Trainroom Items:

3.2.19.1.1 The following items are to be included on all WMATA Platforms either underground, or above ground (at grade or aerial):

3.2.19.1.1.1 Granite edge with platform edge lights

3.2.19.1.1.2 2-ft. strip of ADA detectable tiles inboard and next to the granite edge

3.2.19.1.1.3 Slip resistant paver tile floor

3.2.19.1.1.4 Telephones

3.2.19.1.1.5 Map cases

3.2.19.1.1.6 Advertising panels and dioramas

3.2.19.1.1.7 Escalators and accessible elevators to the mezzanine

3.2.19.1.1.8 Precast concrete or stainless steel and glazed parapet

3.2.19.1.1.9 Lighting

3.2.19.1.1.10 CCTV

3.2.19.1.1.11 Signage and graphics

3.2.19.1.1.12 Double-sided PIDS for all Station platform types with display screens visible from a maximum distance of 150 feet measured along any platform edge

3.2.19.1.1.13 Granite benches

3.2.19.1.1.14 Glazed shelters (above ground stations only)

3.2.19.1.1.15 Mechanical and Lighting Pylons (underground stations only)

3.2.19.1.1.16 WMATA-Approved Bomb-Resistant Trash Receptacles

3.3 UNDERGROUND STATION PASSAGEWAYS

3.3.1 Underground Station Design Principles:

3.3.1.1 The station entrance passageway is the connecting element that brings the pedestrian patron from a surface entrance or an adjacent facility to the free area of the mezzanine. In underground stations it resolves horizontally and vertically the inevitable conflict between a logical entrance point within the street grid and the required track alignment (e.g. Judiciary Square). In some stations it allows the pedestrian to pass under a major street or site obstacle (e.g. Wheaton). In some cases, the passageway contains the fare vending equipment. Minimize the passageway length and number of turns. Avoid creating dark, obscure recesses.

3.3.1.2 Passageways and other main paths of travel shall avoid using ramps as much as possible. When ramps are necessary, slope shall be less than 5%, otherwise it shall be treated as a ramp to meet ADA Requirements, with intermediate landings and handrails and will be subject to review by WMATA Office of ADA Policy and Planning.

3.3.1.3 Locate swing-type closure gates at the entrance portal. Gates shall be operable by a single person.

3.3.1.4 The surface elevator to the mezzanine for the disabled shall be located on the main entrance passageway with minimum secondary passageway length. (*The WMATA elevator passageway minimum width = 5'-0" clear, with continuous handrail on both sides*). All elevator access shall be to the free area, so that access to the platform area shall be only through the faregate array.

3.3.2 Underground Station Design Elements:

3.3.2.1 Curved concrete walls with modular reveals at 8'-0" on center, maximum, divided equally along length of passageway.

3.3.2.2 Paver tile floor

3.3.2.3 Metal panel ceiling or concrete ceiling with recessed luminaries

3.3.2.4 Continuous handrail on both sides; stainless steel except for historic stations, which shall use bronze.

3.3.2.5 Closure gate with trench drain detail

3.3.2.6 Information/advertising panels

3.3.2.7 Farecard transaction equipment (when not at mezzanine)

3.3.2.8 Map cases

3.4 STATION PLATFORM AND TRAINROOM ELEMENTS

3.4.1 Station Platform and Trainroom Items:

3.4.1.1 The following items are to be included on all WMATA Platforms either underground, or above ground (at grade or aerial):

3.4.1.1.1 Granite edge with platform edge lights

3.4.1.1.2 2-ft. strip of ADA detectable tiles inboard and next to the granite edge

3.4.1.1.3 Tile floor

3.4.1.1.4 Map cases

3.4.1.1.5 Advertising panels and dioramas

3.4.1.1.6 Escalators and accessible elevators to the mezzanine

3.4.1.1.7 Precast concrete or stainless steel and glazed parapet

3.4.1.1.8 Lighting

3.4.1.1.9 CCTV

3.4.1.1.10 Signage and graphics

3.4.1.1.11 Double-sided PIDS for all Station platform types with display screens visible from a maximum distance of 150 feet measured along any platform edge

3.4.1.1.12 Granite benches

3.4.1.1.13 Glazed shelters (above ground stations only)

3.4.1.1.14 Mechanical and Lighting Pylons (underground stations only)

3.4.1.1.15 WMATA-Approved Bomb-Resistant Trash Receptacles

3.4.2 Station Platform and Trainroom Item Modulations:

3.4.2.1 The platform and train room are modulated by the following dimensions:

ITEMS TO BE SPACED	MODULE DIMENSION	NUMBER OF MODULES
Platform edge lights on platform edge	4'-2"	144
Vault ribs / coffers / beams and columns	8'-4"	72
Public address speakers	16'-8" 25'-0"	36 24
Granite benches A/C pylons	33'-4"	18
Closed circuit TV cameras	See Section 27	See Section 27
Manholes, fire standpipes, emergency call stations, electric, convenience outlets	200'-0"	3
PIDS	See Section 3.2.10.3.1.7	See Section 3.2.10.3.1.7
Approved Bomb Resistant Trash Receptacles	Location as directed	Quantity as directed

3.4.3 Glazed Windscreen Shelters

3.4.3.1 Above Ground Stations

3.4.3.1.1 See Standard Drawings

3.4.4 Station Tunnel Doors:

3.4.4.1 Reference Design Criteria Section 15 (Structural) of this Manual: Metro Underground Structures Design for Air Pressure Caused by Running Trains.

3.4.5 Station Exit Stair Doors:

3.4.5.1 All doors in a tunnel leading to exit stairs serving as a path of egress shall be a swing-type door, 4 ft. wide by 7 ft. 2 in. high. Door assembly, including the hardware, must shall be corrosion resistant, meet the air pressure criteria and shall meet NFPA Codes 80, 101 and 130.

3.4.6 Station Roof Design Criteria:

3.4.6.1 Roof Design shall meet or exceed the strictest requirements of international, national, regional, and local building codes for wind, weather, and fire resistance with appropriate regard for safety of persons and property. Roof designs shall follow a "system approach" utilizing approved products of a single source recognized leading manufacturer to the greatest extent possible. Approved roofing designs shall incorporate quality detailing and materials for appropriateness, appearance, weatherability, ease of maintenance, protection of persons and facilities, and economy of construction.

3.4.6.2 Roof designs shall incorporate details for ease of maintenance accessibility for roofing and roof-mounted equipment while providing maximum security protection from vandalism or unauthorized entry. Particular attention shall be paid to equipment supports, equipment fluid overflow pans, roof access doors, and pedestrian traffic areas. Roofs bounded by parapet walls or curbs are preferred to control blow off of rain and snow during periods of inclement weather. Locate roof drains away from walls, curbs, parapets, penetrations, or other obstructions. Provide watershed and overflow designs, drains, scuppers, or gutters and downspouts to eliminate ponding and standing water on roof surfaces.

3.4.6.3 Avoid the use of volatile organic compounds or products, and all material subject to attack by rodents, vermin, birds, and all other pests. Provide a standing seam metal roofing system with a curved or gabled profile for sloped. For low-sloped and flat roof applications either a multi-ply or a single ply membrane system may be used. These shall be fully adhered systems. If single-ply membrane system is used it shall have a minimum thickness of 1.5 millimeters and shall incorporate pedestrian access paths to all rooftop equipment. Use either pressure-treated or fire-retardant treated lumber for blocking and nailers as dictated by code.

3.4.6.4 All roofing systems shall have a minimum 30-year manufacturer's warranty.

3.5 WAYSIDE FACILITIES

3.5.1 Rail Yard Facilities

3.5.1.1 Administrative Facility

3.5.1.2 Operations Facility

3.5.1.3 Maintenance Facility

3.5.1.4 Train Wash Facility

3.5.1.4.1 All interior surfaces of the car wash area shall be protected from damage by the wash chemicals used. Coatings, penetrating sealers, protection panels, admixtures for concrete, etcetera shall be considered.

3.5.1.5 Storage Facility

3.5.2 Traction Power Equipment Facilities

3.5.2.1 Traction Power Substation

3.5.2.1.1 Access doors and/or panels to high voltage equipment shall be enclosed and protected from the elements, with a minimum of 5 feet of clearance from the access point and 2 feet to each side, for personnel safety.

3.5.2.1.2 Lighting, convenience outlets, heating and ventilation shall also be provided.

3.5.2.2 Tie Breaker Station

3.5.2.2.1 Access doors and/or panels to high voltage equipment shall be enclosed and protected from the elements, with a minimum of 5 feet of clearance from the access point and 2 feet to each side, for personnel safety.

3.5.2.2.2 Lighting, convenience outlets, heating and ventilation shall also be provided.

SECTION 4 - SITE AND STATION LIGHTING

4.1 DESIGN OBJECTIVES

4.1.1 The lighting design of the Metrorail system is an integral part of the architectural concept, to provide comfort, safety and accessibility to patrons, as well as lighting system reliability and efficiency. Visual coherence and integrity have dictated color compatibility between different luminaires, and freedom from visual noise, such as disorderly light patterns or overly bright lamps. Minimum maintained illumination levels have been based on the locations and functions of the various areas in and around the stations. Careful consideration must be taken in the design of lighting systems regarding ease of maintenance for servicing of the luminaires and with particular attention to the access and dimensional limits of servicing equipment.

4.1.2 Lighting design and installation shall be closely coordinated with the following:

4.1.2.1 ADA Regulations

4.1.2.2 Landscaping and Architecture

4.1.2.3 Safety & Security Requirements

4.1.2.4 CCTV Systems

4.1.2.5 Maintenance

4.2 EXTERIOR SPACE SITE LIGHTING - DESIGN ELEMENTS & APPLICATION

4.2.1 The lighting for parking lots, kiss-and-ride areas, bus loading areas, pedestrian walkways, station entrances and other supporting facilities shall provide for amenity and safety of the user. The arrangement of the lighting shall make both pedestrians and drivers aware of the organization of the station by providing visual information for maximum clarity. The lighting shall be arranged as a lead-in to the station entrance.

4.2.1.1 As the organizational focus, the entrance area shall be well-lit within a 30 ft. radius from the entrance or the parapet wall of the stair/escalator well. Disturbance of the neighborhood through glare and light spillage shall be avoided.

4.2.1.2 The sense of security in a parking lot is increased when the perimeter is well-illuminated; therefore all perimeter conditions shall be continuously illuminated, in addition to the minimum interior illumination of each lot. The maximum-to-minimum lighting level ratio shall be low to avoid overly bright spots, which make the overall average illumination appear darker. The site lighting luminaire layout and photometric performance shall provide illumination with average-to-minimum illumination ratio of 4:1, and maximum-to-minimum illumination ratio of 8:1.

4.2.1.3 Close coordination is required between the outdoor lighting and landscaping disciplines to avoid problems such as conflicting layouts of luminaries and trees, and tree shadows over parking spaces and drive aisles.

4.2.1.4 All site lighting luminaires shall minimize backlight, uplight and glare in accordance with IES TM-15-11. All lighting design projects at environmentally sensitive areas as define by local jurisdictions shall conduct light pollution and glare studies utilizing a 3-dimensional lighting model for evaluation by WMATA.

4.2.2 WMATA Site Lighting Poles by Location (refer to WMATA standard drawings):

4.2.2.1	Parking Lots (Park & Ride, Kiss & Ride)	97G-25 & 97G-40
4.2.2.2	Walkways	97G-15
4.2.2.3	Station Entrance	97G-10 & 97G-15
4.2.2.4	Bus Platform	97G-15
4.2.2.5	Roads (including bus loops)	97G-25

4.2.3 Parking Structure Lighting: Refer to the Design Criteria Section 2 and Table 4.5.1 of this Manual for lighting requirements in Parking Structures.

4.2.4 Parking Lot Lighting: Parking lots shall be illuminated by a combination of 97G-25 and 97G-40 light poles and solid-state luminaries of the type, configuration and distribution as required to meet Table 4.5.1. All the luminaries in a station's parking areas shall be by the same manufacturer. The 97G-25 light poles shall be located at the perimeter of parking lots and along driveways and the 97G-40 light poles shall be located in the main parking lot interior.

4.2.5 Pedestrian Walkway and Station Entrance Lighting: Walkways shall be illuminated by a combination of 97G-10 and 97G-15 light poles and solid-state luminaries of the type, configuration and distribution as required to meet Table 4.5.1. The primary purpose of the 97G-10 luminaries shall be to provide direction and orientation, and to delineate pedestrian access to the station entrance. The 97G-15 light poles shall be used for perimeter and site access pedestrian walkways. At elevator and escalator entrances, illuminance levels shall be in accordance with ASME A17.1, Safety Code for Elevators and Escalators.

4.2.6 Bus Platform: Bus platforms shall be illuminated by 97G-15 light poles and solid-state luminaries of the type, configuration and distribution as required to meet Table 4.5.1. Covered pedestrian walkway canopies shall be illuminated by indirect high-efficiency fluorescent or solid-state luminaire of the type, configuration and distribution as required to meet Table 4.5.1 and shall be mounted to the canopy structure.Bus Shelter Lighting: Bus shelters shall be internally illuminated by solid-state luminaries of the type, configuration and distribution as required to meet Table 4.5.1.

4.2.7 Parking Access & Bus Roadway Lighting: Roadways shall be illuminated by 97G-25 light poles and solid-state luminaries of the type, configuration and distribution as required to meet IES, RP-8, Recommended Practices for Roadway Lighting. The design must be appropriate for the site and must provide the level and uniformity of light suggested by IES. The recommended design values represent the minimum maintained average lighting level. Facilities may be designed with higher average lighting levels, but must provide the required uniformity. In all cases, WMATA must approve the higher lighting levels.

4.2.8 Structured Bus Bays and Structured Kiss & Ride Area Lighting: Structured Bus Bays and Structured Kiss & Ride areas shall be illuminated by surface or pendant-mounted solid-state luminaires of the type, configuration and distribution as required to meet Table 4.5.1. Luminaire layout shall mitigate shadows cast by buses so as not to reduce the required illumination levels on bus platforms or pedestrian walkways. Luminaries shall be specifically designed to not cause glare and shall shield light source from driver's eye.

4.2.9 Lighting Controls: Refer to Design Criteria Section 13 of this manual for site lighting controls.

4.2.10 Site Lighting Retrofit: All applicable lighting design elements and applications of this manual shall be utilized to greatest extent possible for all site lighting retro fit projects at existing stations.

4.3 UNDERGROUND STATION LIGHTING - DESIGN ELEMENTS & APPLICATION

4.3.1 In order to achieve a comfortable ambiance, an indirect and direct lighting system shall be used. Wherever possible, the lighting shall be integrated with the structure and furnishings to conceal the light sources. The indirect lighting is intended to minimize "visual noise" from discordant sources and patterns. It is especially important to light the trainroom vaults, because the perception of a space is dependent upon its illumination, and the perception of light itself is based on the brightness of surfaces in the visual field .Even if the platform is well illuminated, dark walls will give the train room a gloomy appearance.

4.3.2 Side-Platform Underground Station Lighting: The trainroom vault shall be illuminated by continuous, warm-white luminaries located behind the platform parapets and in the louvered trough under the safety walk between the tracks as required to meet Table 4.5.2.Platform edge lights shall be provided in conformance with WMATA Standard Drawings and Design Criteria Section 13 of this Manual.

4.3.3 Center-Platform Underground Station Lighting: The trainroom vault shall be illuminated by continuous, warm-white luminaries located in the louvered trough under the safety walks along the sides of the station, and luminaries mounted in the top of the pylons as required to meet Table 4.5.2. Recessed, direct luminaries shall be located under the mezzanine as required to maintain the illumination levels. Platform edge lights shall be provided in conformance with WMATA Standard Drawings and Design Criteria Section 13 of this Manual.

4.3.4 Underground Station Mezzanine Lighting: The trainroom vault at the mezzanine shall be illuminated by continuous, warm-white direct/indirect pendant luminaries suspended from the vault ribs as required to meet Table 4.5.2. Luminaries shall have 60% indirect uplight and 40% direct downlight component with semi-specular parabolic baffle.

4.3.5 Underground Station Kiosk Lighting: Kiosks shall be illuminated by recessed, dimmable luminaries as required to meet Table 4.5.2 on the work counter for reading instruments and writing, with minimum disturbance by glare and specular reflections. Task luminaries may be utilized to supplement ambient lighting levels to meet required illumination levels. Station kiosk luminaries shall be controlled by a dimmer.

4.3.6 Underground Station Passageway Lighting: All passageways shall be illuminated by recessed luminaries as required to meet Table 4.5.2. Farecard transaction equipment shall be illuminated with recessed, wall washer luminaires as required to meet Table 4.5.2

4.3.7 Escalator Way and Station Entrance Lighting: Escalator way and station entrance walls and ceilings below ground, and enclosing walls above ground, shall be illuminated by continuous, warm-white solid-state luminaries on a controlled circuit, concealed on the incline at the two outermost escalators. Escalators shall have continuous solid-state step lights on both sides illuminating the treads in accordance with ASME A17.1, Safety Code for Elevators and Escalators.

4.3.8 Underground Station Stairway: All stairways with the exception of enclosed emergency egress stairways shall have continuous solid-state luminaires integrated in the handrail, illuminating the treads as required to meet Table 4.5.2.

4.3.9 Underground Station Elevator Lighting: Elevator entrances, alcoves and cabs shall be illuminated by warm-white solid-state luminaries, recessed or concealed in a soffit cove. Illuminance levels shall be in accordance with ASME A17.1, Safety Code for Elevators and Escalators.

4.3.10 Underground Station Emergency Lighting: Refer to Design Criteria Section 13 of this manual for emergency lighting requirements.

4.3.11 Underground Station Lighting Controls: Refer to Design Criteria Section 13 of this manual for lighting control requirements.

4.3.12 Underground Station CCTV Surveillance Lighting: The illumination levels as outlined in this manual shall be sufficient for normal monitoring requirements.

4.3.13 Underground Station Ancillary Space Lighting: Refer to Design Criteria Section 13 of this manual for ancillary space lighting.

4.3.14 Underground Station Lighting Retrofit: All applicable lighting design elements and applications of this manual shall be utilized to greatest extent possible for all underground station lighting retrofit projects at existing stations.

4.4 ABOVE GROUND STATION LIGHTING - DESIGN ELEMENTS & APPLICATION

4.4.1 Due to the limited areas of vertical surfaces, direct lighting sources shall be used to illuminate and define the shape and extent of the platform and platform canopies. The lighting sources shall be consistent with the architectural elements, and shall not compete with the building definition. Disturbance of the neighborhood through glare and light spillage shall be avoided.

4.4.2 Mezzanines and entrances lighting design shall highlight the way into the station. Where possible, walls shall be washed with light to prevent a dark, gloomy appearance.

4.4.3 Above Ground Station Platform Lighting: The platform section under the canopy shall be illuminated by warm-white, recessed or surface-mounted luminaires as required to meet Table 4.5.3.Forplatformsections without canopy cover, luminaires shall be mounted on free-standing vertical elements. Platform edge lights shall be provided in conformance with WMATA Standard Drawings and Design Criteria Section 13 of this Manual.

4.4.4 Above Ground Station Mezzanine Lighting: Mezzanines shall be illuminated by warm-white, recessed or surface-mounted luminaires as required to meet Table 4.5.3.Faregate, farecard transaction equipment, kiosk, passageway, elevator, stair and escalator lighting criteria shall meet the same design elements and application as underground stations.

4.4.5 Above Ground Station Emergency Lighting: Refer to Design Criteria Section

13 of this manual for emergency lighting requirements.

4.4.6 Above Ground Station Lighting Controls: Refer to Design Criteria Section 13 of this manual for lighting control requirements.

4.4.7 Above Ground Station CCTV Surveillance Lighting: The illumination levels as outlined in manual shall be sufficient for normal monitoring requirements.

4.4.8 Above Ground Station Ancillary Space Lighting: Refer to Design Criteria Section 13 of this manual for station ancillary space lighting requirements.

4.4.9 Above Ground Station Lighting Retrofit: All applicable lighting design elements and applications of this manual shall be utilized to greatest extent possible for all above ground station lighting retrofit projects at existing stations.

4.5 SITE AND STATION ILLUMINATION TABLES

4.5.1 Exterior Space Site Lighting (TABLE 4.5.1)

STATION AREA	AVERAGE ILLUMINATION LEVEL		MINIMUM ILLUMINATION LEVEL	
	MAINTAINED	INITIAL	MAINTAINED	INITIAL
Parking Structures: Stairs & Vestibules Ramps and Corner	10 FC	14 FC	5 FC	7.1 FC
Parking Structures: Covered Decks	5 FC (50 FC daytime at vehicle entrance/exit area)	7.1 FC	3 FC	4.3 FC
Parking Structures: Roof Decks	3 FC	4.3 FC	1 FC	1.4 FC

Parking Lots	3 FC	4.3 FC	1 FC	1.4 FC
Kiss & Ride	3 FC	4.3 FC	1 F.C.	1.4 FC
Pedestrian Walkways	3 FC	4.3 FC	1 FC	1.4 FC
Station Entrance Within 30-ft. of the Entrance or Parapet Wall	3 FC	4.3 FC	1 FC	1.4 FC
Bus Platforms	3 FC	4.3 FC	1 FC	1.4 FC
Bus Shelters	20 FC	29 FC	10 FC	14 FC
Structured Bus and Kiss & Ride Areas	5 FC	7.1 FC	3 FC	4.3 FC

4.5.2 Underground Stations Lighting (Table 4.5.2)

STATION AREA	AVERAGE ILLUMINATION LEVEL		MINIMUM ILLUMINATION LEVEL	
	MAINTAINED	INITIAL	MAINTAINED	INITIAL
Platform Open to Vault Above	10 FC	18 FC	3 FC	5 FC
	Average Luminance of Vault: 10 Foot lamberts			
Platform Under Mezzanine	10 FC	18 FC	3 FC	5 FC
Mezzanine	10 FC	18 FC	3 FC	5 FC
	Average Luminance of Vault: 10 Foot lamberts			
Kiosk	30 F	43 FC	15 FC	21 FC
Passageways	10 FC	18 FC	3 FC	5 FC
Stairs and Stairs Landings	10 FC	14 FC	5 FC	7 FC
Faregates	20 FC	28 FC	10 FC	14 FC
Farecard Vendors and Smartrip Card Dispensers	20 FC (Vertical)	28 FC	10 FC	14 FC

4.5.3 Above Ground Station Lighting (Table 4.5.3)

STATION AREA	AVERAGE ILLUMINATION LEVEL		MINIMUM ILLUMINATION LEVEL	
	MAINTAINED	INITIAL	MAINTAINED	INITIAL
Platform – Under Canopy	10 FC	14 FC	3 FC	4 FC
Platform – Outside Canopy	10 FC	14 FC	3 FC	4 FC
Mezzanine	10 FC	18 FC	3 FC	5 FC
Platform Edge, Kiosk Passageways, Stairs, Escalators, Faregates, Farecard Vendors and Smartrip Card Dispensers, Ancillary Spaces			See Table 4.5.2	

All minimum maintained illumination levels shall be measured horizontally at 3 ft. above the floor or ground, and at stair & escalator treads unless otherwise indicated in this manual or by applicable code.

4.6 STATION AND SITE LIGHTING MAINTENANCE FACTORS:

Direct lighting	0.70
Indirect Lighting	0.55
Site & Parking Structure Lighting	0.65

SECTION 5 (Not Used)

SECTION 6 - BUS FACILITIES

6.1 Facility Types

6.1.1 A modern bus maintenance facility is classified as a Level I, II, or III, depending on the kind of maintenance and servicing provided:

6.1.1.1 **Level I.** A primary service facility providing running maintenance and storage. Activities include fueling, washing, fare collection, lamp replacement, wiper-blade replacement, fuel-level checks, etc.

6.1.1.2 **Level II.** A secondary maintenance facility, sometimes called an inspection garage for light maintenance, i.e., engine tune-ups, lubrications, inspections, tire changing, brake repair, and minor body work, as well as unit change out.

6.1.1.3 **Level III.** A tertiary maintenance garage that is basically a full maintenance garage. Activities include engine and transmission rebuilding, testing, major body repairs, painting, etc.

6.1.2 Most modern bus maintenance facilities are a combination of Levels I, II, and III. A typical large city or regional bus transportation system generally has a large central Level III shop served by satellite combination Level I and II garages. The central shop provides major component repair and overhaul of units shipped to it from the satellite garages. The secondary garages provide all Level I and II operations as well as unit replacement, but no major repairs. On the other hand, a small local transit company is most efficiently served by a Level I or II garage, with major maintenance sent out to contract garages.

6.1.3 This criteria is primarily for a Level II facility servicing diesel fuel buses. Section 6.27 addresses compressed natural gas (CNG) vehicles.

6.1.4 Maintainability and constructability requirements for Bus Facilities are located in Section 14.18.

6.2 Bus Service Area

6.2.1 General Design Considerations

6.2.1.1 Bus servicing is performed as a daily routine that includes fare removal, refueling, interior and exterior cleaning and some minor maintenance/fluid checks. Smooth operation of the bus servicing facilities is one of the most important functions of the entire maintenance facility because it has a direct impact on time and schedules. Service lanes must facilitate as quick a turnaround time as possible. The location and layout of all items within the service area is critical in accomplishing this goal. The following section will provide general guidelines toward that end, with the understanding they should be customized as required by the unique aspects of the specific maintenance facility under consideration.

6.2.1.2 The service lanes should be flexible enough to handle all the different models and sizes of buses in the existing fleet, as well as what is anticipated for the future. It is imperative to obtain and understand this information before designing the service area.

6.2.1.3 The service lanes should be immediately accessible upon entering the maintenance facility. The order of operation is:

6.2.1.3.1 Queuing

6.2.1.3.2 Fare removal

6.2.1.3.3 Exterior cleaning

6.2.1.3.4 Interior cleaning (usually done at the same time as fueling service)

6.2.1.3.5 Fueling and minor maintenance/fluid checks

6.2.1.4 Since fueling and washing take approximately the same amount of time, a linear (inline) design configuration provides the greatest efficiency of operation. In this design, buses can be refueled while the previous bus is being washed. The linear configuration is WMATA's preferred design for service lanes.

6.2.1.5 While WMATA's preferred standard facility houses the service lanes and maintenance area in the same building, the linear design allows for the entire servicing lane operation to be housed in a separate building from the maintenance operation if, because of site issues, that juxtaposition is deemed appropriate. Another variation used by some transit operations is to completely segregate washing from the other service lane activities. In the linear configuration, service lanes can act like wind-tunnels. Spray from washers can blow back through the servicing area, making an unpleasant working environment in cooler weather. Serious consideration should be given as to which of these variations is appropriate dependent upon wind and weather conditions, the specific site configuration and the specific operational requirements of the individual facility under design.

6.2.1.6 The number of service lanes required is determined by a combination of the total number of buses serviced by the facility and the amount of time allocated to this activity. To assist in this determination, it should be noted that based upon an operational average of six(6)minutes to wash a bus, ten (10)buses in one lane can be washed in one (1) hour. As a general planning rule, one (1) service lane can service one hundred

(100) buses per day. Additionally, one (1) "spare" service lane shall be provided for each facility. This "spare" lane will be used for fare removal, fueling, fluid checks, and interior cleaning. The "spare" lane shall also be provided with adequate utility services to accommodate a future bus wash system.

6.2.1.7 Consideration should be given to providing an exterior by-pass lane that by-passes the service lane when servicing is not necessary.

6.2.1.8 Fast actuating rollup doors shall be used for service lane entrance and **exit doors.**

6.3 Interdependencies

6.3.1 The interdependencies necessary in a bus maintenance facility are based on the basic systems evident in a garage and how they relate to one another.

6.3.2 The three basic systems, illustrated in Figure 6.1, are as follows:

6.3.2.1 **System A**: Fueling / cleaning / bus storage.

6.3.2.2 **System B:** Maintenance / parts / bus storage

6.3.2.3 **System C:** Administration / drivers / bus storage.

6.3.3 **System A** consists of the fueling of a bus, a level check of oil and other fluid levels, i.e. windshield-washing fluid, engine coolant, air, etc., and interior and exterior visual checks for defects. In addition, the bus is cleaned both inside and out and then sent to a storage area. It is in this phase that vehicle fare receipts are removed from the bus and into a coin room or vault pulling area, and also where brake inspections are often made. If an electronic fluid management system is present, data from the bus is entered into that system.

6.3.4 **System B** is the maintenance area and, for a Level II facility, can be in the same building as the other systems or in its own separate building. Maintenance is either programmed maintenance based on the vehicle miles or breakdown maintenance because of vehicle failure. In either case, the need is identified in the servicing area of System A and the bus is then sent to a storage area to await maintenance. The maintenance area is the heart of any well-run transit operation. It is here that building design can affect great savings in time. A maintenance area consists of parking bays, some with work pits, others with lifts and some flat bays for doing maintenance work. Specialized areas are devoted to tires, air conditioning, degreasing, upholstering, bodywork, painting, machine shop, carpentry, electronic fare boxes, batteries, testing, etc. The maintenance areas must be readily accessible to the parts area because the mechanics are constantly working with the parts department; much efficiency is lost if ready accessibility is not provided. Finally, the maintenance area must also be convenient to the storage area, both for retrieving buses to work on as well as returning repaired vehicles to service.

6.3.5 **System C** deals with the administration of the garage and the drivers who operate the buses on the road. This system has the most interrelationship with the other systems because of the need to know and control the activities in the other systems. This is particularly true of the money removed from the buses in the servicing system and, because of the large financial investment, of parts inventory associated with the maintenance area. Typically, drivers pick up their route and bus assignments in this area or relax between routes.

6.3.6 In reviewing the three systems, it is important to note the juxtaposition of key elements as well as the elements common to more than one system. For example, the receipts, although removed in System A, are controlled by System C. On the other hand, the storage area is common to all three systems. Figure 6.1 illustrates basic relationships:

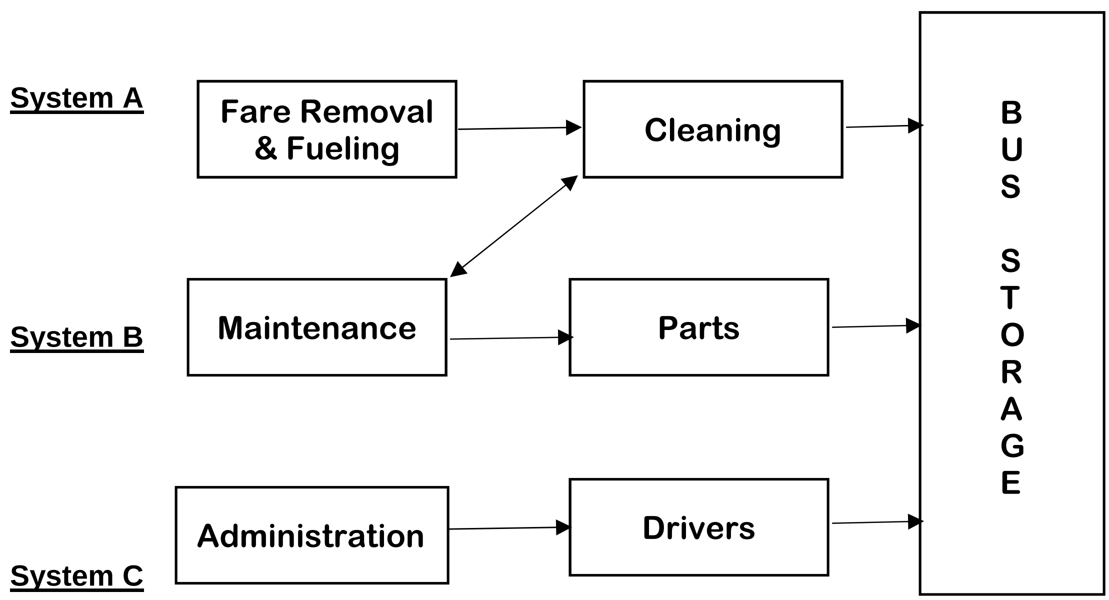

FIGURE 6.1. Bus maintenance servicing systems.

6.4 Efficiency of Operation

6.4.1 Efficiency of the operation is of paramount importance in the design of a bus maintenance facility since many of the operations are repetitive and are done time after time, day after day. Small savings in time and/or distance can have dramatic savings over the life of a facility.

6.4.2 Critical adjacencies among spaces are shown in Section 19,Figure 19.3. However, of equal importance is to design around a repair philosophy that results in having a crippled bus "down" for as little time as possible. The sooner it is back into revenue operation, the more advantageous it is to the operator.

6.4.3 Figure 6.2 shows, diagrammatically, the assembly line component repair that reflects this philosophy. The crippled bus arrives at location 1.0 and the damaged part is removed. Subsequently in 2.0 to 4.0 the part is disassembled, cleaned and sorted. A damaged, unusable part is either discarded in 4.3 or, if still under warranty, returned to the manufacturer for a new part. A serviceable part is either repaired in 5.0 or rebuilt in 6.0, and then tested in 7.0. The inventory and storage area, as a result, is critical to this operation since parts waiting for an assembly, parts replaceable under warranty, or tested assemblies waiting to be used, are constantly going back and forth.

6.4.3.1 The overall goal, in 8.0, is to have the crippled bus that arrived in 1.0, receive a new assembly in 8.0 and be back on the street as expeditiously are possible, without having to wait long periods of time to receive the proper part or assembly

6.4.3.2 Upon adoption of this philosophy and subsequent design of a facility with this in mind, an efficient operation results.

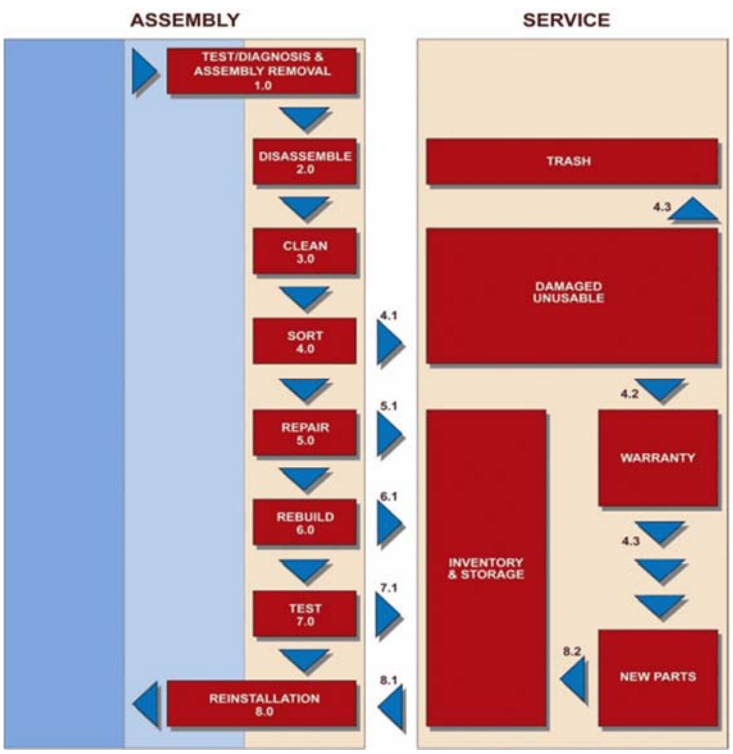

FIGURE 6.2 Component repair process.

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6.5 Climatic Considerations

6.5.1 It is important to recognize that difficulties may arise when a modern diesel engine is stored in air temperatures below 40°°F (4°°C). As a result, special precautions must be taken for buses that operate in cold climates. Storage should be inside at controlled temperatures of 50-55°^{0}F (10-13°°C), otherwise electric engine block heaters must be utilized or extraordinary means taken during cold weather, like running the buses during the night. For optimum performance, inside storage is preferable.

6.5.2 Warm-weather operations, on the other hand, are significantly different. Circulation patterns can be outside, and many of the system elements are often in separate buildings. One building might be for servicing and another for maintenance and administration. Also, the bus storage elements are generally outside. In this case, the need for shading and protecting the buses is of concern. A bus parked in the sun heats up and requires substantial running time of the engine and the air conditioning unit to cool it before placing it in service. Bus-shading elements reduce the cool-down time and associated fuel usage.

6.5.3 WMATA is located in a “border line” area. While some cold, inclement days occur they are not, generally, enough to require an indoor bus storage area. For the occasional occurrence of less than 40°°F weather, the engines may be left running. On the other hand, there are enough hot, sunny days to require shading. As a result these standards will focus on a facility that provides outdoor storage, outdoor circulation, and shading for the parked vehicles.

6.6 Vehicle Configurations

6.6.1 In the following figures 6.3, 6.4 and 6.5 the profile and dimensions of typical buses that will use this facility and provide the design standards to be shown. It is important, however, to review the actual buses that will be using the garage, paying particular attention to the vehicle mix as well as any new bus innovations. In 1999, the first “low floor” buses were introduced and they had a major impact on some garages. See Standard Drawings ST-BUS-01 through ST-BUS-05.

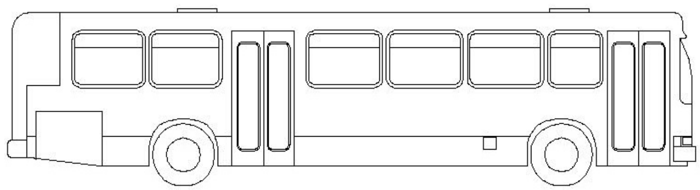

Figure 6.3

Standard Low Floor Transit Bus

Length 43'-3"

Width 11'-0"

Height 11'-5"

Outside Turning Radius 48'-0"

Inside Turning Radius 25'-0"

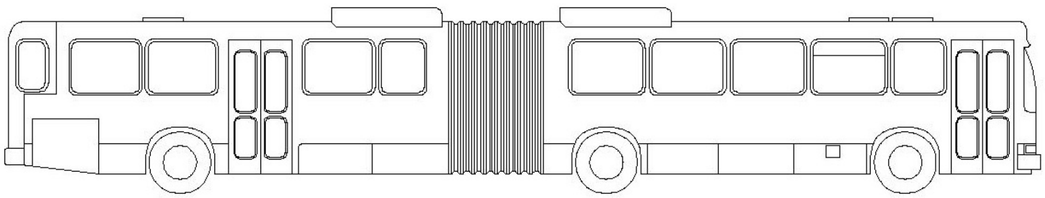

Figure 6.4

Articulated Low Floor Transit Bus

Length 66'-0"

Width 11'-0"

Height 11'-5"

Outside Turning Radius 45'-0"

Inside Turning Radius 23'-0"

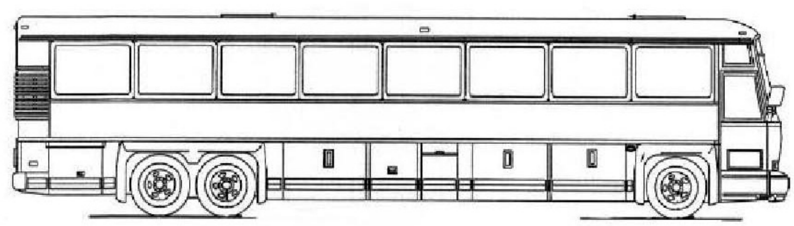

Figure 6.5

Intercity Coach Bus

Length 45’5”

Width 11'-0"

Height 11'-5"

Outside Turning Radius48'-0"

Inside Turning Radius 25'-0"

6.7 Criteria

6.7.1 Operational efficiency is the first and single most important factor in locating a bus maintenance facility. In doing so, the minimizing of deadhead time and miles is of critical importance. The time and miles necessary to reach the first stop and return from the last stop of a revenue-producing run is defined as deadheading. In the lifetime of a facility, these costs will dominate from an annual operating cost perspective.

6.7.2 To evaluate the deadhead time and miles it is first necessary to calculate, for a particular facility, the Center of Bus Operations (CBO). The CBO takes into account the number of buses and the routes they travel. The CBO is a hypothetical point which, if every bus started and finished at that point, would result in the generation of zero deadhead miles (non-revenue miles). Minimizing deadhead miles is an important factor in reducing operating costs. These reduced annual costs, can potentially offset initial adverse site development costs.

6.7.3 Site Size: The site should have a minimum area of 2.1 times the required combined area of the building, automobile parking and revenue vehicle parking. Also, it should ideally be rectangular with a 2 to 1 ratio of sides.

6.7.4 Traffic: Volume of traffic on fronting streets and adjacent intersections should not be adversely affected by the buses. Sight distances for buses entering and exiting the site should be generous.

6.7.5 Circulation: Bus circulation on the site should be predominately counter clockwise and provide an opportunity to separate vehicles by type (i.e. buses from cars from deliveries etc.). Sufficient space must be provided for turning of articulated buses. The maintenance area should be designed with a “drive through” traffic pattern to minimize the need for backing buses.

6.7.6 Utilities: Adequate utilities should be approximate to the facility and should also not have to be relocated.

6.7.7 Topography: The site should be relatively flat but still have adequate drainage.

6.7.8 Neighborhood: Zoning and land use should be appropriate and sites adjacent to residential areas, schools and churches should be avoided. The following chart on the next page illustrates zoning requirements for the areas in which WMATA operates. Local jurisdictions are to be consulted to verify zoning designation and proper land use regulations.

6.7.9 Site Contamination: Sites requiring extraordinary environmental remediation could impose substantial additional costs; on the other hand, they should not be considered “deal breakers”, since government aid may be available for clean-up of sites termed “brownfields”, and, in many cases, development of such sites has proven satisfactory.

Zoning Requirements for Bus Maintenance Facilities						
County	**Alexandria, VA**	**Arlington, VA**	**Fairfax, VA**	**Montgomery, MD**	**Prince George's, MD**	**DC**
County Website	www.ci.alexandria.va.us	www.co.arlington.va.us	www.co.fairfax.va.us	www.co.mo.md.us	www.co.pg.md.us	www.dcra.dc.gov.org
Land Use Designation	UT	Vehicle Repair & Overhaul	WMATA Facilities	Vehicle Repair & Service	Vehicle Repair & Vehicle Storage Yard	2302 Repair Garage & 2302 Parking Lot
Where Permitted	UT	CM, M1, M2	PDH, PDC, PRC	C-2, C-3, I-1, I-4	I-1, I-2	All
Where Permitted with Special Exception			R-E, R-1, I-2 - 1-6, R-2, R-MHP, C-1, C-9, I-1			

6.8 Criteria Weighing

6.8.1 After site selection criteria are known, it is important for each facility under consideration to "weight" the importance of the criteria. The weighing objectives reflect the assessment of the relative importance of each criterion with respect to other criterion. For example, Operation Costs, which continue over the life of the building, will be given more weight than Construction Costs, which occur only at the beginning of the facility's life cycle. The weight given to zoning on the other hand may reflect the individual importance on a specific site. The resulting weighing of objectives is the second factor that the sites under consideration should be evaluated against.

6.8.2 Deal Breakers" in a site selection process are always present; however, they always include operational efficiency and size. A site in the wrong location, particularly with respect to deadhead cost, will have a very high annual operating cost. A site that is too small will certainly cause major compromises.

6.9 Service Lane Queuing

6.9.1 Storage

Bus servicing can be initiated in one of two ways. The way chosen is both an operational decision and a design decision. The first way is retrieval of a bus by a hostler (facility personnel who are responsible to retrieve buses for servicing and maintenance operations and then return them to their designated parking storage locations) from a parking space where it was left by an operator at the end of his work shift. This parking space may be in the storage bays or an exterior staging area. The buses are then systematically serviced during off-peak hours. No bus awaiting service in this arrangement should extend into a street.

6.9.2 Immediate Queuing

The second way for bus servicing to be initiated is the bus operator bringing the bus directly to the maintenance facility for immediate servicing at the end of his work shift instead of to a parking area. This requires more queuing space directly on-site than retrieving buses from parking areas for servicing during off-peak hours. This space shall be exterior to the building, and should be of sufficient space to allow for peak-hour queuing.

6.9.3 Bus Facility Administrative and Operational Requirements

6.10 General Description

6.10.1 The Administrative & Operations Area consists of functions required for the smooth day to day operations of the facility. These include offices for administrators and facilities for bus operators and their supervisory personnel. This area is separated from the maintenance area, with particular attention given to relationships between dispatchers, bus driver's day room, bus parking, employee parking and locker room facilities.

6.10.2 Functional Space Descriptions

Space requirements for this area are dependent on the fleet size and level of management at the particular facility. Refer to Section 18 for further elaboration in this regard. In general adequate space for the following shall be provided:

6.11.1.6 Dispatcher Room: The daily routines of the bus system are conducted by the dispatcher. These include the dispatching of bus drivers, route schedules and record keeping. The dispatch room shall have direct visual contact with buses entering / leaving the facility and the bus storage area.

6.11.1.7 Day Room: This room is the place where the bus drivers report for duty, spend off time between runs, prepare necessary reports and have meals. Typically it is divided between an active area and a more quiet space. Allocation of 15 sq. ft. per person for this area is adequate. In addition, space for kitchenette and vending machines shall be planned. The Day Room is adjacent to the dispatcher, separated by a pass thru window. The dispatcher should also be able to view the entire space. There should be easy access from employee parking, bus parking, locker and toilet facilities.

6.11.1.8 Supervisor Room: Shall be located convenient to their area of supervision and their office shall include some degree of privacy for consultation purposes.

6.11.1.9 Lockers and Toilet Facilities: Separate facilities for male and female management and male and female hourly employees are required. Female facilities shall be designed for expandability to a 50/50 male/female ratio, where initial requirements are for less than this ratio.

6.11.1.10 Training / Conference: These spaces may or may not be combined depending on the facility size, larger facilities tending to have separate spaces. The rooms should be sized at 15 SF per person. Acoustical and climate control within the room shall be carefully considered and acoustical separation from adjoining rooms is essential. Lighting of the room shall be designed to function for the type of presentations intended. Within the training room considerations for bus simulation equipment may be necessary.

6.11.1.11 Facility Manager's Office: Office shall be adequately sized to provide space for the necessary furnishings. Should provide for closed door private conversations. Offices for general managers shall be designed to provide space for small meetings within the room.

6.11.1.12 General Office: This space is sized according to the level of management of the facility. The Administrative and Clerical Personnel are the space users and should be located conveniently to all upper management.

6.11.1.13 Storage: Rooms and areas for storage shall be carefully considered for size and conveniently located according to need.

6.11.1.14 Furniture Requirements: The following chart represents the types of furnishings that are normally found in the different types of spaces. Quantities and specific types need to be decided during program development of the specific facility.

	SPACE TYPE										
Equipment	Manager Office	General Office	Dispatcher	Day Room	Supervisor	Conference Room	Training Room	Storage	Drivers Locker Room	Management Locker Room	**Remarks**
Staff Desks											
Desk Chair											
Side Chairs											
File Cabinets											
Shelving											
Wastebasket											
Large Lockers											
1/ 2 Height Lockers											
Benches											
Lunch Tables											
Café Seating											
Tackboards											
Chalkboards											
Projection Screen											

Figure 6.6 - Furniture Requirements

6.11 FARE REMOVAL

6.11.1 WMATA System: The WMATA system for fare collection is:

6.11.1.1 To have the fare removal as the first step of the service lane operation and,

6.11.1.2 To have the fare box removed from the bus and placed inside a fare box collection unit, the money is removed, the empty fare box is immediately replaced in the bus, and the bus continues on for service.

6.11.1.3 2 CCTV camera/vault.

6.11.2 Fare Box Maintenance Area (Electrical Shop): A Fare Box Maintenance Room, shall be located parallel to the fuel dispensing station. The Fare Box Maintenance Room shall be a secured minimum 20’ x 20’ space and shall be separated with a masonry wall for security reasons. All windows in the Fare Box Maintenance Room shall have bullet-resistant glass and should be alarmed. Access doors should also be alarmed for security reasons. The room shall be provided with sufficient work benches, electrical power for computers, security camera, lighting, HVAC, electrical resistance heaters and test equipment.

6.11.2.1 Fare box collection equipment will be purchased and installed per WMATA requirements as the bus maintenance facility is constructed. Adequate space, power service and data service shall be provided. Coordinate specific requirements with WMATA.

6.12 FUELING AND MAINTENANCE FLUIDS/UTILITIES

6.12.1 Fueling: Each service lane shall have it’s own diesel fuel dispensing system, which shall be connected to the fluid monitoring system.

6.12.1.1 The fuel dispenser in the service lane shall not be located further than 50 feet from the building entrance, per NFPA 30A.

6.12.1.2 Fueling Hose and Nozzle (Revenue Vehicles): A flexible 1 inch hose and fueling nozzle with swivel feature, which operates only when connected to an adapter on the vehicle, eliminating spills and reducing odors. Include hose rest hooks to accommodate extra length hose. Nozzles shall be 8 inches long.

6.12.1.3 Overhead Tramway Fueling System: This system is an overhead suspended fueling hose and post mounted support system which allows all fleet vehicles to be refueled with one nozzle within a 20’-0” fueling envelope length, and with spill-proof separation feature in the event the refueling vehicle moves away from the fuel island with the nozzle still attached. Install with 12’-0” minimum clear height and 4’-0” from edge of fueling lane, unless otherwise indicated. Included with the system shall be one (1) stainless steel 24” desk top, which is mounted on one of the support posts.

6.12.1.4 Fuel Dispensing Pump: This is a traditional mechanical registration type dispenser, and accommodates twin hoses as required by WMATA. One for revenue vehicles and one for non-revenue vehicles, which shall be fitted with a standard fueling nozzle. Include provisions for connection to fluid management system, filter and vapor recovery.

6.12.1.5 Controls: The transfer of diesel fuel from storage tanks to the dispensers shall be regulated from one of two control cabinets. The main control cabinet shall be located as directed by WMATA. A remote control cabinet shall be located in the fueling area. This cabinet shall include a “mushroom” panic button to shut down the system in case of emergency. Level indication should be here also.

6.12.1.5.1 The main control panel shall be self contained and shall include the following:

6.12.1.5.1.1 Starters and circuit breakers

6.12.1.5.1.2 H-O-A switches for each pump

6.12.1.5.1.3 Test switches

6.12.1.5.1.4 Running lights – indicators for each pump

6.12.1.5.1.5 Required switches for the remote control panel

6.12.1.5.2 The remote control panel shall include running light indicators, selector switch and low tank level indicators.

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6.13.2 Storage Tanks

6.13.2.1 Underground Storage Tanks

6.13.2.1.1 The diesel gasoline and other fluid systems shall conform to the latest requirements of the N.F.P.A., the EPA, CENF, and all state and local codes, including the District of Columbia Fire Department. All underground fuel and fluid storage tanks shall be located outside the building. While an underground location is preferable from a safety and security perspective, the environmental implications must be considered. WMATA'S facilities typically utilize underground tanks for all fuel and fluids except, where possible, above ground storage tanks are used.

6.13.2.1.2 Gasoline fuel is prohibited by N.F.P.A. from being stored or dispensed inside the building.

6.13.2.1.3 A popular storage capacity in the past was 150 – 200 gallons per bus which would be equivalent to four to six days of normal operation for buses realizing 5 miles per gallon. Economics and today's fuel situation has altered that parameter. The following are average storage capacities for a 150 bus maintenance facility:

6.13.2.1.3.1 Diesel Fuel: 2 – 20,000 Gallon Storage Tanks

6.13.2.1.3.2 Engine Oil: 2 – 3,000 Gallon Storage Tanks

6.13.2.1.3.3 Automatic Transmission Fluid: 1-6,000 Gallon Storage Tank

6.13.2.1.3.4 Engine Coolant: 1– 6,000 Gallon Storage Tank

6.13.2.1.3.5 Gasoline (Non-Revenue Vehicles): 1– 8,000 Gallon Storage Tank

6.13.2.1.4 All fuel and fluid storage tanks shall be constructed of double-wall fiberglass in accordance with UL 1316, and shall be connected to the fluid monitoring system (See Section 6.16.). All piping shall enter the tank through a man way. Each tank shall be provided with the following:

6.13.2.1.4.1 Two watertight man ways

6.13.2.1.4.2 Mechanical high level cut-off valve

6.13.2.1.4.3 Interstitial and man way leak detection

6.13.2.1.4.4 Positive displacement flow meter.

6.13.2.1.4.5 Inventory control and high level alarm systems

6.13.2.1.4.6 Fill cap with 15 gallon, below grade catchment basin vent connections

6.13.2.1.4.7 Overfill prevention (fill limiter valve and audible alarm)

6.13.2.1.4.8 Individual service access for all functions.

6.13.2.1.5 Roadway manhole covers over the man ways shall be constructed of fiberglass and have an H-20 rating. The covers shall be configured to prevent water entry.

6.13.2.1.6 The leak detection system shall be connected to an audio visual alarm at a 24-hour manned location. The over-fill alarm shall be connected to an audio visual alarm mounted near, and in sight of, the fill box.

6.13.2.1.7 Buried tanks containing petroleum products (diesel, gasoline, oil, etc.) shall be within a structure that prevents any transfer of surface loads to the fiberglass tanks. The District of Columbia Fire Department or other authorities outside of the District shall approve the design and inspect the installation.

6.13.2.1.8 Underground storage tanks containing flammable or combustible liquids shall be buried not less than 2 feet below grade. Underground storage tanks shall be located a sufficient distance from the facility per applicable code, Fire Marshall and Insurance carrier requirements.

6.13.2.1.9 The underground storage tanks shall be vented separately to the exterior. The vent shall discharge not less than 12 feet above the adjacent ground level and terminate with a vent cap to minimize the effect of weather and air borne dirt. The vent discharge point shall not be closer than 15 feet from any operable building opening or outside air intake.

6.13.2.1.10 All underground piping shall be double-wall fiberglass, sloped toward the tank. Piping that cannot be sloped shall be provided with a point type or long line leak detection system. Fill lines shall be provided with flow meters and spill containment with a hinged roadway cover. The flow meter shall have remote readout mounted in the Superintendent's office.

6.13.2.1.11 Underground storage tank areas shall be paved over so delivery trucks have easier access and do not block bus circulation.

6.13.2.1.12 Pumping System: One submersible pump shall be provided with each storage tank. The diesel fuel pumps shall be manifolded and shall be connected and valved so that each pump may feed any or all of the diesel fuel dispensers. A filtration system consisting of dual filters and a water separator shall be provided in each fuel dispenser line. An emergency, mushroom style, shunt-trip switch shall be located on the facility wall such that in the case of an emergency power will be cut to all underground storage systems. The emergency shut-off switch will be located not greater than 75 feet from the dispensers. The diesel pumps shall have a capacity of 50 GPM and the gasoline pump (if required) shall have a capacity of 10 GPM.

6.13.2.2 Above Ground Storage Tanks.

6.13.2.2.1 If above ground storage tanks are used for maintenance fluids (not including diesel fuel), and are located within the building, they shall be located in a 2-hour rated lubrication room. The amount of fluid stored in this room shall not exceed 10 gallons per square foot. This room shall not exceed 500 square feet in area and shall have the floor slab depressed a minimum of 4" from the surrounding floor slab. All joints in this room must be fluid-tight. In lieu of a 2-hour room, 2-hour rated tanks, UL rated 2085, may be used, if allowed or if required by the local fire Marshall and code officials.

6.13.2.2.2 All above ground fuel and fluid dispensing piping shall be schedule #40, black steel. Fitting and valve classification shall be as appropriate for the pump discharge pressure plus 25% but in no case less than class 150. All above ground fuel and fluid dispensing piping shall be painted in accordance with WMATA's standard color code. The fuel and fluid dispensing piping shall be further identified with plastic pipe markers, which will also indicate the direction of fluid flow.

6.13.2.2.3 Maintenance fluids typically stored in the building in above ground tanks would be engine coolant, automatic transmission fluid, new engine oil and used engine oil. These tanks would be connected to the overhead service reels. The remaining maintenance fluids would typically be stored in multiple 55-gallon drums on spill-pallets. These would be chassis grease, gear oil, windshield washer fluid, and wheelchair oil. These drums would be connected to the overhead service reels.

6.13.2.2.4 Used oil recovered from the buses shall be stored in an above ground used oil storage tank of minimum 2000 gallon capacity. The tank shall be double wall steel with a corrosion resistant coating and a 2 hour fire rating (UL 2085). The tank unit shall include primary tank, secondary containment chamber, leak detection system, vent, pump, suction tube, discharge hose and shall be furnished with roll collection caddys. The tank and fittings shall conform with NFPA 30, 30A and UL requirements.

6.14 OVERHEAD SERVICE REELS

6.14.1 The following maintenance fluids and utilities shall be provided by means of properly labeled overhead service reels at each fueling station in the service lane:

6.14.1.1 Engine coolant (EC)

6.14.1.2 Automatic transmission fluid (ATF)

6.14.1.3 Compressed air (CA)

6.14.1.4 Engine oil (EO)

6.14.1.5 Water

6.14.1.6 Chassis grease (CG)

6.14.1.7 Gear oil (GO)

6.14.1.8 Windshield washer fluid (WWF)

6.14.2 Overhead service reels shall be of heavy duty double pedestal frame design, spring powered and self-retracting constructed from non-sparking alloy for use in fueling environments. .

6.14.3 Hose

6.14.3.1 CA & WWF - 65' x 3/8" ID 300 psi pressure rating

6.14.3.2 GO, ATF & EC - 50' x ½" ID 2000 psi pressure rating

6.14.3.3 CG - 50' x 3/8" ID 4000 psi pressure rating

6.14.4 All piping shall be as described previously in Section 18.4.2.2 for above-ground storage tanks.

6.14.5 All fluid transfer pumps for overhead service reels shall be air driven, self-priming positive displacement pneumatically operated pumps. Provide pumps capable of mounting on top of 55 gallon drums where used. Provide controls to automatically start and stop pumps when fluid is required at the overhead service reels. All pumps to operated below OSHA noise standards.

6.15 CLEANING

6.15.1 Bus Interior Cleaning

6.15.1.1 Methods / Equipment

6.15.1.1.1 In the linear (in-line) service lane design, the interior cleaning of the buses is done as part of the service lane operation. This interior cleaning is done by means of a 4" diameter hose vacuuming system, and is done at the same time the bus is being fueled.

6.15.1.1.2 Portable air blowers are used by the workman to sweep the seats and floor to dislodge dirt, papers and other debris which will be drawn into the vacuum hose and deposited into a portable dumpster. The transportation air then passes thru a secondary filter to remove particulate matter prior to its return to the building space.

6.15.1.1.3 The Vacuum shall be designed to provide for the collection of debris in dry form and discharge after compaction of same into a loading dumpster of the type presently used. Provisions shall be made for minimizing the exhaust of dust inside the building through double filtration. 100% of the air input shall be returned to the garage area.

6.15.2 Bus Exterior Cleaning

6.15.2.1 Methods and Equipment Options

6.15.2.1.1 Bus washing is the final element of the service cycle prior to parking the bus in its storage space. Preferably there is one bus washer unit per service lane. One washer unit may serve more than one service lane, but adequate space must be provided to by-pass or line up a bus for the washer. If fewer washers than service lanes are provided, the lanes without washers should be provided with piping and wiring to accommodate the addition of a future washer unit.

6.15.2.1.2 Provide the bus washer as part of the service lane operation and to provide one washer unit per individual service lane.

6.15.2.1.3 There are several alternatives available in regard to type and operation of bus washers. Minimum Automatic Washers have a rotating brush and water spray side-washing capability. Complete automatic washers have additional front and rear capability with rotating brushes that move across the front and rear as the bus progresses through the device. The roof washer is usually a wet mop, however, a rotating brush is available. Wheel washers consisting of a high pressure water spray are sometimes used.

6.15.2.1.4 There are two types of automatic bus washer systems commonly available, the Drive Thru type and the Gantry type. The Drive Thru System is the type generally used at a service island. Following fuel servicing and vacuum cleaning, the bus is driven slowly thru the washer. Upon leaving the washer, if a stripper has been made part of the system, it will dry off the bus with high velocity air prior to the bus being parked**.**

6.15.2.1.5 When a Gantry System is employed, generally for fleets with 35 buses or less, the bus is driven to the Gantry location and parked between guide rails. Adjacent to the guide rails is tracks on which the Gantry travels. Adjacent to the tracks is usually a wall on which a traveling umbilical is mounted which supplies air, electric and water to the Gantry. The Gantry contains side and top brushes. When the start button is pushed, the top brush lowers itself to a position a few inches above the floor and the machine moves toward the vehicle traveling along the tracks. The Gantry moves along the length of the vehicle with the vertical brushes cleaning the sides and the top brush cleaning the front, roof and back of the vehicle. During this cycle water and soap are sprayed on all surfaces. On its return pass the vehicle is rinsed with fresh water while the brushes counter-rotate. At the end of the rinse cycle all brushes automatically move aside to allow the vehicle to be drive away.

6.15.2.2 Drive Through Bus Washing System and Equipment: The drive thru type with a blower/dryer assembly and water reclamation system shall be as follows**:**

6.15.2.2.1 Operations: Washer components shall be automatically actuated in sequence by vehicles, primarily transit buses, driven in centered path between tire guides, at a nominal speed of 1.0 to 1.5 feet per second through wash washing stage without stopping. Entry shall be through a pumped pre-wetting/detergent application cycle, progressing through a brush washing cycle which shall effectively scrub all vertical body surfaces of front, sides and rear of vehicles including windshield and windows, using a minimum of four vertical rotary brushes, each equipped with detergent spray applicators. Effective washing of the horizontal and curved portions of the vehicle roof shall be by a full width oscillating mop augmented by a detergent spray applicator. Final rinse of the front, roof, sides, rear and wheels shall be by a canted rinse spray assembly. All equipment including piping, conduits, support devices, etc contained in this area or routed through this area to be of corrosion resistant material.

6.15.2.2.2 Major Components: Complete system shall include the following major components.

6.15.2.2.3 Automatic Controls: Vehicle actuated switch gear including prewired electric control panel and manual override controls. The bus wash shall be operated through an operator interface touch panel (HMI). The panel shall be connected to the WMATA Local Area Network for remote monitoring, alarm notification, and connectivity to the building information system. The HMI shall contain screens for diagnostic and analytical purposes to include but not limited to: all elements that automatically stop the operation of the system, pump or equipment run times for each pump, rotating brush etc., total number of successful wash cycles and number of incomplete cycles, number of successful cycles per day, gallons of water used and gallons of water discharged, gallons of detergent used, alarms or warnings for filter and backwashing status, event manager logs for every input.

6.15.2.2.4 Tire Guides: Full length, one pair min. 4" dia. tubular galvanized steel with capped ends and no breaks or edges which could damage tire sidewalls.

6.15.2.2.5 Skid Plates: One pair, flat 3/16" stainless steel mounted flush to slab. Angled entry section of tire guide shall minimize tire sidewall damage caused by resistance to lateral movement resulting from misaligned entry to vehicle washer. Plates to be nominally 3 feet wide tapering with tire guide angled to 2 feet wide at entrance to straight section of tire guides.

6.15.2.2.6 Pre-wetting/Detergent Spray Arch Assembly: Automatic, frame mounted, freestanding unit, positioned to provide optimum detergent penetration before brush wash cycle begins. Side nozzle pipe assemblies shall be canted away from approaching bus to provide sequential application of detergent starting at bottom and progressing to top of bus. Nozzle total output to be 20 gallons per minute at 40 psig and shall be of the quick disconnect type for easy removal for cleaning and replacement. Lowest point on each pipe to be fitted with valve to allow pipes to be fully drained during freezing conditions. Liquid detergent shall be stored in a 500 gal. poly tank.

6.15.2.2.7 Oscillating Mop: Roof mop assemblies shall be suspended from two separate frames supporting three mops each. Mops to be mildew resistant Ozite type carpet hung from galvanized steel frame. Each frame shall be hung by 2 pieces of Goodyear four ply conveyor belting (12000 lb combined pull strength). Sprays shall supply 20 gallons per minute at 100 psig lowest point to be fitted with valve for draining. High pressure spray at 90 gpm and 200 psig shall be angled to hit the fronts, hoods, wheels and windshields of the vehicles.

6.15.2.2.8 Vertical Brushes: Washing of bus vertical surfaces shall be by four electrically driven rotary brushes with integral detergent spray and supporting frame assembly. The brush yoke arm shall be curved to allow clearance for the extreme corners of the bus during the washing motion. All brush shaft and brush yoke bearings shall be protected from moisture. Movement of brush arm shall be by pneumatic cyclinders, brush yokes shall retract when power is off, permitting unobstructed vehicle passage through wash lane.

6.15.2.2.9 Rinse Spray Arch: Automatic frame mounted, free standing, fresh water unit.

6.15.2.2.10 Washer Equipment Miscellaneous: Brush yokes, support structure, columns, base plates, anchor bolts, pump, detergent storage tanks and detergent distribution system.

6.15.2.2.11 Radiant heated concrete floor slab from end of bus wash equipment to exit door. Exit shall be designed in order to reduce or eliminate ice build up on slab.

6.15.2.2.12 Water Reclamation System: As follows:

6.15.2.2.12.1 Waste water run-off from the bus washer is collected in a reticulent drain, under and parallel to the bus, and is directed to a sump-well in which grit settles out of the liquid. A pump transfers this liquid to a separate adjacent storage-well through a filter that removes most of the suspended impurities. This clarified water is then pumped back to the bus washer by a separate hi-pressure pump for reuse in the wash cycle. Fresh water make-up is provided by the final rinse arch. Also, additional fresh water is added to the clarified water in the storage well to account for water lost by evaporation and carried away by the vehicle. A separate storage-well and pump system is provided for the wheel washer system. Provide closed tanks and water recirculation to control odor accumulation.

6.15.2.2.12.2 The bus washes and water reclamation system shall be controlled through a central

HMI panel located in the Water Reclamation Area. Bus wash shall be part of the building monitoring system.

6.16 FLUID MONITORING SYSTEM.

6.16.1 The bus garage will be furnished with a fluid monitoring and leak detection system. The System shall monitor all storage tank levels and fluid usage. The monitoring system shall be computer based capable of providing but not limited to high and low level alarming, leak detection alarming, vehicle usage and mileage reports, vehicle bar code identification, pump/meter usage reports, product reports, time and date reports, inventory, inventory reconciliation and tank levels, and fleet reports. The system shall also be capable of providing remote access to allow the downloading of all the reports.

6.16.2 The system design shall be based on the Veeder Root TLS-PC system and supporting monitoring consoles and software. In addition to the level and metering devices the system shall be furnished with a personal computer, modem, report printer, Windows® based software and a stand alone monitoring consoles. All of the computer related devices and software shall be the most recent technology and releases.

6.17 PAINT PREPARATION AREA, PAINT BOOTH AND PAINT SHOP

6.23.6 Provide a paint preparation area large enough for an articulated bus to be cleaned, sanded, filled and otherwise prepared to receive new paint in the paint booth. Provide adequate space all around the bus for mechanics, materials, tools and equipment. Refer to Section 14.19 for ventilation and exhaust requirements.

6.23.7 Paint Booth: Provide a fully enclosed, prefabricated pressurized cross-draft type vehicle paint room (booth) for spray painting of buses and large trucks. Booth shall be large enough to accommodate articulated buses and shall be provided complete with fluorescent lighting, heavy duty exhaust with totally enclosed fan cooled motor, personnel access doors, product doors, manometer (draft gauge), man lift, intake and exhaust filters with grids, and all necessary hardware. Construction shall be heavy duty, of minimum 18 gauge sheet steel panels, fabricated to provide a smooth interior surface. Refer to Section 14.19 for breathing air system and further ventilation requirements.

6.23.8 Provide a Paint Shop Room adjacent to the paint booth for storage, mixing and containerizing of paints. Provide a Paint Shop Room adjacent to the paint booth for storage, mixing and containerizing of paints. Room to be ventilated and heated and contain a flammable material cabinet.

6.18 STEAM CLEAN / CHASSIS WASH BAY

Provide one fully enclosed area for steam cleaning of buses, preferably located adjacent to the lift bays and arranged for the same drive-forward-and-through-access as previously discussed. The bay shall be provided with a stainless steel parallelogram lift .Provide high pressure hot water cleaners specified above in this area. Equipment for this area to be located in adjacent area if possible in order to protected against water/corrosion. If equipment is located in bay then equipment should be shielded in order to protect it from water. This area to be provide with a hose bibb and compressed air (disconnects on wall located per detailed design). Equipment located in this area to be rated for water environment (waterproof and watertight) and constructed of corrosion resistant material. Forklift access to this area will be required.

6.19 PARTS STORAGE

Parts storage shall be provided in vertical carousel part storage systems, similar to a Kardex Remstar system. This system has a large floor load ensure that the floor slab is properly rated. Provide a secure room for parts storage, for the dispensing of replacement parts for buses and for replacement parts for maintenance equipment. This room shall contain a Paint Storage System, large parts shelving, large parts storage cabinets and small parts drawer storage. Include a service door for parts deliveries.

6.20 TIRE STORAGE

Provide a room for tire storage with enough height to accommodate vertical storage of tires and a jib crane and other tire handling equipment. Provide tire storage racks constructed of steel with typical construction as shown in Figure 6.8 below. Tire storage to be located adjacent to Tire Bay.

6.21 SECURED TOOL STORAGE

Provide an area room enclosed by a wire mesh partition with locking door, for secure storage of tools. Size of room shall be 15 by 25 feet minimum.

6.22 HVAC REPAIR SHOP

Provide an enclosed room, temperature and humidity controlled, for repairs to HVAC equipment. Size of room shall be 15 by 25 feet minimum.

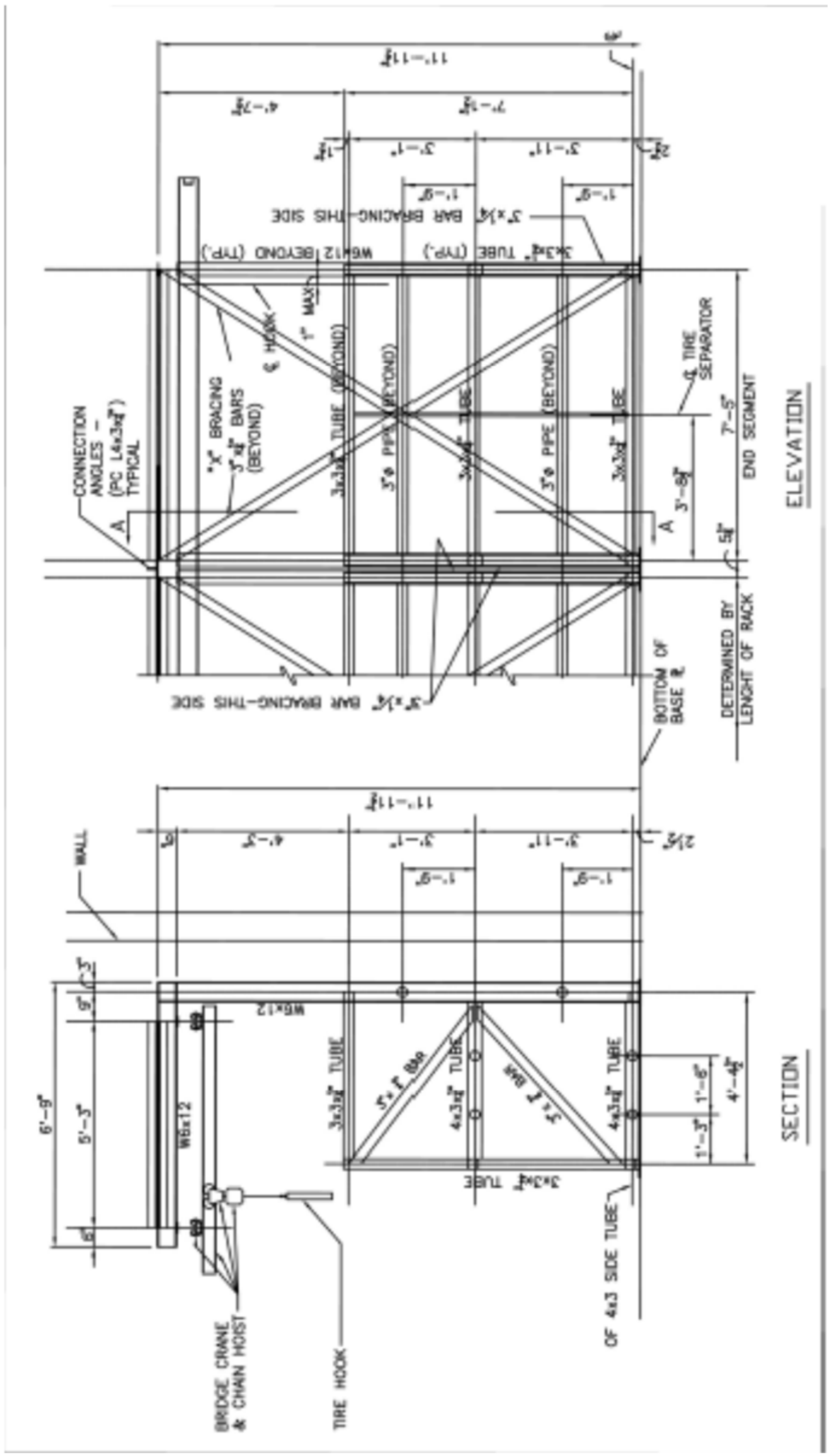


FIGURE 6.8 - Tire Storage Rack Details

6.23 TYPICAL SERVICE LANE DESIGN

6.23.1 Typical Plan Layout With Critical Dimensions: Refer to Figure 6.9 .

6.23.1.1 Design Considerations

6.23.1.1.1 Dimensional Criteria

6.23.1.1.1.1 Drive Lane Between Curbs: 12'-0" Minimum**.**

6.23.1.1.1.2 Width of island between drive lanes if only fueling equipment is located on it: 6'-0" minimum.

6.23.1.1.1.3 Width of island between drive lanes for fueling equipment and bus vacuuming system located on it: 8’-0” minimum.

6.23.1.1.1.4 Width of island between drive lanes if fueling equipment is located on it and each drive lane has it’s own bus wash unit: 12'-0" minimum.

6.23.1.1.1.5 Width of end island in service lane: 3'-0" minimum.

6.23.1.1.1.6 Width of entrance door into fueling area for a single drive lane: 15'-0" clear, minimum.

6.23.1.1.1.7 Width of single entrance door into fueling area for two drive lanes which share one bus wash unit: 30'-6" clear, minimum**.**

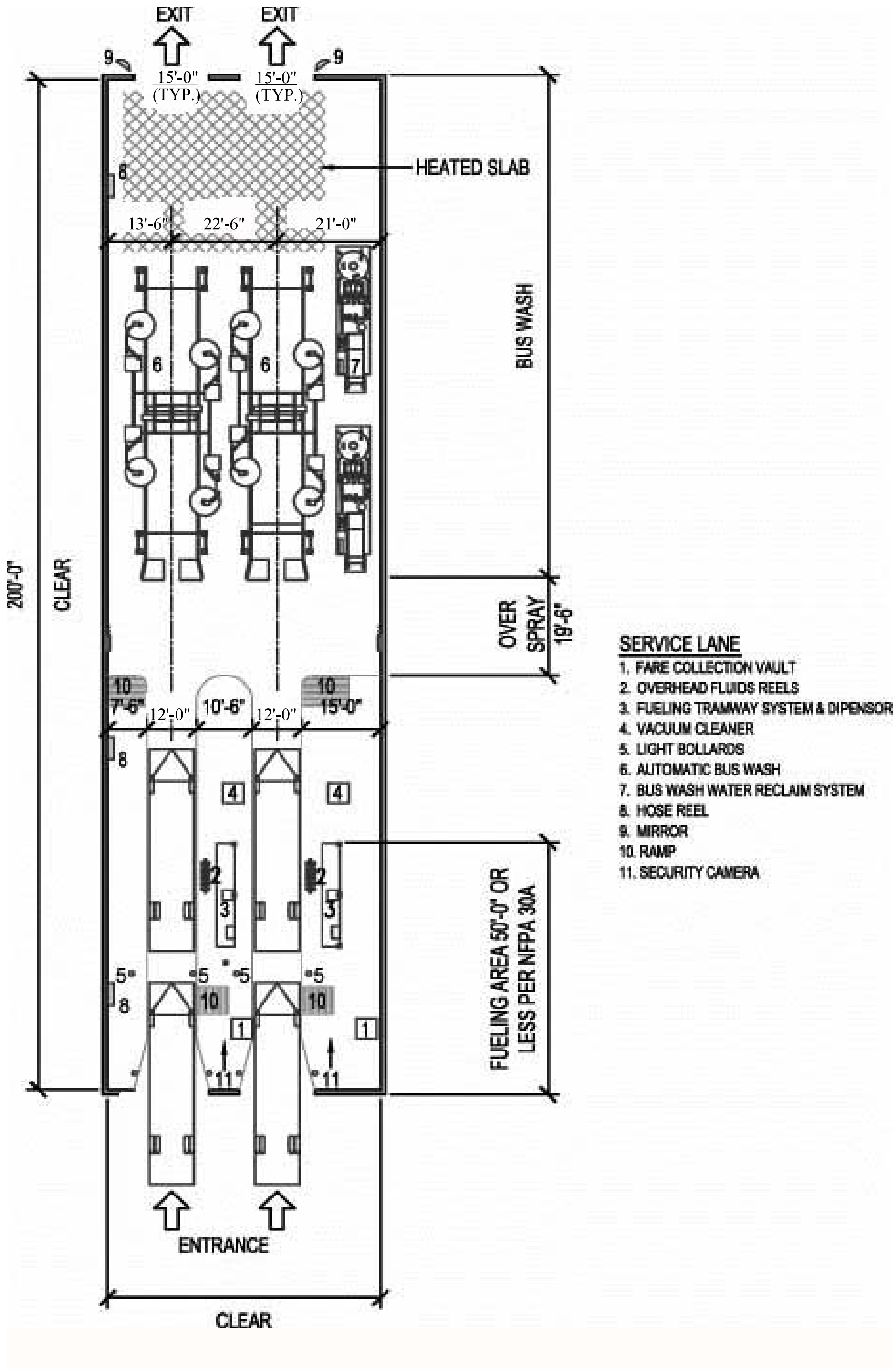


FIGURE 6.7 – Typical Service Lane

6.23.1.1.1.8 Width of entrance doors into fueling area for more than two drive lanes, each of which have it's own bus wash unit: Recommend 1 door per drive lane, each one 15'-0" clear, minimum.

6.23.1.1.1.9 Height of entrance doors: 15'-0" clear, minimum.

6.23.1.1.1.10 Minimum clear height required from the finish floor to the underside of any structure:

6.23.1.1.1.10.1 Service Lane: 16'-0" clear

6.23.1.1.1.10.2 Maintenance Lift Area: 20'-0" clear

6.23.1.1.1.10.3 Bus Storage Area (Shading): 15'-0" clear

6.23.1.1.1.10.4 Bus Parts Storeroom: 10'-0" clear

6.23.1.1.1.10.5 Paint Booth: 21'-0"clear

6.23.1.1.1.10.6 Boiler Room: 16'-0" clear

6.23.1.1.1.10.7 Electrical Distribution Room: 16'-0" clear

6.23.1.1.1.10.8 Communications Equipment Room: 10'-0" clear

6.23.1.1.1.10.9 Office Areas: 8'-0" clear

6.23.1.1.1.10.10 Repair Shops: 12'-0" clear

6.23.1.1.1.11 Dispensing Equipment: The fuel dispensing system in the service lane can not be located no further than 50 feet from the building entrance.

6.23.1.1.2 Other Design Considerations

6.23.1.1.2.1 If an exterior apron is provided for exterior queuing of buses, it should be made of concrete and be sloped away from the building.

6.23.1.1.2.2 Queuing for buses in the service lanes should be planned and laid out to insure that there is no backup into a street when buses return at their peak rate.

6.23.1.1.2.3 One service lane will service approximately 100 buses per day.

6.23.1.1.2.4 If the fleet size requires only one service lane, consider providing two service lanes for fare collection, fueling and interior cleaning with a shared bus wash unit so that the fueling operation is not shut down due to equipment failure.

6.23.1.1.2.5 Consider a by-pass lane for buses not going through the wash cycle.

6.23.1.1.2.6 Consider a direct access from the service lanes to the maintenance area, located in the area between servicing and washing.

6.23.1.1.2.7 Verify that fueling hoses on a tramway are long enough to reach all filler-neck locations, especially where interior cleaning systems may fix the location of the buses front door in the service lane operation.

6.23.1.1.2.8 All fuel and fluids used in the service lane should be connected to the fluid monitoring system.

6.23.1.1.2.9 The service area should have a non-skid surface on the floor slab. Refer to Room Finish Schedule in DD Drawings (DD-ASC-003 thru DD-A-SC-007).

6.23.1.1.2.10 Service islands should be elevated at least 4" above the floor slab. This dimension needs to be coordinated with requirements for low-floor buses.

6.23.1.1.2.11 Provide pipe bollards filled with concrete for protection of all service islands and service lane equipment.

6.23.1.1.2.12 Provide pipe bollards with flood lighting mounted on top or drop lighting suspended from the structure above to illuminate the engine compartment when the bus is located in the fueling/interior cleaning position.

6.23.1.1.2.13 Equipment on the service islands should be placed so that it clears the projecting rear-view mirrors on the bus as it passes the equipment.

6.23.1.1.2.14 Depending on the exiting configuration of the service lane, consider placing mirrors on the exterior of the building to facilitate the driver's vision and provide safe exiting from the service lane.

6.23.1.1.2.15 Vacuum system could be a central unit serving multiple service lanes or individual units for each service lane.

6.23.1.1.2.16 Consider preheating exterior buses during the fueling operation in cold weather so water does not freeze on the buses during the wash cycle.

6.23.1.1.2.17 Gasoline storage or dispensing is not allowed in the building.

6.23.1.1.2.18 Entrance door operation for the service lanes shall be high speed doors rollup fast actuating type.

6.23.1.1.2.19 Modify service lane design as required if articulated buses are to be serviced.

6.23.1.1.2.20 Sufficient distances between service and washing equipment should be provided to prevent water misting from the bus wash unit from drifting into the service area.

6.23.1.1.2.21 Provide a continuous trench drain from the beginning of the bus wash unit to the end of the blower dryer assembly. Connect drain to water reclamation system.

6.23.1.1.2.22 The plumbing system for the floor drainage shall include an oil/water separator as a part of the design.

6.23.1.1.2.23 Slope the slab on grade to the floor drains.

6.23.1.1.2.24 Provide a men's and women's toilet room and utility closet near the service lane for use of the service lane personnel. The toilet rooms shall be accessible. In the men's room, provide a water closet, urinal, lavatory, toilet paper dispenser, paper towel dispenser and soap dispenser. The women's room shall have two (2) water closets, a lavatory, toilet paper dispenser, paper towel dispenser and soap dispenser. The utility closet shall have a service sink and have shelving to stock toilet room supplies.

6.23.1.1.2.25 Luminaries, motors, etc. are to be water tight.

6.23.1.1.2.26 Proper lighting should be provided, both in regard to location and color-correction, in order to read the gauges of the fluid levels.

6.23.1.1.2.27 All electrical devices in the service lane area shall be specified as waterproof devices.

6.23.1.1.2.28 Provide overhead service reels in the service lane.

6.24 MAINTENANCE AREA

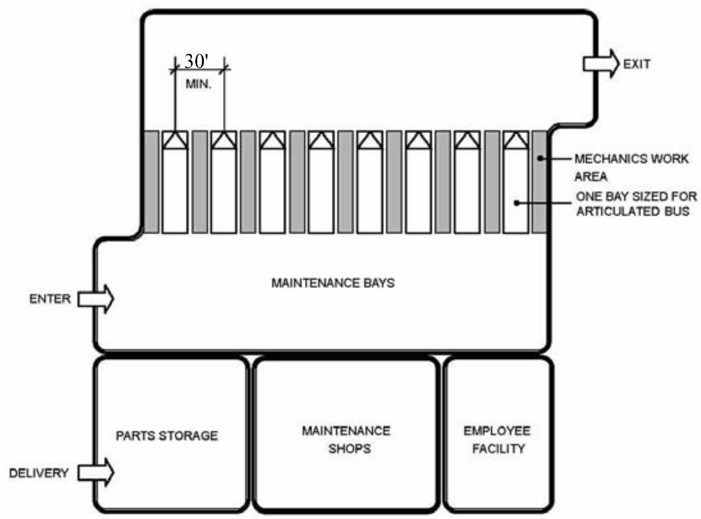
6.24.1 Introduction

6.24.1.1 This section describes circulation, spatial and equipment requirements for the maintenance area, which is the area provided for the servicing and repair of buses with specific maladies which are outside the realm of the service lanes. Such servicing and repair includes, but is not limited to tune-ups, lubrication, parts replacement, tire repair and replacement, and body repairs and painting.

6.24.2 Vehicular Traffic Pattern

6.24.2.1 Pull-In and Drive Through Service: WMATA requires that buses requiring maintenance drive forward through an entrance service door, through interior circulation space, into the required maintenance bay and then drive forward through interior circulation space to an exit service door when the required maintenance is completed. This is much easier and more efficient than a pull-in and back-out traffic pattern. Service doors remain open for a short period of time, thus conserving energy, and maintenance staff spend less time directing buses out of the maintenance area, thus providing a more efficient operation. Refer to Figure 6.9 below for an illustration of desired maintenance area circulation.

FIGURE 6.9 - Maintenance Area Diagram



6.24.2.2 Service Door Quantities: WMATA requires / desires that there be only one service door entrance and one service door exit for buses in the maintenance area. Although this arrangement requires more interior circulation space, it also conserves a great deal of energy and increases worker comfort, especially during cold weather months. Refer to DD Drawings (DD-A-SC-008 thru DD-A-SC-011) for material and design requirements for exterior service doors.

6.24.3 Maintenance Bays:

6.24.3.1 Design maintenance bays with enough space at front, rear and sides of each space for circulation and access for mechanics, as well as tool and equipment storage bins. Refer to Figure 6.9 above for an illustration of desired maintenance bay spacing.

6.24.3.2 Quantity and Type: Provide one maintenance bay for every 10 buses stationed at the facility. Of these bays, one bay each shall be provided for the following:

6.24.4.3.6 Steam clean bay (enclosed).

6.24.4.3.7 Tire changing bay.

6.24.4.3.8 HVAC repair bay.

6.24.4.3.9 Handicapped lift repair bay.

6.24.4.3.10 Articulated bus and intercity coach bus repair bay.

6.24.4.3.11 Paint booth and prep area for 40 ft. bus.

6.24.3.3 In addition to the quantity and types of maintenance bays above, provide two inspection bays with below-grade pits. Each below-grade pit shall be provided with two sets of stairs for exiting, a safety net and a rolling oil pan.

6.24.3.4 Provide maintenance bays with skylights for additional day lighting and with ceiling fans for additional ventilation.

6.24.3.5 Provide fall protection in every bay.

6.24.4 Vehicle Lifts:

6.24.4.1 WMATA bus facilities use three lift types; portable lifts, drive on parallelogram lifts and in-ground lifts. The distribution of lift type shall be based on optimizing the facility's current requirements and allowing for future expansion. Hydraulic lifts with in-ground plunger-cylinder units are not allowed. The following are WMATA requirements for lift types and capacities:

6.24.4.2 Portable Lifts: Hydraulic mobile lifts specifically designed to elevate large buses, 18,000 lb. capacity each, 4 lifts per bus minimum.

6.24.4.3 Drive-On Parallelogram Lifts: Heavy duty recess mounted parallelogram platform lift with non-skid surface, electro-hydraulic operation, automatic wheel chocks front and rear and a total of two rolling jacks. Platform to raise a min. of 63" above finish floor at a min. rate of 50" per minute with a min. of 10 lock stops. Safety locks will ensure a min. amount of travel in a hydraulic failure and maintain the lift at that height in this situation. Lift sizes to be 50,000 lb. capacity and 32 ft. and 75,000 lb capacity and 48 Waterproof model is to be installed in Chassis Wash Bay.

6.24.4.3.1 Adjustable Axle Lift 2 and 3 Post Modular: Lifts shall consist of two or three individual lifting assemblies in line with the longitudinal axis of the vehicle, each lifting assembly equipped to engage the axle and suspension. Lift to be housed in a totally contained environmentally safe housing, post to be equipped with shutter plate covers which move with the post to cover the trench at all times. Lift to be electro-hydraulically operated and contain a variable equalized control system. Lift locks shall be rated for same capacity as jack unit and lock in 18 positions on 3 inch increments.

6.24.4.3.2 Axle Lift 2 Post: rated for 60,000 lbs

6.24.4.3.3 Axle Lift 3 Post: rated for 90,000 lbs

6.24.4.4 In-ground Lifts:

6.24.4.4.1 In ground lifts to have integral sump and sump pump to pump out any water than accumulates in bottom of lift pit, shop floors are routinely cleaned with a water hose. Pumps to be serviceable from above the pit, entry into the pit should not be required. Pumps to be minimal emulsifying type and be capable of passing ¼" solids.

6.24.4.4.2 Lift controls shall contain Modbus RTU communication for remote monitoring and connected to the building automation system. Lifts shall not be capable of remote control. The intent is to monitor the lifts for the following conditions: lift out of service, high water level in sump, number of cycles and any other maintenance indicators.

6.24.5 Overhead Service Reels:

6.24.5.1 Provide one overhead service reel for each two maintenance bays. Construction shall be of heavy duty design, spring powered and self-retracting, with double pedestal arm design adjustable to 360 degrees. Services on reel to include water (W), engine oil (EO), electric power, automatic transmission fluid (ATF), chassis grease (CG), gear oil (GO), window wash fluid (WWF) and engine coolant (EC). In addition, at the handicapped lift repair bay, provide separate wheelchair lift oil supply.

6.24.5.2 Refer to Section 6.26 for piping to reels and pumps to propel fluids to reels.

6.24.6 Hoists / Cranes:

6.24.6.1 Jib Cranes: Provide a one jib crane for every four lift bays. Provide bridge crane with electric chain hoist at with a 1 ton capacity and a 12 foot reach in the tire storage area. The jib crane is to swing approximately 180 degrees with stops to prevent any portion of the boom, hoist, or tagline system from coming in contact with building walls or structure.

6.24.6.2 Bridge Crane: Provide a self-supporting monorail bridge crane with electric chain hoist rated for 1 ton, in one of the articulated repair bays. Crane to run the entire length of the bay and be interlocked with the bus lift to ensure the hoist is at the end of the lift prior to the bus lift operation. This will ensure that buses are not lifted into the hoist damaging either the hoist or bus.

6.24.7 Miscellaneous Maintenance Equipment

6.24.7.1 High Pressure Hot Water Cleaner: Provide heavy duty high pressure hot water cleaner to be located outside Steam / Chassis Wash Bay. If unit is located in Bay unit to be shielded from water spray to protect against corrosion and grime/grease ruining unit. Preferred fuel is natural gas, if available. Provide heavy duty high pressure hot water cleaner with 7 to 8 gpm discharge, 3000 psi operating pressure, with adjustable spray pattern nozzle, extra hose lengths, hose reel, wand extensions, quick couples, downstream detergent injectors, rotating brush, and foam applicator.

6.24.7.2 Parts Washers: Provide a small parts washer and a large parts washer. Washers to be vented to outside of building if this is not possible than locate washers in Chassis Wash Area. If located in Chassis Wash Area ensure units are shielded from pressure washer spray in order to protect unit from corrosion and grease/grime.

6.24.7.2.1 Small Parts Washer: Provide industrial jet washer. Washer shall be top loading, hot water and detergent automatic parts washer, with floating oil removal, sludge removal, and subsequent recycling of wash water. Weight capacity shall be 500 lbs of parts.

6.24.7.2.2 Large Parts Washer: Provide industrial jet washer. Washer shall be front loading turntable type, hot water and detergent automatic washer, with two parts baskets, one removable, for extra parts cleaning capacity. Turntable diameter shall be 30 inches minimum, with weight capacity of 1500 lbs. Include filtration system to trap particles and sediment for removal, oil skimming system to remove floating oils and subsequent recycling of wash water. Include water level control and steam exhaust features.

6.24.7.3 Bearing Presses: Provide 50 ton hydraulic bearing press. Includes manually operated two speed pump, liquid filled gauge to measure ram force in pounds and tons, safety oil bypass and overload system, hand operated winch to raise / lower press bed, and self-retracting ram moving laterally on head channel.

6.24.7.4 Brake Drum Lathe: Provide heavy duty, double spindle lathe designed to cut heavy duty drums up to 16 inches deep and 24 inches in diameter, and simultaneously turn brake lining to the exact diameter of the newly refaced drum Drum spindle housing shall extend to support the largest transit dual wheel assemblies without additional support. Include lubrication system, hood enclosure, and portable chip collector. Spindle speeds shall be variable from 20 to 90 rpm.

6.24.7.5 Work Bench with Vise: Provide heavy duty work bench with vise.

6.24.7.5.1 Work Bench: Heavy duty design with heavy gauge adjustable height steel legs and maple butcher block top with protective oil finish.

6.24.7.5.2 Vise: Maximum opening 6-1/2 inches with a 6 1/4" throat depth replaceable main and pipe jaws facings, steel top jaws, built-in anvil, 360Elocking swivel base, keyed round slide bar with sealed lubrication.

6.24.7.6 Large Parts Shelving & Storage:

6.24.7.6.1 Large Parts Shelving: Provide heavy duty shelving units. Provide units with minimum 14 gauge steel uprights, beams and columns; and 5/8 inch thick particle board decking. Units to have load capacity of 1650 3300 lbs per pair of beams and 20,000 lbs per upright assembly. Shelving shall be adjustable on 1-1/2 inch centers. For pallet storage, provide shelving units equivalent to Lyon Pallett Rack by Lyon Metal Products, with same construction as above bulk storage rack, but without particle board deck and with load capacity of 4100 - 9900 lbs per pair of beams and 17,200 - 30,200 lbs per upright assembly, and with shelving beams adjustable on 2 inch centers.

6.24.7.6.2 Large Parts Storage Cabinets: Provide storage cabinets. Provide units of all welded, minimum 14 gauge steel construction, with padlock hasp and heavy duty brass pin hinges on doors, 1450 lb load capacity per shelf, and shelves adjustable on 3 inch centers.

6.24.7.7 Small Parts Storage: Provide steel drawer cabinets for small parts storage. Provide units with 400 lb load capacity per drawer, variable drawer heights, and variable interior drawer layout kits as required.

6.24.7.8 Flammable Liquids Storage Cabinet: Provide heavy duty cabinets. Provide units constructed of minimum 18 gauge steel with reinforced double walls, leak-proof pan bottom, heavy gauge adjustable shelves with 350 lb load capacity, doors with built-in key lock, grounding wire connectors, dual vents with fire baffle and cap, large warning labels and adjustable leveling.

6.24.7.9 Brake Tester: Provide portable computerized electronic brake tester Unit measures vehicle speed at braking and distance traveled, brake effort, and can also be used to test acceleration. Accuracy shall be +/- 2 percent. Unit shall be completely self-contained, portable, and shall include keyboard, LCD display and printer. Unit shall display step by step instructions for each procedure, and shall be suitable for testing service and hand brakes on all types of vehicles.

6.24.7.10 Wheel Alignment Tester: Provide computerized wheel alignment tester for heavy duty vehicles. System shall include drive-on plate in floor, computer console and printer. As each axle is tested, results are displayed on the computer console and hard copy automatically printed. Capacity 30,000 lbs each single axle, 44,000 lbs each tandem axle.

6.24.7.11 Wheel Alignment Adjuster: Provide computerized wheel alignment system for heavy duty vehicles. System shall include computer console with keyboard, 27 inch color monitor and printer, and cordless sensors with self-centering wheel adapters. System provides on-screen, step-by-step instruction for sensor placement, measurement and adjustment for a wide variety of axle configurations.

6.24.7.12 Moveable / Mobile Equipment:

6.24.7.12.1 Forklifts / Snow Removal Equipment: Provide standard counterbalance truck type upright forklifts. Include seat deck mounted hydraulic levers, stop lights, headlights, back-up lights, strobe lights, audible back-up alarm, and rear turn signals. Provide size and capacity of forklifts to suit each facility. Provide forklift storage area and areas for snow removal equipment.

6.24.7.12.2 Floor Scrubbers: Floor scrubber to be battery powered walk behind unit designed for use on rough textured floors. Unit to have recycling system which recycles the solution allowing 3 hours of continuous runtime and leave the floor virtually dry. Brushes shall be attached using spring clip system requiring no tools for changes. Squeegee to be of parabolic breakaway design the assembly shall be free floating swing type constructed of stainless steel and aluminum with no tools required for change out. Scrubber shall have a minimum 36 inch scrubbing path, minimum aisle turn of 67 ½ inches max, squeegee width of 45 ½ inches, solution tank of 30 gallons, and a 40 gallon recovery tank. The scrubber shall have a forward speed of 0 to 3 mph. Provides storage area for floor scrubbers.

6.24.7.12.3 Parking Lot Scrubbers: Provide riding, motorized floor scrubber. Provide scrubber with minimum 54 inch wide scrub path, 60 inch wide sweep path, 100 gallon solution and recovery tanks, and power steering.

6.24.7.12.4 Wheel & Brake Dollies: Provide wheeled dollies. Provide dollies specifically designed to lift and carry all hub and drum assemblies, with lift and tilt controls and removable drip tray.

6.24.7.13 Battery Charging Bench: All-welded steel frame bench with 2" hardwood rollers on top, five rollers per bank of rollers. Capacity 200 lbs per linear foot. Acid-resistant black finish on steel.

6.24.7.14 Unit shall be capable of charging 1 to 36, 12 VDC batteries. Unit shall be provided with Bus bar set with fiberglass backboard assembly with connecting cables, insulated clamp storage bar and 10 pair of 10 gauge, 300 amp rated charging leads 36 inches long premounted at bus bar end with vinyl insulated safety clamps on other end. Three foot 4 AWG cables shall allow connection to charger or additional bus bar. Room to have ventilation, see Section 14.4.2.3 for air exchange rates. Provide dry sump, floor slope to sump to capture any spills.

6.24.7.15 Rolling Oil Pan: Provide heavy duty rolling pit drain pan designed to run on rails or angles along edge of pit

6.24.8 Dust Collection / Exhaust Collection

6.24.8.1 Refer to Section 14.19, WMATA Manual of Design Criteria, for ventilation requirements for hood exhaust requirements at lathe, welding, cutting and grinding areas, and for tailpipe exhaust collection requirements.

6.25 BUS STORAGE

6.25.1 One of the principle functions of any bus maintenance facility is bus storage. Efficient bus parking configurations on a garage site are essential for smooth operations within the site.

6.25.2 The WMATA buses will be stored outside since there are not enough nights when the temperature is below 40 degrees F to warrant building large indoor bus storage areas. Buses will be parked such that they do not have to back up, either to enter the parking space or leave it.

6.25.3 Circulation and Parking Patterns

6.25.3.1 Access to the parking area should be as straightforward as possible with the minimum number of turns. Circulation into and through the bus storage area should be counter-clockwise, that provides for a left-hand circulation pattern. This provides the driver with an unrestricted travel view and minimizes the chance of damage to vehicles and buildings.

6.25.3.2 When planning the bus storage area, the turning radius of the buses is the most important factor. Although the area should be planned to house the buses used in that particular fleet, there should be some part of the area that could handle larger, intercity and articulated buses, even if they are not part of the existing fleet.

6.25.3.3 There are several parking configurations that can be used, depending on the size of the site and the transit operations. Refer to Figure 6.10. The first is parking the buses head to tail in rows, double rows or in-line (stacked) patterns. This is the most efficient in terms of land use but it means that the first bus in line must always be the first to leave and all others must follow in order.

6.25.3.4 The second configuration is the single pull-through, usually in an angled or double angled pattern. A herringbone pattern is another option, but requires backing out. This configuration is WMATA's preference as it offers the maximum flexibility for bus pull out as any bus can enter or leave independently. These patterns consume much more space as there needs to be an aisle wide enough for the bus to turn into a parking stall. This aisle is shared by the row behind as an exit row. A double row is a variation of the single row, with resulting loss of some flexibility.

6.25.3.5 The choice of parking pattern for a particular application is influenced by site and circulation constraints. Conventional stacked parking is only selected when the site is small. If possible, modern facilities are constructed on sites large enough to permit parking patterns that allows access to every vehicle at all times. Direct access greatly simplifies maintenance access, pull-outs and pull-ins.

6.25.4 Paving

6.25.5.6 The bus areas are to be paved with concrete in order to withstand the constant starting, stopping and turning of heavy vehicles. Refer to Section 2 and Section12 for concrete pavement design requirements. The storage area should be sloped a minimum of 1/4" per foot to drain well, but should not exceed a 4% slope, except in rare cases.

6.25.5.7 Automobile parking areas are to be paved with asphalt, refer to Sections 2 and 12 for design requirements.

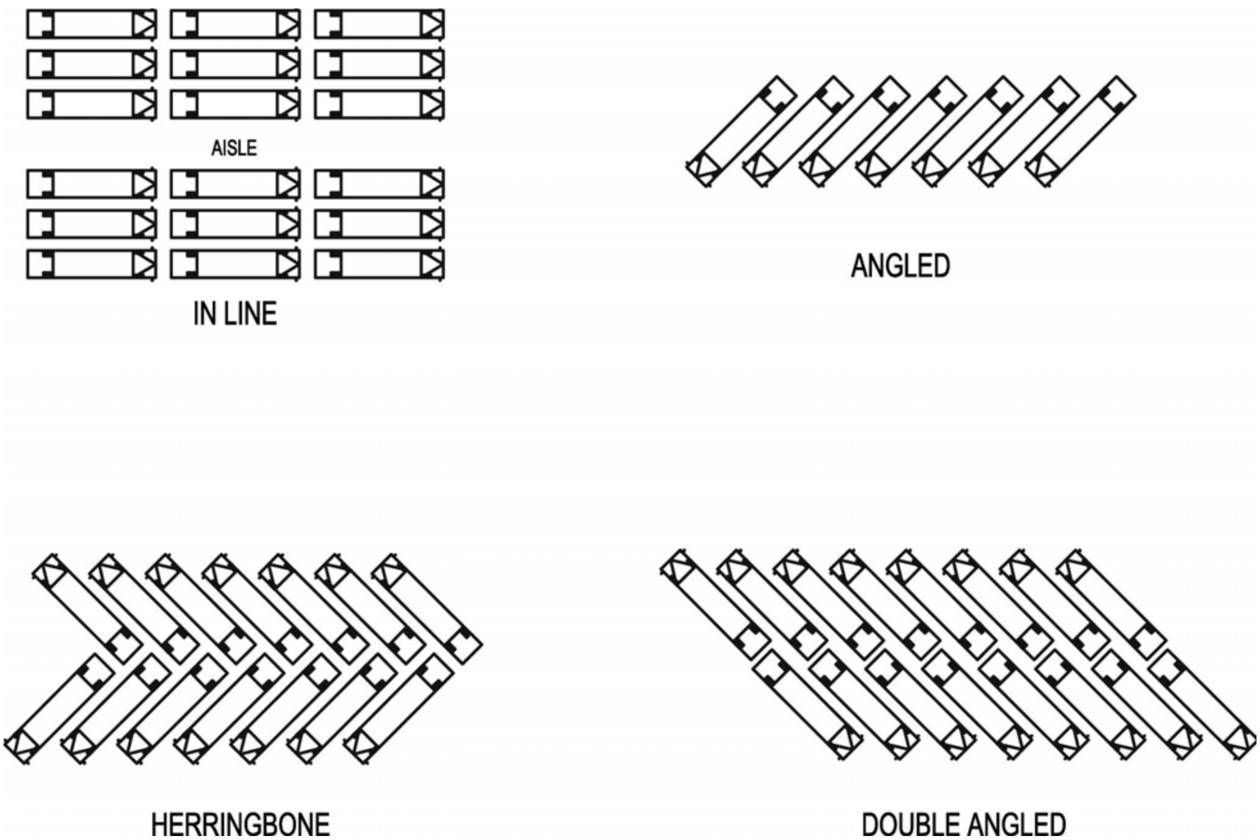


FIGURE 6.10 - Bus Storage Parking Patterns

6.25.5 Services

6.25.5.1 A canopy for shading the buses reduces the build up of heat in the bus and the consequent time needed to let the bus air conditioning run to cool it down. This saves not only on fuel, but also on time that the bus is running but not in service earning revenue. There is also a reduction in air pollution. Canopies also reduce snow accumulation on buses, reducing time for snow removal. Canopies shall be included as an optional design element for cost comparison.

6.25.5.2 Site lighting is required for driver safety but it is important that the light is directed onto the site without spillover onto neighboring properties. Canopies can provide shielding for light patterns, where lighting is mounted under canopy roofs. Electrical and compressed air outlets should be located on light standards or canopy columns and shall be spaced throughout the parking area. Depending on the size of the parking area, a dedicated air compressor may be used, but, in any case, air drying is important to prevent line freezes in cold weather.

6.26 MECHANICAL REQUIREMENTS FOR BUS FACILITIES

6.26.1 Fire Protection

6.26.6.1 General

6.26.1.1.1 The fire protection systems shall be designed per all local and state codes as is appropriate for the project site. In addition, the systems shall be designed in accordance with the latest versions of the NFPA as they apply to the space and/or application being served. Where the NFPA and, local and state codes differ, the design shall follow the most stringent requirements.

6.26.1.1.2 Coordinate building systems and services with the Fire Protection and Alarm such that there shall be, where appropriate, automatic shutdown of the affected system(s) or service(s) should any of the fire protection systems be activated. (e.g. fuel dispensing system shutdown where the associated fire protection system is activated.)

6.26.1.1.3 Coordinate fire protection requirements with WMATA's fire protection underwriter.

6.26.6.2 Wet Sprinkler Systems

6.26.1.2.1 The building sprinkler systems shall be designed in accordance with NFPA 13, other appropriate NFPA sections, and the local and state building code requirements. The system shall be designed under the direct supervision of an engineer experienced in the design of such system and shall be licensed within the state or district where the building will be located.

6.26.1.2.2 All areas of the building shall be protected by a wet sprinkler system, except as allowed below. The system shall be separately connected to the local municipal water main with connections being in accordance with the water purveyors connection and back-flow prevention requirements.

6.26.1.2.3 The system shall be completely hydraulically designed to meet the density and flow requirements set-forth in NFPA 13 and 30. Unless otherwise indicated in the NFPA requirement, the areas of the building shall generally fall into the following Hazard Classifications:

6.26.1.2.3.1 General Areas: Ordinary hazard

6.26.1.2.3.2 Office Areas: Light hazard

6.26.1.2.3.3 Fuel Dispensing Areas: Ordinary hazard

6.26.1.2.3.4 Paint Spray Booth: Extra hazard

6.26.1.2.4 The sprinkler head selection shall be made according to the hazard classification and specific requirement of the areas served in accordance with the applicable NFPA standards. The sprinkler system shall be provided with test fittings, inspector test valves and drainage fittings. Test fitting, inspector test valves and drainage fittings shall be provided for in each fire zone. The test fittings and drainage fittings shall be discharged to the exterior of the building so as to avoid water damage. The sprinkler heads shall be the upright type except where ceilings or other obstructions prohibit their use.

6.26.1.2.5 The sprinkler piping system shall be designed with Schedule 40, black steel pipe. The fittings shall be screwed type joist for sizes below 2 ½" and either screwed or mechanical type for sizes 2 ½" and larger. The building sprinkler piping system shall be designed with sprinkler risers to meet the NFPA 13 area requirements. Each riser shall be provided with appropriate riser trim and a seismic connection and check valve. Coordinate the connection requirements with the local fire department and WMATA's insurance carrier requirements. Each fire zone shall be designed with a manual shutoff valve (with tamper switch) and flow-indicating device. The tamper switches and flow indicating devices shall be tied into the Fire Alarm System. All fittings, valves and devices shall be FM approved. The sprinkler piping system shall be supported in accordance with NFPA 13 requirements.

6.26.6.3 Foam Systems:

6.26.6.3.1 In areas within the building where fuel is dispensed or in Class I, II and III Liquid Storage Rooms, foam-water sprinkler systems may be used. In addition to observance of the local and state building codes, these systems shall be designed in accordance with NFPA 30, 30A and other appropriate NFPA sections regard these types of systems. The system shall be designed under the direct supervision of an engineer experienced in the design of such systems and shall be licensed within the state or district where the building will be located.

6.26.6.4 System Testing:

6.26.6.4.1 After the system has been installed, a pre-test and final acceptance test shall be performed. The testing shall be in accordance with the requirements of the appropriate NFPA sections and local and state requirements.

6.26.6.5 Fire Protection Guidelines:

6.26.6.5.1 Provide types of fire protection for specific areas as indicated below.

Occupancy	Suppression
Battery Storage	FE Electrical
Equipment Areas	FE Fuel
Dispensing	HH
Maintenance and Service Areas	WS
Mechanical Equip. Rooms	WS
Boiler Rooms heads)	WS (165°F
Elevators	WS
Office Areas	WS
Storage: Hazardous	HH
General	WS
Paint Booth	HH

ABBREVIATIONS:

WS	Wet Sprinklers

HH Sprinklers	High Hazard Wet
FE	Fire Extinguishers

6.26.2 Plumbing / Drainage

6.26.2.1 **General**: The plumbing systems shall be designed per the International Building Code, local and state codes as are appropriate for the project site. The system shall be designed under the direct supervision of an engineer experienced in the design of such systems and shall be licensed within the state or district where the facility will be located.

6.26.2.2 **Municipal Water Service**: The plumbing system will be served by a separate municipal water service. The water service shall be separated from the domestic water system by a Reduced Pressure Zone type backflow preventer.

6.26.2.3 **Fixtures**: The plumbing fixtures shall be designed in accordance with ADA requirements, where applicable. All fixtures shall be provided with removable handle type stops. The Urinals and Water Closets shall be wall-hung type with flush valves. The locker room areas shall be furnished with stainless steel wash fountains for hand washing. Individual Restrooms shall be designed with wall hung lavatories utilizing single lever faucets. Electric water coolers shall be provided in locker rooms, the maintenance areas, service area, and outside of grouped restrooms. Provide stainless steel kitchen sink(s) with disposal(s) in breakroom(s) or otherwise as requested by WMATA. Janitor and custodial rooms shall have mop service basins with bucket holding supported spout fixture and a short flexible hose connection.

6.26.2.4 Plumbing Specialties

6.26.2.4.1 The plumbing system shall include emergency eyewashes and combination eye wash and shower units. These shall be tied to a tempered water loop that shall provide water at the proper volume and temperature, and for the duration necessary to meet OSHA requirements. Combination units will be located in the Shop Areas, Maintenance Repair Bays, Chassis Wash, Lube/Compressor Room, Pant

Booth Area, Service Lane, and the Battery Charging/Storage Area. Provide eyewash units in rooms where hydraulic lift pumps are located and other areas where the potential for eye damage exists and as required to meet local, state and federal requirements.

6.26.2.4.2 The system shall include shock absorbers, on the cold and hot water distribution system, where the action of quick operating valves could result in a water hammer condition. Provide dielectric fittings at connections of dissimilar metals.

6.26.2.4.3 Hose bibbs shall be provided, on the exterior of the buildings and in the interior, and as required by WMATA. Hose reels with 50 feet of 1" hose shall be provided every third bay in the maintenance area, at the beginning and end of the washbays, in the tire bay and in the paint booth area. Freeze proof wall hydrants shall be provided every 100 feet around the perimeter of the building.

6.26.2.5 Cold and Hot Water

6.26.2.5.1 The cold and hot water distribution system shall be designed as predominately flush valve systems. The distribution system will serve both the domestic water load and the bus wash system requirements. The Flow required for the bus washer(s) shall be considered a constant demand and be added to the domestics water flow.

6.26.2.5.2 The water distribution system shall be constructed with the following:

6.26.2.5.2.1 2 1/2" and smaller - aboveground ASTM B 88 Type L drawn-temper copper tubing with soldered joints or press fit. Below grade or within slabs ASTM B88 Type K annealed-temper copper tubing with soldered joints. 3" and larger - Provide ASTM A53/A53M, Type S Grade A or B, Sch. 40 galvanized.

6.26.2.5.2.2 The water supplies to the bus washer(s) shall be protected from the backflow of wash water by Reduced Pressure Zone backflow preventer.

6.26.2.5.3 The design shall include a gas or electric water heater (gas preferred). The heater will operate on natural gas or electric. It will be sized to meet the demanded of the domestic hot water load along with any building core area loads resulting from cleaning equipment or wash down requirements. Remote hand sink or similar hot water loads will be met through point of use or small tank type electric or gas water heater. Provide cleanouts at the base of risers and wall cleanouts at gang toilets.

6.26.2.6 Sanitary and Vent System

6.26.2.6.1 All above grade sanitary piping shall be No-Hub service weight cast iron. All below grade sanitary piping shall be Hub and Spigot service weight cast iron. Provide cleanouts at all changes in direction of 45° or greater, every 50 feet on piping 4" and less, and every 100 feet for piping over 4".

6.26.2.6.2 The vent system shall be: 2 ½" and smaller above ground DWV copper tube with soldered joints. 3" and larger above ground: Copper DMW tube with soldered joint or Cast-Iron soil piping, stainless steel or cast iron couplings.

6.26.2.6.3 All below ground pipe shall be cast iron with gasket and gasket joints.

6.26.2.7 **Storm Piping**: All above grade storm piping shall be No-Hub service weight cast iron or stainless (304) couplings. All below grade storm piping shall be Hub and Spigot service weight cast iron with gasketed joints. Provide cleanouts at all changes in direction of 45° or greater, every 50 feet on piping 4" and less, and every 100 feet for piping over 4".

6.26.2.8 **Roof Drainage**: Unless otherwise stated by local or state code, the roof drainage system shall be designed based on the maximum local hourly rainfall intensity. Provide system with both roof drainage and overflow drainage systems. Direct all downspouts in parking and sidewalk areas underground to storm water to prevent ice and standing water.

6.26.2.9 **Interior Floor Drainage**: All floor drainage from the maintenance and Fuel and wash lanes area which have vehicular traffic shall be piped to the oilwater separation system. Provide floor drains at all equipment having condensate drains. Mechanical/Electrical and Compressor Rooms shall all have a minimum of one floor drain. Do not provide drains in shop and parts storage areas due to misc. parts getting trapped in drain system, floor scrubber to clean these areas. Provide additional floor drains where required to eliminate horizontal drainage piping from equipment exceeding 10 feet. Battery storage rooms to have no floor drain, floor to be sloped to dry sump. All gratings used to cover trench drains, catch basins, etc. shall be hot dip galvanized H-20 load rating. Gratings which are greater than 30 lbs shall be accessible by forklift in order for removal (removal by chain and forklift).

6.26.2.9.1 Bus Wash Area: A longitudinal trench drain shall be located along the entire length of the bus washers, including the blower/dryer assembly, and shall be centered in the bus wash lane. Each trench drain shall be pitched to accommodate the Wash Water Reclamation System and shall terminate with a sediment trap. The trench drains shall be sloped at not less than 1/8" per foot. The overflow from the Reclamation System shall be directed to the Sanitary Sewer System if permitted by local discharge limits.

6.26.2.10 Maintenance Area and Service Lane

6.26.2.10.1 Trench drains shall be run across the entrance to these areas and be located within 2'from the face of the overhead doors. A trench drain shall also be located in the steam clean bay. The trench drains shall be pitched to allow efficient flow of water and terminate with a sediment trap. The trench drains shall be not less than 12" wide to allow cleaning with a shovel and the grating shall accommodate H-20 loading.

6.26.2.10.2 An oil water separator shall be designed as part of the drainage system serving the vehicle entrances described above. The oil water separator shall be capable of removing the petroleum product typically seen in similar applications. The separator shall be designed based on American Petroleum Institute (API) standards, a maximum horizontal velocity of 3 fpm, a maximum depth-to-width ratio of 0.5, and continuous flow operation. The separator shall be additionally designed based on local, state and federal requirements. The local sewer district should be contacted to determine if there are specific requirements and discharge limits.

6.26.2.10.3 The oil water separator shall be designed with: a sediment trap; integral holding tank; a top capable of H-20 loading; and applicable features necessary for the use and installation requirement where it will be installed.

6.26.2.10.4 A catch basin will be installed just upstream of the oil water separator described above. The catch basin shall be not less than 36" in diameter and be used for initial sedimentation of the floor drainage. The outlet of the catch basin shall consist of a vertically oriented tee with a 12" open drop leg and capped top. The bottom of the catch basin will have an invert 24" below the bottom of the open drop leg. The catch basin shall be provided with a manhole cover capable of H-20 loading.

6.26.2.11 Waste water from floor scrubbers and parking lot scrubbers shall be handled in one of the following ways, depending on a cost/benefit analysis, local requirements and WMATA requirements:

6.26.2.11.1 Storage on-site in an above grade holding tank or floor sump, size to be determined by WMATA, prior to removal by a licensed disposal contractor.

6.26.2.11.2 Pre-treatment on-site prior to discharge into the sanitary sewer system.

6.26.2.12 Oil Separation / Pretreatment System

6.26.2.12.1 The following system description is provided for information only. Final design criteria and requirements shall be confirmed during design and shall:

6.26.2.12.1.1 Meet local discharge requirements.

6.26.2.12.1.2 Meet WMATA requirements.

6.26.2.12.1.3 Meet all other applicable requirements.

6.26.2.12.2 Provide one (1) collection manhole for every three (3) maintenance bays. The collection manholes shall be 24" long, 18" wide and 36" deep (all inside dimensions). Provide the manholes with heavy duty fiberglass grates with an opening to allow a suction pipe installation. Each of the manholes will be accompanied by a air driven double diaphragm pump capable of delivering 25 gpm at the calculated pressure differential.

6.26.2.12.3 The pretreatment system generally consists of manholes, transfer pumps (both from the manholes to settling tank and from settlement tank to the oil separator, filter, membrane filter, holding tank, and automatic chemical treatment system.

6.26.2.12.4 The system shall be capable of treating 1000 gallons of solution per day. It shall be capable of maintaining a discharge having a ph of between 5 and 10, oil and grease less than 100 parts per million and filtration to 25 microns.

6.26.2.12.5 The settlement tank shall be installed in the floor. It shall have a 2000 gallon volume and have an invert not deeper than four (4) feet below the floor surface. Provide the settlement tank with a fully removable, heavy duty, steel cover such that each section can be removed by a single individual.

6.26.2.12.6 Above ground transfer piping shall be treaded or mechanical joint, schedule 40 black steel. Provide cleanout at all changes in direct of greater than 45° or at straight runs of pipe greater than 50 feet.

6.26.2.12.7 A 25 gpm double diaphragm pump will transfer the effluent for the settlement tank to and above ground oil/water separator. The oil/water separator shall be sized as described above but in no case have a capacity of less than 20 gpm.

6.26.2.12.8 After passing through the oil/water separator effluent will flow by gravity to a "zero gravity" filter. Backwash from the filter should be returned to the settlement tank.

6.26.2.12.9 Effluent from the filter will flow by gravity to a 25 micron filter and on to final holding tank where the effluent will be chemically treated prior to flowing to the municipal sewer.

6.26.2.12.10 Natural Gas Piping

6.26.2.12.10.1 The natural gas piping shall be designed in accordance with NFPA 54 and the local gas provider's requirements.

6.26.2.12.10.2 The natural gas piping shall be constructed of Sch. #40, Black Steel pipe. Piping 2 ½" and below shall utilize threaded fittings and piping greater than 2 ½" shall be welded steel fittings. Gas shutoff valves and drip legs shall be provided up stream of all gas consumers.

6.26.2.12.11 Compressed Air System

6.26.2.12.11.1 The compressed air system shall be designed for redundancy in order to ensure compressed air is provided to the facility at all times. The compressed air system, when possible, shall consist of a single plant with multiple compressors. Single compressor systems shall be avoided. The compressed air system shall be furnished with two (2) air compressors, each sized for 100% capacity based on a 33 - 50% diversity factor at 100 psig. The diversity factor is to be determined based on the quantity of pneumatic equipment at the facility and the number of personnel who operate this equipment at the facility. The compressors will have soft starts with cross connectable independent air dryers, preferably regenerative desicant type capable of delivering compressed air at a dew point of 28°F. The compressor shall have a power out restart capability which restarts the compressor after a loss of power. The sizing of the compressor shall be based on a comprehensive equipment list of all pneumatic equipment at the facility in order to calculate the air demand.

6.26.2.12.11.2 The overhead compressed air piping system shall be designed based on a working pressure of 150 psig. All valves and fitting shall be class 150. The piping shall be not less than schedule #40 black steel with the branch piping being not less than 3/4" diameter. The size of the branch piping shall be based on most demanding device being served. Each branch shall be furnished with a filter/regulator/dryer and an isolation valve at the branch/main takeoff. Filter/regulator/dryer assemblies shall be per WMATA's standard requirements. Confirm standards prior to installation.

6.26.2.12.11.3 See Sections 18 and 19 for system components downstream of the filter / regulator / dryer.

6.26.2.12.11.4 Provide quick disconnects, at air outlets, to meet

WMATA's standard tool requirements.

6.26.2.12.11.5 Provide general air outlets every 50 feet along the perimeter of the wash bays, maintenance and service bays. Provide two (2) air outlets in the Tire Service bay and four (4) in the Paint Booth bay.

6.26.3 HVAC

6.26.3.1 General

6.26.3.1.1 The HVAC systems shall be designed per the International Building Code, local and state codes as are appropriate for the project site. In addition the systems shall be designed in accordance with the latest versions of the ASHRAE, NFPA, SMACNA, ASME and UL standards as they apply to the systems utilized for the facility. In addition, any generally accepted standards which are recognized or generally accepted within the local engineering community for similar projects and/or systems shall apply.

6.26.3.1.2 The system shall be designed under the direct supervision of an engineer experienced in the design of similar systems and shall be licensed in the state or district where the facility will be located.

6.26.3.1.3 The facility shall be designed in accordance with the latest version of NFPA 30A and 88B, as they apply to the specific areas of the facility.

6.26.3.2 **Heating**: The primary heating system shall be a hot water design. The heating system will be zoned to provide for the varying load requirements of each area.

6.26.3.2.1 Boilers

6.26.3.2.1.1 The boilers shall be fire tube type, each design sized to meet 80% of the design day heating load. Design heating load will be based on ASHRAE Winter Design Dry Bulb 95% and 80% of maximum building ventilation load.

6.26.3.2.1.2 The boilers shall be equipped with duel fuel, modulating type power assisted burners that shall be capable of operation on natural gas and No. 2 fuel oil. The burners shall be designed to swing out allowing full burner face access without having to disconnect fuel piping or wiring. The burners shall have full IRI gas and oil trains and be provided with a combined burner management and flame safeguard system. The burner management system shall be capable of providing lead/lag changeover and fuel selection functions.

6.26.3.2.1.3 No. 2 fuel oil shall be pumped to the boilers from an exterior underground oil tank capable of storing one (1) month's oil at fully loaded boiler operation. The tank shall be dual wall fiberglass design and be provided with leak detection system. Ancillary tank equipment such as oil fill boxes, vents, manholes, oil level indicators, anti-syphon valves, and alarms shall be provided. The fuel oil transfer pumps shall be skid mounted duplex type each being capable of providing sufficient oil for both boilers operating 100% loaded.

6.26.3.2.1.4 The boiler flue venting shall be accomplished through a pre-manufactured stainless steel flue system. The flue system shall be designed in accordance with NFPA requirements. Design shall include make-up air to the boiler room to provide for boiler combustion and ventilation requirements.

6.26.3.2.2 Area Heating Requirements

6.26.3.2.2.1 Entrances and Exits: Heated air curtains shall be provided at all vehicle entrances and exits. Heated air curtains shall be installed at all service area entrances. All air curtains shall be designed for the local winter wind velocity as identified in the latest version of the ASHRAE fundamentals.

6.26.3.2.2.2 Bus Maintenance Areas: The bus maintenance areas heating requirements shall be served by air handling units that will be located on elevated mezzanines. The unit shall be designed to maintain a space temperature of 65° F through the use of a hot water heating coil. (see Ventilation below for further related requirements)

6.26.3.2.2.3 Parts Storage Rooms: The Parts Storage Room shall be maintained at 65 ° F. The hazardous storage rooms shall be designed to Class I, Division 2 requirements (NFPA 30). Space temperature shall be maintained at 65° F.

6.26.3.2.2.4 Bus Wash Area: The Bus Wash Area shall be designed unitizing a combination of space air handling and high intensity, infrared, gas fire unit heaters. The system shall be designed to maintain a space temperature of 65° F.

6.26.3.2.2.5 Offices, Locker Rooms, Training Rooms, Operators Areas:

6.26.3.2.2.6 Maintained at 68 ° F by the central heating system.

6.26.3.2.3 Air Conditioning: The Offices, Locker Rooms, Toilet Rooms, Training/Conference Rooms, Day Rooms and other similar areas in the administration and operations areas shall be air-conditioned, maintained at 75EF. The air conditioning of these spaces shall be accomplished through roof top direct expansion air conditioners which will utilize water coils for heating. Consideration should be made for the use of a packaged Variable Air Volume to maintain zone control.

6.26.3.2.4 Ventilation

6.26.3.2.4.1 Due to the nature of the operation of these facilities, significant amounts of make-up and exhaust air are required. In addition to local and state requirements the ventilation system shall be designed to meet both NFPA and ASHRAE standards. Where any of the requirements and standards differ, the design shall be in accordance with the most stringent.

6.26.3.2.4.2 Air handling units servicing the maintenance areas shall be mounted on elevated mezzanines. The supply air shall be ducted, with the ductwork being fabricated of materials appropriate for the environment they are serving. Where air is to be distributed in high bay areas (20'+) the use of high velocity drum type diffusers shall be considered. The ductwork shall be constructed in accordance with SMACNA standards as appropriate for the pressure class of the system and units being served.

6.26.3.2.4.3 The maintenance area air handling units shall be equipped with variable frequency drives (VFD). The supply fan shall operate at minimum speed and maintain minimum make-up air volume based on the space use. As the space exhaust air demand increases the VFD will increase supply fan speed to maintain space pressurization. The space pressurization shall be monitored through the use of space pressure sensors. The air handling units shall be designed for 100% of the heat recovery exhaust fan and 50% of the roof top centrifugal exhaust fan volumes.

6.26.3.2.4.4 The maintenance area general exhaust shall be accomplished through a combination of heat recovery exhaust fans and roof top centrifugal exhaust fans. The heat recovery exhaust fans shall be sized to handle the minimum ventilation rate of 4 air changes per hour. The roof top centrifugal exhaust fans shall be sized such that their total exhaust volume will provide 8 air changes per hour. The ductwork from the heat recovery exhaust fans shall be such that 50% of the exhaust air is taken from 6" above the finished floor. The ductwork that is run down to the floor level intakes shall be attached and run down walls or columns to protect them from being hit by the buses.

6.26.3.2.4.5 As a result of the large make-up air and exhaust requirements, heat recovery shall be used wherever the exhaust stream allows for its use. The type and application of the heat recovery system selected shall be appropriate for the quality of heat available from and the nature of the exhaust stream.

6.26.3.2.5 Specific Area Ventilation Requirements

6.26.3.2.5.1 Service Lanes - Fuel Dispensing Area: Provide 10 air changes per hour at low speed and 12 air changes per hour at high speed. Provide two exhaust intakes at 6" above finished floor for each fuel island.

6.26.3.2.5.2 Service Lanes - Bus Wash Area: Provide 4 air changes per hour on low speed and 6 air changes per hour at high speed.

6.26.3.2.5.3 Air Compressor and Electrical Distribution Rooms: A mechanical ventilation system shall provide supply and exhaust air to maintain space temperature below 95° F.

6.26.3.2.5.4 Paint Booth Area: The paint booth will be a cross draft style pre-manufactured system to be erected at the site. The booth walls shall be capable of supporting a three axis manlift capable of traveling the length of the booth. Booth air shall be supplied through the use of a makeup unit, which is mounted on the roof of the building. A fully filtered intake and exhaust air system shall be provided, with exhaust being removed from system and facility by ductwork and plenums. Fall protection for maintenance of fans. A low pressure breathing air system shall be provided complete with air compressor, purification system controls and alarms, distribution system with not less than two (2) hook-up stations, portable hoses, vortex air coolers and masks. The system shall be capable of allowing two (2) people to use it simultaneously.

6.26.3.2.5.5 Tail Pipe Exhaust: The tail pipe exhaust system shall be designed to provide 600 cfm per connection with a 50% diversity factor. The exhaust hoses shall be rated for a temperature of 1500°F. Each maintenance bay will be provided with an overhead, pull down hose reel which will automatically start the exhaust fan when the hose is extended for connection to the bus exhaust. The main header will be design per SMACNA standards with the hose and ductwork being as appropriate for the suction pressure generated at the "dead head" condition. The tail pipe connection shall be attached to the tail pipe through the use of an inflatable rubber bellows. The bellows shall utilize compressed air to inflate. Provide an end switch that automatically deflates the bellows should the bus be moved prior to disconnecting.

6.26.3.2.5.6 Battery Charging/Storage Room: To the extent practicable ventilation design shall take advantage of passive ventilation to maintain the hydrogen concentration level below 1% and comply with applicable code requirements. Where passive ventilation is not applicable, mechanical ventilation shall be used to maintain the concentration level below 1%. Redundant ventilation shall be provided. Battery Chargers shall be interlocked with the ventilation system, preventing their operation should the ventilation system not be in operation. Rooms to be mechanically ventilated at temperatures above 77EF. Battery rooms dependent on mechanical ventilation require remote monitoring per code. Hydrogen monitoring is not preferred because it requires regular sensor calibration and replacement.

6.26.3.2.5.7 Locker Rooms / Restroom: Each Locker Room or Restroom shall be designed with a supply air and exhaust system. The space exhaust air shall be designed for 2 cfm per square foot or the sum of 75 cfm per water closet and urinal; 50 cfm per shower; and 15 cfm per locker, whichever is greater. The supply/make-up air shall be design at 90% of the exhaust volume to provide a pressure differential between the Locker/Restroom and the surrounding area. These guidelines or code regulations, whichever requires more cfm, shall be followed.

6.26.3.2.5.8 Office/Training/Operators Areas: The Office, Training and Operators Areas shall be designed to provide a minimum of 15 cfm per person of outdoor air. The spaces shall be zoned such that space with similar use and occupancy are on the same air-handling unit (see Air Conditioning above for further requirements). These areas should be designed to provide a positive pressure relationship as compared to surrounding areas. This will be done to reduce infiltration from the outside and maintenance areas. These guidelines or code regulations, whichever requires more cfm, shall be followed.

6.26.3.2.5.9 Hood Exhaust: Specific exhaust systems will be provided in the welding shop and for the individual brake lathes and grinders. Movable direct capture hoods will be provided at the welding bench and at each grinding and cutting device. Hoods shall be designed to provide a capture velocity of not less than 150 feet per minute over the cross sectional area. Each hood shall be provided with a blast gate to allow balancing and shutoff. The exhaust duct system shall be designed to the SMACNA pressure class which the suction of the exhaust fan will generate at the "dead head" condition but in no case less than 5" w.g.

6.26.3.2.6 HVAC Controls

6.26.3.2.6.1 The control system shall be based on a distributive type Direct Digital Control (DDC), Building Management System (BMS). The system shall be capable of peer to peer communication on a primary or primary/secondary, BACnet open protocol network. Access to the network shall be available through; a local workstation; a portable personal computer able to be plugged into the system devises; or remotely through the use of the Internet.

6.26.3.2.6.2 The Internet access shall be made possible through the creation of a building specific Web Site. The control system shall be furnished with all software, programming, hardware and start-up services necessary for the implementation of the Web Site. The Web Site access shall all full BMS control form a remote personal computer without the need for additional software.

6.26.3.2.6.3 All microprocessor controlled HVAC equipment shall be furnished with all necessary interface equipment and software necessary for full control and monitoring. This equipment would include but not be limited to boilers, chillers, variable frequency drives, air compressors and rooftop air conditioners.

6.26.3.2.6.4 It is the intent that insomuch as possible the entire BMS will be electronic. All sensors and controls devises should be electronic.

6.26.3.2.6.5 In all areas where bus maintenance or service is to take place electronic diesel specific carbon monoxide (CO) monitoring shall be provided. The monitoring system shall directly initiate high fan speed operation of the space exhaust fans, initiate a local audio/visual alarm, and alarm the HVAC control system should a high CO level be sensed. The monitoring system shall be an aspirated type unless approved by engineering. The intent is to eliminate the need to access sensors at the ceiling and to provide for calibration of the sensors by replacement with pre-calibrated units. All maintenance items in the aspirated type units are at ground level.

6.26.3.2.6.6 Battery Charging/Storage Room:

6.26.3.2.6.6.1 To the extent practicable ventilation design shall take advantage of passive ventilation to maintain the hydrogen concentration level below 1% and comply with applicable code requirements. Where passive ventilation is not applicable, mechanical ventilation shall be used to maintain the concentration level below 1%. Redundant ventilation shall be provided.

6.26.3.2.6.6.2 Battery Chargers shall be interlocked with the ventilation system, preventing their operation should the ventilation system not be in operation. Rooms to be mechanically ventilated at temperatures above 77º F. Battery rooms dependent on mechanical ventilation require remote monitoring per code. Hydrogen monitoring is not preferred because it requires regular sensor calibration and replacement.

6.26.3.2.6.6.3 Suspended ceilings are not allowed.

6.26.3.2.6.6.4 Battery Rooms shall be under negative pressure not to exceed 0.1” WG. Battery rooms dependent on mechanical ventilation require remote monitoring by OCC for failure of one of the redundant fans. Local building codes may require monitoring of hydrogen levels. Hydrogen monitoring is not preferred because it requires regular sensor calibration and replacement.

6.26.3.2.6.7 A CNG detection system shall be provided in the Bus Garage and shall be connected into the BMS system.

6.26.3.2.7 HVAC Design Guidelines: As follows:

SUMMARY OF HVAC CRITERIA				
SPACE	**HVAC SYSTEM**	**HEATING DESIGN CRITERIA**	**COOLING DESIGN CRITERIA**	**AIR CIRCULATION AND OUTSIDE AIR**
General office	HWH, RTAC	68 ºF	75 ºF/50%RH	1.0 CFM/SF circ. 20 CFM/person OA
Operations and Training Areas	HWH, RTAC	68 ºF	75 ºF/50%RH	1.0 CFM/SF circ. 20 CFM/person
Corridors (in general areas)	HWH, RTAC	68 ºF	75 ºF/50%RH	0.5CFM/SF circ. 0.1CFM/person OA
Electrical Shop	HWH, RTAC	68 ºF	75 ºF/50%RH	0.5CFM/SF circ. 0.1CFM/person OA
Locker Rooms	HWH, RTAC	68 ºF	75 ºF/50%RH	(see Section 7)
Air Conditioning	HWH, RTAC	68 ºF	75 ºF/50%RH	(see ASHRAE)
Service Lanes & Maintenance Areas	HWH, ADH	65ºF	N/A	4 ACH general OA 8 ACH rooftop exhaust
Storage Rooms	HWH	65ºF	N/A	6 ACH exhaust
Air Compressor and Electrical Room	HWH	65ºF	N/A	Maintain below 90ºF
Battery Charge Room	HWH	65ºF	N/A	15 ACH exhaust
Boiler Room	HWH	65ºF	N/A	10 CFM/boiler HP
Break Lathe				Industrial ventilation handbook

SUMMARY OF HVAC CRITERIA

SPACE	HVAC SYSTEM	HEATING DESIGN CRITERIA	COOLING DESIGN CRITERIA	AIR CIRCULATION AND OUTSIDE AIR
Welding Room				Industrial ventilation handbook
Paint Booth				100FPM across the cross sectional area
Repair Shop				Std. 15
Tail Pipe Exhaust				600 cfm per connection

ABBREVIATION LIST

HWH	Hot Water Heat
RTAC	Rooftop Air Conditioning
ADH	Above Door Heater (Hot Water)
RH	Relative Humidity
CIRC	Circulation
OA	Outside Air
ACH	Air Change Per Hour
HP	Horse Power
N/A	Not Applicable
CFM	Cubic Feet Per Minute
SQ. FT.	Square Foot
FPM	Feet Per Minute

6.27 COMPRESSED NATURAL GAS (CNG) BUS FACILITY REQUIREMENTS

6.27.1 INTRODUCTION

6.27.1.1 This section will provide basic criteria and guidelines for the design and implementation of a Compressed Natural Gas (CNG) Vehicle fueling system, for WMATA transit bus fleet(s). Some of the CNG infrastructure design issues that will be outlined include; efficient vehicle fueling, reliability, safety, local, state, and national codes, and equipment service and maintenance. In addition, vehicle storage and maintenance facility design impacts will be identified. Specific facility system effects include mechanical and electric systems.

6.27.2 CNG FUELING SYSTEM

6.27.2.1 Site Layout

6.27.2.1.1 **Compressor Package Location:** There are several issues to be evaluated in selecting the location of a fast-fill (typically 5 to 15 minutes fueling period per vehicle), CNG fueling station. [Slow-fill stations will typically not provide the fueling rates required by a transit fleet.] These issues include, but are not limited to the following:

6.27.2.1.2 The system location should meet International Building Code, local, state, and national code requirements, specifically NFPA 52 Compressed Natural Gas (CNG) Vehicular Fuel Systems Code. Refer to the "Code Compliance and Industry Standards" Section 6.29.3.5.

6.27.2.1.3 The system should meet local, state, and national code requirements for distance from property line, sidewalk, and street (minimum of 10 feet per NFPA 52).

6.27.2.1.4 Appropriate distance from adjacent businesses or homes where compressor noise would be an annoyance.

6.27.2.1.5 Distance from railroad tracks (minimum of 50 feet per NFPA 52, consult RR Company for specific RR requirements).

6.27.2.1.6 Location relevant to overhead and underground utilities (contact local utilities for specific distances and requirements). Do not install a CNG fueling station below overhead power lines or above underground utilities.

6.27.2.1.7 To reduce installation and equipment costs, location should be as close to natural gas and electrical utility services as reasonably possible.

6.27.2.1.8 Allow service and maintenance clearance around the CNG fueling equipment as recommended by the manufacturer.

6.27.2.1.9 CNG storage vessels should be kept as close to the compressor package as possible.

6.27.2.1.10 Distance between compressor package and dispenser should not be greater than 100 feet.

6.27.2.1.11 Distance from adjacent facility air intakes, doors, and windows (recommend minimum of 20 feet).

6.27.2.1.12 Select location that will not disturb site aesthetics, and/or allow space for a landscaped earth berm.

6.27.2.1.13 Location that would allow the installation of proper site drainage, and not allow flooding or ponding. Perform a topography survey.

6.27.2.1.14 Location should allow for safe, efficient snow removal.

6.27.2.1.15 Perform soil boring tests to establish the soil composition for construction, and the requirements of a retention wall (if required).

6.27.2.1.16 Allow appropriate space for future expansion.

6.27.2.1.17 **Fueling Location**: The location of the fueling dispenser is critical for efficient CNG fueling and operator safety.

6.27.2.1.17.1 The dispensing system location should meet local, state, and national code requirements, specifically NFPA 52. Verify the NFPA edition adopted by the authorities having jurisdiction, and the local Fire Marshall. Refer to the "Code Compliance and Industry Standards" Section

6.29.3.5

6.27.2.1.17.2 It is recommended in most applications to install the CNG dispenser outside of the building, adjacent to or in front of the service lanes. This arrangement allows for an efficient fueling arrangement and increases valuable site space for other uses. The installation of the CNG dispenser near the service lanes will typically increase construction costs due to the increased length of CNG tubing and utilities, in addition to increased facility construction costs to meet codes, regulations, and guidelines.

6.27.2.1.17.3 Per NFPA 52, the fueling island location should easily provide access to a remote, manual ESD (emergency shut-down device). A second ESD is required is be within "view" from the fueling location and a minimum of 5 feet from the CNG dispenser.

6.27.2.1.17.4 The fueling island location should be designed to account for the following CNG related issues:

6.27.2.1.17.5 Vehicle turning radii - design for greatest possible vehicle turning radius.

6.27.2.1.17.6 The fueling point location on the vehicle(s) (typically the curbside rear corner on CNG transit buses).

6.27.2.2 Fueling Station, Compressor and Gas Storage

6.27.2.2.1 **Utility Services:** Utility services are one of the most critical elements required for the operation of a CNG fueling station, and often have a substantial impact on installation and operational costs. Natural gas and electric utility feeds should be "take offs" from the facility's main utility services, unless it is more economical to install a dedicated service for the CNG fueling station. The CNG fueling station loads should be included in the sizing of the utility services, and coordinated with the local utility companies (refer to Section 12, Section 13 and Section 14).

6.27.2.2.2 **Utility Trenches:** Natural gas piping, electrical conduit, and communication cable, shall share a common utility trench. Each utility line shall be separated by a minimum of 12 inches of compacted earth. Electrical conduit shall be the uppermost buried utility, with a minimum of 36 inches cover in traffic areas.

6.27.2.2.3 **Natural Gas Service:** Below is a list of the key design issues that should be evaluated during design, and investigated with the local gas utility.

6.27.2.2.3.1 **Gas piping and tubing:** Supply piping shall be steel pipe, ASTM A 53, Type E or S, Grade B, Schedule 40, black, welded joints. CNG tubing shall be seamless, stainless steel, annealed SA 213, Type 316, ASTM A269, with maximum working pressure of 5,000 psig.

6.27.2.2.3.2 **Location of gas main serving facility:** The **closer the service is to the proposed site, the less** expensive gas piping costs will be.

6.27.2.2.3.3 **Gas main pressure:** The higher the available gas pressure, the less gas compressor equipment purchase and operational costs will be.

6.27.2.2.3.4 Gas quality, should be of "pipeline quality" gas and meet or exceed NFPA 52 and SAE J1616. Supply gas should not contain greater than 7 lbs. water vapor per mm scf. Carbon dioxide concentrations should not be greater that 2%, otherwise corrosion may occur in piping when mixed with water vapor.

6.27.2.2.3.5 **Gas regulator:** A natural gas regulator should be provided on the CNG fueling station gas supply line. The regulator shall be set for a pressure in accordance with manufacturer's recommendations, for the specific equipment to be installed.

6.27.2.2.3.6 **Gas submeter:** A natural gas submeter should be provided downstream of the CNG fueling station gas supply line. This will enable the owner to record and analyze gas usage.

6.27.2.2.3.7 **Gas service and contract:** Provide the gas utility with the fueling station's maximum gas load in SCFM, and periods of peak load (greatly impacted by the selection of an electric driven compressor vs. a natural gas driven compressor). Determine the rate tariff or negotiate a gas service term contract with a specific rate per cf (Ccf or MCF) for delivery. Determine whether the tariff would be an interruptible or non-interruptible gas service.

6.27.2.2.4 **Electric Power Service:** Below are key issues that should be evaluated during design, and discussed with the local electric utility.

6.27.2.2.4.1 Electrical wire shall be encased in rigid, schedule 40 PVC pipe, with properly sealed joints. All materials and equipment to conform to UL requirements, and be listed by UL, FM, or nationally recognized testing laboratory (NRTL).

6.27.2.2.4.2 Location of electrical panelboards in facility: The closer the panelboard is to the proposed site, the less expensive electrical conduit and wire costs will be, as it relates to the installation of a CNG fueling station.

6.27.2.2.4.3 Electrical service voltage and capacity should be determined by a system load calculation and information provided by the equipment manufacturer (greatly impacted by the selection of an electric driven compressor vs. a natural gas driven compressor). Typical voltage is 480v, 3 phase for electric driven compressor and 120v, single phase for associated system controls.

6.27.2.2.4.4 **Emergency Power System:** the CNG vehicle fueling system's electrical load and requirements shall be included in the design and sizing of the emergency power system. The emergency power system shall enable complete and full operation of the CNG fueling system.

6.27.2.2.5 **Natural Gas Dryer:** The purpose of a natural gas dryer is to eliminate moisture from the gas supply, and to maintain a minimum level of moisture vapor entering the gas compressor. Special attention is required in determining dryer specifications as they relate to outside air temperature in various geographic locations.

6.27.2.2.5.1 A manually activated, closed loop, heat regenerative twin tower dryer, with a molecular sieve 3A low pressure gas dryer shall be supplied. The dryer shall dry the gas before it is compressed so that the pressurized dew point (measured at 5,000 psi) will not allow moisture to condense at design ambient -10 deg. F. to 95 deg. F. Have special molecular sieve for minimal effect on natural gas odor.

6.27.2.2.5.2 The natural gas dryer shall be designed, constructed, and tested in conformance with the following:

6.27.2.2.5.2.1 Compressed Natural Gas Vehicular Fuel Systems (NFPA 52)

6.27.2.2.5.2.2 National Electric Code (NEC), NFPA 70

6.27.2.2.5.2.3 American Gas Association (AGA)

6.27.2.2.5.2.4 Underwriters Laboratories (UL)

6.27.2.2.5.2.5 Society of Automotive Engineers (SAE)

6.27.2.2.5.2.6 American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code

6.27.2.2.6 **Compressor:** Two types of prime mover compressor systems are currently available. They include electric driven and natural gas driven compressor systems.

6.27.2.2.6.1 **Electric Driven:** Drive motors shall be three phase, AC induction motors, soft start, TEFC type, NEC Div. 2 rated, premium efficiency rated, including starter, starter housing, motor protection circuit.

6.27.2.2.6.2 **Natural Gas Driven:** Gas engine shall consist of an industrial (heavy duty), four stroke, spark ignited internal combustion engine. Associated engine components shall include; lubrication systems, cooling systems, temperature and pressure switches and gauges. Gas engines are available in naturally aspirated or turbo-charged options.

6.27.2.2.6.3 **Compressor (package) performance and**

conformance specifications:

6.27.2.2.6.3.1 **Piston rings:** Minimum design life of 4,000 hours lubricated or 2,000 hours non-lubricated.

6.27.2.2.6.3.2 **Piston rod packing:** Leakage rate of no greater than 0.5% of throughput. Minimum design life of 4,000 hours lubricated or 2,000 non-lubricated.

6.27.2.2.6.3.3 **Lubricated oil consumption:** No greater than 0.5 pounds of oil per mmscf. Oil recycling capability - blowdown tank to crankcase.

6.27.2.2.6.3.4 **Synthetic oil lubricated.**

6.27.2.2.6.3.5 **Interstage separators:** Centrifugal separator or coalescing filter required after each pressure lubricated stage.

6.27.2.2.6.3.6 **Discharge filter:** Only single coalescing filter for non-lubricated, pre-coalescing and coalescing filter required for lubricated.

6.27.2.2.6.3.7 **Automatic gas recycling system.**

6.27.2.2.6.3.8 **Controls: PLC**

6.27.2.2.6.3.9 **Codes and regulations:** NEC and NFPA 52 compatible. All components UL listed, FM approved or otherwise approved by a NRTL.

6.27.2.2.6.3.10 **Enclosure:** Maximum noise emission level of 85 dbA at15 feet, or local noise ordinances as applicable. Unit shall include heat, light, and gas detection.

6.27.2.2.6.3.11 **Lifting and rigging mounts and supports.**

6.27.2.2.6.4 The selection of an electric vs. natural gas prime mover is very complicated. Each application requires a technical and economic analysis, to determine the most feasible and cost effective option. Refer to Table 6.1 below for summary of key comparison issues between electric and natural gas prime movers.

6.27.2.2.7 Storage: Cascade, fast-fill CNG fueling system applications utilize vessels to store CNG until required by the dispensing system. A slow-fill CNG fueling system does not utilize storage to enable complete vehicle fueling in a short period of time. Storage of CNG enables the system to fuel vehicles during high demand periods. Unlike the transfer of a liquid fuel, natural gas flows from storage to the vehicle due to a pressure difference. Natural gas flows from high pressure (storage) to low pressure (CNG Vehicle). As a result of this, it is impossible to utilize the entire storage volume. Typically, 30% to 40% of the storage volume is used to "fill" a CNG Vehicle, the remaining 60% to 70% is provided by the operation of the compressor.

Performance Issue	Gas Engine	Electric Motor
Energy (fuel) Cost	Low compared to motor, price of natural gas fairly uniform across U.S. Only minimal electrical service needed for station, 3 phase power not necessarily required for station.	High compared to engine, local electrical costs vary considerably across U.S. Expensive electrical service upgrades often required for motor operation.
Maintenance Cost	Regular maintenance required, moderate cost involved.	Virtually no maintenance required.
Reliability	Good, however lower than Motor reliability.	Very high, seldom any problems.
Operating Emissions	Some unburnt methane, CO, $CO_{2,}$ NOx, and H_20. Little evidence of emissions on site.	No emissions with exception of those produced at site of electrical power generation.
Noise Pollution	Considerable noise generated in comparison to motor.	Very little noise generated, virtually undetectable when adjacent to reciprocating compressor.
Capital Cost	Several times more than an equivalent electric motor.	Much less expensive than a gas engine.
Control System	More elaborate controls required: starting, warming-up, idle, full speed, shut down etc.	Controls relatively simple in comparison to those required for engine. Soft-start, run, shutdown.
Packaging	Requires more space, stronger mounting, additional parts, increased compressed air requirements and an exhaust system.	More compact, lighter and less complex than engine.
Other	Power output affected by altitude and temperature.	Power o independent utput Virtually of ambient conditions.

Table 6.1 Summary Comparison between Gas Engine and Electric Motor Driven CNG Compressors

6.27.2.2.7.1 Storage (Skid) Performance Specifications:

6.27.2.2.7.1.1 Compressed Natural Gas (CNG) ASME 3-Vessel storage tank assembly.

6.27.2.2.7.1.2 Manufactured to ASME UPV Code Section VIII Division 1 App. 22

6.27.2.2.7.1.3 Safety factor rating of 3:1 for dry gas, non-corrosive service.

6.27.2.2.7.1.4 5,500 psi design pressure, 5,000 psi operating pressure.

6.27.2.2.7.1.5 Total storage volume of product at 5,000 psi (to be determined based on NGV fleet requirements).

6.27.2.2.7.1.6 Skid footprint no greater than 2' wide x 12' long.

6.27.2.2.7.1.7 Full port stainless steel (½") ball valves on front and rear of each vessel.

6.27.2.2.7.1.8 Safety relief valves on each vessel.

6.27.2.2.7.1.9 Dome outlet drain valves on each vessel.

6.27.2.2.7.1.10 Saddle mount frames for horizontal mounting of vessels.

6.27.2.2.7.1.11 Lifting and rigging mounts and supports.

6.27.2.2.7.1.12 Complete priming and painting of storage skid and assembly.

6.27.2.2.7.2 The volume, arrangement, and type of each CNG fueling system's storage package varies with the fleet. Proper fueling rates and capacities need to be calculated and evaluated for each fleet fueling application.

6.27.2.3 Fueling Island - Dispensing System

6.27.2.3.1 **Components:** The fueling island should contain several components including, but not limited to; CNG dispenser, fuel management system, equipment and driver protection, safety devices, proper signage, fueling hoses, and an emergency shut down system. The function of a dispenser is to act as the interface between the CNG fueling station and the CNG vehicle, including authorizing fueling, metering, recording, and displaying of fueling data for each transaction.

6.27.2.3.2 Fueling Island

6.27.2.3.2.1 Stainless steel island form, 4 feet wide x 14 feet long, full round ends, double wall side. Fill with concrete, rebar enforced, slope at 1%.

6.27.2.3.2.2 Provide schedule 80 steel bollards, 8 inch diameter x 8 ft. long. Fill with concrete, round top.

6.27.2.3.2.3 Provide site lighting meeting hazardous area classification, Class 1, Division 1.

6.27.2.3.2.4 Provide fire extinguisher with 20-B:C rating, mounting post and accessories.

6.27.2.3.2.5 Provide placard stating the name and address of the CNG fueling location, and the name and phone number of the nearest Fire Company.

6.27.2.3.3 Dispenser Performance Requirements:

6.27.2.3.3.1 Maximum delivery pressure of CNG shall be controlled for 3,000/3,600 psi vehicle fueling requirements affording optimal vehicle fills. Maximum storage pressure of the gas, after compression, is to be maintained at not more than 5,000 psi compensated at 70°F ambient temperature for outdoor installations.

6.27.2.3.3.2 All components shall be assembled, piped, wired and interconnected, so as to provide an operable system requiring minimal field construction and installation.

6.27.2.3.3.3 System design pressure shall be 5,000 psi with operating pressures to be 3,000/3,600 psi as specified.

6.27.2.3.3.4 Dispensing equipment shall be designed for outdoor use and equipped with means to protect all operating controls and electrical wiring from climatic conditions. Exposure to normal weather conditions shall not interfere with the performance and safety of the equipment supplied.

6.27.2.3.3.5 Dispensing system to provide site specific number of dispensing hoses (TBD), and be capable of fueling site specific number of NGVs simultaneously (TBD).

6.27.2.3.3.6 The dispensing system shall be able to operate independently from compression equipment.

6.27.2.3.3.7 Vehicle fuel cylinders shall be protected by pressure relief valves set at or below the designated maximum allowable vehicle filling pressure. Pressure relief valves shall comply with Section VII, Division 1 of the ASME Boiler and Pressure Valve code.

6.27.2.3.3.8 Dispenser fueling hose shall be conductive type designed for CNG service and appropriately marked. Each hose shall incorporate a breakaway connection to prevent loss of CNG and minimize damage to the dispenser in the event the fueling hose is pulled away from dispenser.

6.27.2.3.3.9 Minimum fuel flow rating of the dispenser shall be determined by fleet requirements.

6.27.2.3.3.10 Each hose shall be:

6.27.2.3.3.10.1 15 feet long if connected to upper part of dispensing unit or, 12'-6" long if connected to side of dispensing unit

6.27.2.3.3.10.2 Electrically conductive and constructed with a non-metallic braid

6.27.2.3.3.10.3 Rated for 5,000 psi, SAE 100R8

6.27.2.3.3.10.4 Equipped with a stainless steel breakaway connector that limits breakaway to hose not greater than 150 lbs.

6.27.2.3.3.11 Dispenser shall operate on 120 Volt single phase power supply.

6.27.2.3.3.12 In line filters of not greater than 25 micron shall be provided for each line of fuel supply. Filters shall be incorporated into the dispenser cabinet.

6.27.2.3.3.13 Dispenser shall provide LCD display to indicate the quantity in GGE of fuel dispensed.

6.27.2.3.3.14 Dispenser shall not utilize pressure gauge indication of vehicle fueling status but instead shall indicate LCD "Percent of Fill" status.

6.27.2.3.3.15 Fueling nozzles shall be at a minimum, ANSI/AGA NGV 1, Type 1 of the appropriate pressure rating for the identified filling pressure requirements. All nozzles shall provide capture of disconnect gas for safe venting away from vehicle connection point.

6.27.2.3.3.16 Dispensers supplied for this application shall incorporate only electronically controlled temperature compensated fuel control systems, which shall include the following:

6.27.2.3.3.16.1 Algorithm based software to provide vehicle filling control that calculates the vehicle's required fuel capacity compensating for ambient temperature, heat of compression and vehicle cylinder temperature rise so as to provide accurate fills to within 93-98% of vehicle rated capacity.

6.27.2.3.3.16.2 Computer based adjustable control of sequential set points for low, mid and high banks of storage with full low flow cut off.

6.27.2.3.3.17 Dispenser fuel metering shall be accomplished through the use of a coriolis mass flow meter consisting of a sensor and an electronic control module that measures the mass of the gas flow independent of density, pressure or temperature. An independent coriolis metering system, Micro Motion DH038 or equivalent, for each fueling hose of the dispenser. Certified metering accuracy of +/1.5%.

6.27.2.3.3.18 High Flow Cut Off - provides shutoff of fuel flow if gas is dispensed at a rate determined by fleet requirements.

6.27.2.3.3.19 Pressure Drop Cut Off - provides shutoff of fuel flow if there is a sudden pressure drop during fueling process.

6.27.2.3.3.20 Pressure Rise Cut Off - provides shutoff of fuel flow if the fueling pressure does not rise in accordance with the mass of gas dispensed.

6.27.2.3.3.21 ESD Interlock - Closes the fuel system's ESD valves when the dispenser is not in use. Closes the fuel system's ESD valves if the dispenser control system senses a fault with a control component.

6.27.2.3.3.22 A pit frame shall be provided for dispenser mounting that can be installed at installation site.

6.27.2.3.3.23 Fueling dispenser shall be designed, constructed, and tested in conformance with the following:

6.27.2.3.3.23.1 American Gas Association (AGA).

6.27.2.3.3.23.2 American National Standards Institute (ANSI).

6.27.2.3.3.23.3 American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code, Section VIII, Division 1.

6.27.2.3.3.23.4 Compressed Gas Association (CGA).

6.27.2.3.3.23.5 Underwriters Laboratories (UL).

6.27.2.3.3.23.6 Nationally Recognized Testing Laboratory (NRTL).

6.27.2.3.3.23.7 Factory Mutual Research Association (FM).

6.27.2.3.3.23.8 National Electrical Manufacturers Association (NEMA).

6.27.2.3.3.23.9 National Fire Protection Association (NFPA) NFPA70 National Electric Code NEC.

6.27.2.3.3.23.10 National Fire Protection Association (NFPA), NFPA52.

6.27.2.3.3.23.11 National Pipe Threads (NPT)

6.27.2.3.3.23.12 Uniform Fire Code (UFC)

6.27.2.3.3.23.13 Occupational Safety and Health Administration (OSHA)

6.27.2.3.4 Fuel Management System

6.27.2.3.4.1 **Components:** A fuel management system should include a card reader, software, and communication equipment necessary for an owner to monitor and evaluate fuel usage data. Typical fuel management systems provide fueling transaction data such as; vehicle number, operator name, vehicle mileage, quantity of fuel, date, and time. The complexity of a CNG fuel management system can vary greatly depending on the application and owner requirements.

6.27.2.3.4.2 **Fuel Management System Performance Requirements:**

6.27.2.3.4.2.1 System to be a fully automated fuel dispensing system and capable of providing inventory and transactions data without the need for a fuel station attendant.

6.27.2.3.4.2.2 System must be capable of selective card lockout, computing pump totalizer reading for inventory control, telephone modem hookup from remote sites to the existing central system.

6.27.2.3.4.2.3 System to be capable of controlling and relaying information to a remote computer system.

6.27.2.3.4.2.4 System components to be FCC and UL listed.

6.27.2.3.4.2.5 Island Card Reader: Island card reader to be island (base) mounted, two key system, with a weatherproof enclosure, built-in diagnostic system, capable of controlling a minimum of two hoses simultaneously, and including an emergency stop button. Suitable for Class 1, Division 2 areas. Illuminated system faceplate, LCD display and keypad suitable for all weather installation with back lighting or display suitable for viewing in lighted nighttime island setting. Capable of being activated and de-activated by the owner's fuel management system terminal. Must be compatible with owner's fuel management system, and provide vehicle and fueling data as required.

6.27.2.3.4.2.6 Voltage Regulator: Provide a UL listed voltage regulator to give voltage regulation, transient suppression and common mode protection for the island card reader, pump control units, site controller and phone modem.

6.27.2.3.5 Compliance and Industry Standards

6.27.2.3.5.1 NFPA 30A - Code for Motor Fuel Dispensing Facilities and Repair Garages

6.27.2.3.5.2 NFPA 52 - Compressed Natural Gas (CNG) Vehicular Fuel Systems: NFPA 52 is the encompassing standard that should (typically) be used in the design of a CNG fueling station. The intent of this standard, as written, is to serve as a minimum guideline, not a specification. NFPA 52 is not universally adopted throughout the United States. Fueling station design should conform to the NFPA 52 version that has been adopted by the authorities having jurisdiction, and the local Fire Marshall. NFPA 52 versions vary significantly, specifically as they pertain to electrical requirements. It should also be stressed that NFPA 52 may not be the encompassing design standard if the site's local Fire Marshall has not adopted NFPA 52 as a code. Regional codes may augment and/or supersede NFPA 52.

6.27.2.3.5.3 NFPA 70 - National Electric Code (NEC): NFPA 70, Chapter 5 Special Occupancies, contains several sections relating to hazardous locations that apply to CNG fueling stations. NFPA 52 defines where each of the hazardous electrical areas are located, but does not define what type of electrical equipment is required, or how it is to be wired and installed. As with NFPA 52, NFPA 70 NEC needs to be verified as the applying code by the local authorities having jurisdiction.

6.27.2.3.5.3.1 Article 500, 501, 504, 511 - Hazardous Locations: NFPA codes classify hazardous areas according to the likelihood of the particular hazardous or flammable material being present in a given location. Often the most unclear and confusing code requirement issues involve determining the electrical "Classes" and "Divisions" as they apply to hazardous area equipment. The following description should help to generally understand this issue.

6.27.2.3.5.3.1.1 Class 1, Division 1, Group D: A location where natural gas is present all of the time, or where it may be present as the result of faulty equipment operation or gas relief.

6.27.2.3.5.3.1.2 Class 1, Division 2, Group D: A location where natural gas is normally contained in a gas vessel or pipe, and can only escape as the result of equipment failure or abnormal circumstance.

6.27.2.3.5.3.1.3 NFPA 37 - Stationary Combustion Engines and Gas Turbines: This code outlines the necessary instrumentation, mechanical, and electrical requirements, for the installation of a natural gas engine. This code would only apply for the installation of a natural gas prime mover CNG fueling station.

6.27.2.3.5.3.1.4 NFPA 497 - Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

6.27.2.3.5.3.1.5 Uniform Fire Code (UFC): The main issue in this code is the equipment separation requirements as outlined in sections 5201 and 5204 in the 1994 edition.

6.27.2.3.5.3.1.6 National Electrical Manufacturers Association (NEMA): A CNG fueling station designer should be familiar with NEMA electrical equipment ratings. NEMA provides a method of rating electrical enclosures for the environment and applications they can be installed.

6.27.3 CNG SERVICE, MAINTENANCE AND STORAGE AREAS

6.27.3.1 This Section is written only as a general guideline, as no encompassing code covers the indoor storage and service of CNG vehicles, and as a result, design practices are determined on a case by case and application basis. Facility design should include careful consideration of the vehicles and the facility's systems, and should be coordinated with local fire and safety officials follow codes and standards described in Section 6.29.3.5.

6.27.3.2 Mechanical Systems and Equipment

6.27.3.2.1 Ventilation System - Service and Maintenance Areas

6.27.3.2.1.1 Ventilation system shall provide 4 ACH continuously (as required by OSHA and NFPA 88B). Powered ventilation system shall be spark resistant, centrifugal, roof exhaust fans, with Class 1, Division 2, explosion proof motor and power accessories. OA shall be introduced to the space at ground level. Design shall ensure that all areas of the ceiling are ventilated, regardless of ceiling geometry.

6.27.3.2.1.2 Emergency ventilation system shall provide a total of 8 ACH, and shall be automatically activated by the gas detection system, as well as a manual emergency button.

6.27.3.2.1.3 Where possible, ventilation fans shall be located directly above CNG service bays.

6.27.3.2.2 Ventilation System - Storage Areas

6.27.3.2.2.1 Ventilation system shall provide 1 cfm per square foot of floor space, continuously during normal business hours. Powered ventilation system shall be spark resistant, centrifugal, roof exhaust fans, with Class 1, Division 2, explosion proof motor and power accessories. OA shall be introduced to the space at ground level. Design shall ensure that all areas of the ceiling are ventilated, regardless of ceiling geometry.

6.27.3.2.2.2 Emergency ventilation system shall provide a total of 8 ACH, and shall be automatically activated by the gas detection system, as well as a manual emergency button.

6.27.3.2.3 Space Heating System

6.27.3.2.3.1 Heating devices within the hazardous area (facility) shall be hot water or indirect (sealed combustion), Class 1, Division 2 rated (per NFPA 30A and 88B). All combustion air is to be supplied from outside the facility.

6.27.3.2.3.2 Electrical Systems and Equipment

6.27.3.2.3.3.6 Panelboards and sub-panelboards should not be installed in hazardous areas. Panelboards should be located outside of CNG service and storage areas, or in a dedicated electrical room, without the possibility of gas infiltration by natural or mechanical means.

6.27.3.2.3.3.7 Equipment - (Motors, Luminaries, etc.)

6.27.3.2.3.3.8 All electrical equipment, components, and accessories - located 18" down from the underside of the roof deck - shall be Class 1, Division 2 rated.

6.27.3.2.3.3 Specialty Service Equipment

6.27.3.2.3.3.1 Welding and Grinding

6.27.3.2.3.3.2.6 Welding, grinding, other spark or open flame related work - work area to be a minimum of 50 feet from CNG service or storage areas. Work area shall contain a spark/vapor curtain.

6.27.3.2.3.3.2.7 NGVs to be serviced by a welding or grinding activity shall be "de-fueled" to at least half of rated tank pressure, and NGV fuel tank and manifold isolation valves closed. NGV engine shall be turned-over to burn residual gas.

6.27.3.2.3.3.2 Hand Tools

6.27.3.2.3.3.2.1 Hand held lighting and electrical tools shall be appropriate and listed for Class 1, Division 2 rated areas.

6.27.3.2.3.3.2.2 Hand held methane detectors should be provided to inspect CNG Vehicle fueling lines and storage tanks, prior to commencing service work.

6.27.3.2.3.4 Facility Design - Coordination Issues

6.27.3.2.3.4.1 Roof trusses shall be of open design, and not allow gas to be "trapped" in ceiling spaces, design shall allow for through ventilation.

6.27.3.2.3.4.2 Facility indoor partitions should be continuous from floor to ceiling, securely anchored, and have a minimum of 2 hour fire resistance.

6.27.3.2.3.4.3 CNG service bays shall be located directly under any necessary "high points" in ceiling design.

6.27.3.2.3.4.4 Deflagration panels may be designed into exterior facility walls where highly hazardous areas are considered.

6.27.3.2.3.5 Gas Detection System

6.27.3.2.3.5.1 Complete gas (methane) detection system and accessories including; infrared gas detector transmitter and receiver assembly with reflector panel, gas personality modules and mounting brackets, explosion proof insulating power supplies. Control system to include; dual channel control card with independent digital displays, site specific programmable alarm levels per channel, power and fault diagnostics indicators, test/reset and alarm inhibit switches, system enclosure, mounting brackets, power supply, audio/visual alarm devices, remote zone alarm indicator, PDT relays, termination assembly, 115v AC power operation.

6.27.3.2.3.5.2 The gas detection system shall open outside doors, start emergency ventilation fans, sound alarms, and disable certain equipment.

6.27.3.2.3.6 Code Compliance and Industry Standards: It should be made clear that existing codes lack emphasis and clarity on significant CNG issues. The following codes and guides should be referenced when designing a CNG service, maintenance, or storage facility, but common sense and experience should prevail. The use of an experienced Architect and Engineer is recommended.

6.27.3.2.3.6.1 NFPA 30A and 88BA - Parking Structures and NFPA 88B Repair Garages: These codes provides requirements for flammable and combustible liquids (NFPA 30), and liquefied petroleum gas (NFPA 58), which in vapor form are heavier than air, and will collect along the facility floor. Natural gas is lighter than air, and will travel from the source, to the facility ceiling. Natural gas under pressure will tend to flow in the direction of leaking force, then rise to the ceiling. These codes basically describe that the requirements on/along the floor for diesel fuel vapors, should be applied to the ceiling area for natural gas. The Class 1, Division 2 zone in the maintenance area shall be 18" down from the underside of roof deck.

6.27.3.2.3.6.2 Federal Transit Administration (FTA) - Garage Guidelines for Alternative Fuels: This document provides a general description of CNG service, maintenance, and storage hazards, however it does not provide specific design requirements or equipment ratings.

6.27.3.2.3.6.3 IBC - International Building Code: These codes mainly provide minimum standards for building design and construction. Most sections dealing with hazardous materials and how they impact system design and construction, refer the reader to NFPA. This code does however, identify building "group" classifications based upon the intended use of a building or area, and/or the hazards which may be stored in a particular building or area. Design and construction shall meet all IBC requirements, specifically chapter 3, sections 307, 309, and 311.

6.27.4 GLOSSARY OF ABBREVIATED TERMS

AGA - American Gas Association

ANSI - American National Standards Institute

ACH - Air Changes per Hour

ASME - American Society of Mechanical Engineers

ASTM - American Society Testing Materials

BOCA - Building Officials and Code Administrators International, Inc.

CGA - Compressed Gas Association

CF - Cubic Feet

CFM - Cubic Feet per Minute

CNG - Compressed Natural Gas

dbA - Decibel Absolute

FCC - Federal Communication Commission

FM- Factory Mutual Research Association

GGE - Gasoline Gallon Equivalent

IBC - International Building Code

LCD - Liquid Crystal Display

NEMA - National Electrical Manufacturers Association

NFPA - National Fire Protection Association

NPT - National Pipe Threads

NGV 1 - Natural Gas Vehicle Standard

NEC - National Electric Code

NRTL - Nationally Recognized Testing Laboratory

OA - Outside Air

OSHA - Occupational Safety and Health Administration

PLC - Programmable Logic Controller

PSIG - Pounds per Square Inch Gauge

SAE - Society of Automotive Engineers

SCF - Standard Cubic Feet

SCFM - Standard Cubic Feet per Minute

TEFC - Totally Enclosed Fan Cooled

UFC - Uniform Fire Code

UL - Underwriters Laboratories

6.27.5 REFERENCES

International Building Code (IBC) published by the International Code Council

Building Officials and Code Administrators International, Inc. (BOCA) - National Building Code

Federal Transit Administration (FTA) - Garage Guidelines for

Alternative Fuels National Electrical Manufacturers Association

(NEMA) Standards NFPA 30A

National Fire Protection Association (NFPA) 37 - Stationary Combustion Engines and Gas Turbines

National Fire Protection Association (NFPA) 52 - Compressed Natural Gas (CNG) Vehicular Fuel Systems

National Fire Protection Association (NFPA) 70 - National

Electric Code (NEC) National Fire Protection Association

(NFPA) 88A - Parking Structures National Fire Protection

Association (NFPA) 88B - Repair Garages NFPA 497 Natural

Gas Vehicle (NGV) Institute - Certification Training Program

Manual Uniform Fire Code (UFC)

SECTION 7 LIGHT RAIL

7.1 (FUTURE)

SECTION 8 - DESIGN POLICIES FOR THE OPERATING METRORAIL SYSTEM

8.1 GENERAL

The following design criteria in sequence first establishes the criteria for the Metro Design Vehicle and then provides the criteria for the facilities required for the safe operation of the Metro Design Vehicle in the Metrorail System.

To facilitate operations in a single-track mode to by-pass emergencies, maintenance and repair, all tunnels and aerial guide-ways shall be separate single track structures, except where necessary for special trackwork. Double track structures may be considered when approved by WMATA.

8.2 DESIGN VEHICLE

System rolling stock will be designed and operated in two car multiple units. Multiple car trains in lengths of two, four, six and eight cars will be scheduled for revenue service. The maximum train consist is eight cars or 600 feet. Moving a bad order train will result in a maximum train length of 1200 feet.

WMATA cars will be high performance, lightweight, electrified vehicles having the following characteristics:

8.2.1 Dimensions

Length over coupler faces, maximum	75' - 0"
Approximate length over anti-climbers	74' - 9"
Width, maximum	10' - 1¾"
Height at centerline above top of rail, maximum	10' - 10"
Floor height, above top of rail	3' - 4"
Truck Spacing	52' - 0"
Truck Wheel Base, minimum	6' - 6"
maximum	8' - 6"
Wheel Gage	4' - 7 11/16"
Basic Track Gage	4' - 8 ¼"
Wheel Diameter	28"

Roll Angle (AREA Static Lean Test) 1° 30' max.

8 .3 CLEARANCE ENVELOPE

The Rohr, Breda, CAF, Alstom and Kawasaki Cars also have design characteristics that differ slightly from the WMATA Car. The clearance envelope shown on Standard Drawing ST-C-RCAR-001 incorporates all of these different car characteristics. The final design must allow for the car outline found on ST-C-RCAR-001 which is described as follows: The **clearance envelope** is defined as the space occupied by the dynamic outline of the 10'-1¾" wide design vehicle plus an additional allowance of 2" around the dynamic outline. The following factors have been considered in developing the clearance envelope:

8.3.1 Dynamic Outline

The dynamic outline of the design vehicle includes the following car body movements:

8.3.2 Vertical Upward Displacement

Track construction tolerance	0.250 "
Car construction tolerance	0.500 "
Car body camber	0.500 "
Bounce against stops	1.500 "
Vertical track curvature	0.375 "
Total	3.125 "

8.3.3 Vertical Downward Displacement

Wheel wear Rail wear	0.750 " *
Air springs against stops	0.750 " *
Primary springs against stops	1.500 " *
Vertical track curvature	0.375 "
Total	4.87"5
Total - Truck Parts Only	1.531 "

8.3.4 Lateral Displacement

Lateral of wheels 0.406 " *

Car body against stops	1.500 "
Car construction tolerance	0.125 "
Track construction tolerance	0.250 " *
Truck assembly tolerance	0.125 " *
Wheel wear	0.250 " *
Rail wear	0.500 " *
Total	3.156 "
Total - Truck Parts Only	1.531 "

8.3.5 Roll

3½ degree roll occurring after 1½ inches of lateral movement. The combined effect of these factors is shown on Fig. 11.29 as the dynamic outline. For clearances at Station Platforms only, the following car body movements have been used:

Vertical Downward	3.000 "
Lateral Movement	2.625 "
Roll, after 1½" lateral movement	2.000 "

8.4 PASSENGER CAPACITIES AND CAR LOADINGS AND WEIGHTS

Passenger Capacity Loadings

Seating Capacity per car	81

Passenger Capacity per car, seated plus standees:

Normal Loading	130
Normal Maximum	160
"Crush" Loading	220

Weights per Car with Different Loadings

Lightweight, including air conditioning	82,000 lbs
Normal Maximum Loading	106,000 lbs

"Crush"Loading	115,000 lbs
Absolute Maximum Loading	132,000 lbs

8.5 PERFORMANCE CHARACTERISTICS

8.5.1 Design Velocity

The design vehicle maximum velocity is 75 mph. The minimum desirable design velocity is 40 mph. The train control system limits the operational running speeds to ten preset values.

8.5.2 Normal Acceleration

Fig. 11.32 has been prepared to illustrate a typical Speed-Time-Distance curve for normal acceleration of the design vehicle from a standing stop to the maximum speed attainable of 75 mph on level, tangent track.

8.5.3 Normal loading of 130 passengers per car was assumed in curve development.

The acceleration rate is non-linear, tapering from a maximum of 3.0 mphps at the start of acceleration to balancing speed.

8.5.4 Normal Deceleration

Fig.11.33 illustrates a typical Speed-Time-Distance curve for normal deceleration from a maximum speed of 75 mph to a stop on level, tangent track. Crush loading of 220 passengers per car was assumed in curve development. The following tapered braking rates were assumed:

75 mph to 50 mph – 2.25 mphps increasing uniformly to 3.0 mphps

50 mph to 0 mph – 3.0 mphps

8.6 AUTOMATIC TRAIN CONTROL - ATC

The WMATA Automatic Train Control uses stepped code speeds for operating vehicles on the main line tracks. The code speeds are: 15, 22, 28, 35, 40, 45, 50, 55, 65, 75. The design of a curve for a faster speed than one of the coded speeds will result in the ATC operating the train through the curve and spirals at code speed which is below the rated design speed of the curve/spiral. For example a curve designed for 44.5 miles per hour will be limited to 40.0 mph in Metrorail operation. The determination of maximum design speed through a curve for areas of limited space should recognize this limitation in design flexibility in the design of actual curve superelevation.

8.7 TURNOUTS

The maximum horizontal limits of the design vehicle dynamic outline of the standard design vehicle as it moves through a turnout has been established for WMATA No. 6, 8, 10 and 15 turnouts.

8.8 ACOUSTICAL TREATMENT ALLOWANCE

Critical clearance dimensions are not increased to allow for the application of acoustical treatment. However, this will not preclude the use of acoustical treatment in areas not critically affected by car clearance requirements.

8.9 CONTROL OF ACCESS

8.9.1 General

The rapid transit right-of-way shall be protected in such a manner as to prohibit public vehicular or pedestrian traffic from the right-of-way, except at points of passenger ingress and egress, such as stations and parking areas.

8.9.2 Crossings

All crossings of the right-of-way shall be grade separated.

8.9.3 Right-of-Way Barriers

Along the system, security barriers shall be provided to prevent the public from gaining access to the tracks.

8.9.4 Pedestrian Barriers

Forms of pedestrian barriers include fences, walls, and structural elevation differences. A deterrent in the form of barbed wire or equal physical obstruction must be mounted on the top of the barrier where illustrated in WMATA Manual of Design Criteria Facilities, Section 11, Figure 11.70 to Figure 11.72.

8.9.5 Fencing at Surface Routes

Minimum 6' high chain link security fence with extension arms and 3 strands of barbed wire shall be provided with 4'-0" wide sliding emergency access gates at approximately 800 foot intervals on both sides of the right-of-way to coincide with the trip station lights.

Where the transit right-of-way is crossed by a pedestrian walkway, the barrier on the walkway should effectively prevent objects being dropped or thrown on the transit right-of-way.

8.9.6 Vehicular Barriers

Acceptable vehicular barriers include highway guard rails, barrier curbs, structural walls or earth embankments. In each case, where vehicular access to areas adjacent to the transit right-of-way is possible, individual circumstances must be evaluated including the possibility of accidental entry by runaway vehicles.

8.9.7 Safety Railings

Where elevation differences alone constitute a sufficient pedestrian or vehicular barrier, safety railings must be provided both for the protection of the public and the rapid transit personnel.

8.10 SERVICE ROADS

Service roads as shown on the trackwork designing and standard drawings shall be provided for Metro construction at grade on exclusive right-of-way wherever land use permits and wherever real estate and construction costs make their inclusion economically feasible. The decision to include or exclude a service road shall be made by the Authority upon receipt of the Designer's evaluation of cost and feasibility.

Service roads need not be continuous although this is desirable. A means of access shall be provided for each section of service road. A cul-de-sac shall be provided at the end of a service road where a direct connection to a public road is not possible or feasible. Furthermore, it is not necessary that the service road always be on the same side of the tracks.

For minimum clearances required between the design vehicle dynamic outline and service road structures or installations, refer to Standard Drawing ST-TW-RR-005

Maintain uniform roadway alignment calculations, referencing service roads to track alignment whenever possible. Maintain records of computer output of calculations with clearly referenced sketches and definitions of computer output codes.

8.11 MAINTAINABILITY

The Metrorail System shall be designed to attain the optimum degree of maintainability consistent with established Metrorail architectural and engineering design criteria contained in this Manual. Maintainability is determined by the characteristics of Metrorail structures, finishes, fixtures and installed equipment which make it possible to operate a safe and efficient system with the most economical expenditure of maintenance resources.

Maintenance resources include manpower, equipment, materials and support facilities. Emphasis shall be applied to those maintainability considerations which determine the frequency, rapidity and ease of maintenance operations.

Maintenance operations consist of inspection, adjustment, cleaning, servicing, testing, repair and replacement. Particular attention shall be placed on providing accessibility for performance of maintenance (service hatches, stairs, ladders, lifting equipment, catwalks, structural openings, space, layout and fixture/equipment location). Full consideration shall be given to economic factors, e.g., life cycle costs, in determining the extent to which maintainability is incorporated. Where the principle of maintainability is in conflict with criteria in this Manual or the General Plans, such conflicts, with recommended action, shall be brought to the attention of the Authority.

8.12 CONTRACT DRAWING STANDARDS

8.12.1 General

8.12.1.1 Drawings

Drawings shall be created using CAD procedures that are defined in the latest release of the WMATA CAD Manual. Drawings shall be submitted in hardcopy, .dwg and .pdf formats.

Drawing presentation, size, symbols and details must be standardized as much as possible to facilitate reading and filing by the Authority and contractors. Standardization within each individual contract and throughout the large number of contracts for the rapid transit system is essential.

All contract drawings shall be produced on a 22"x34" - 0.003" thick polyester sheet, matte both sides, identical in format to the sample supplied by the Authority.

DRAWING SEQUENCE FOR CONTRACTS - Design drawings provided for construction contracts shall organize the drawings in the following sequence:

Cover Sheet

General Site Plan

Index of Drawings

Cross Index

Project Signs

Civil Abbreviations, Symbols and Notes (including curve geometry)

Horizontal and Vertical Controls

Survey Plots (including boring locations)

Geotechnical Symbols, Abbreviations and Notes

Boring Logs

Right-of-Way

Plan and Profile (including structural key plans and other key plans if it can be done without loss of clarity)

Alignment Data (coordinate tabulation)

Typical Section (composite)

Construction Staging

Grading Plans (as required)

Paving and Restoration

Standard Barricades

Sediment Control Plans

Utility Symbol and Abbreviation Standard

Composite Utility Plans

Separate Utility Plans (as required)

Utility Profiles (separated by type)

Utility Details (separated by type)

Structural Abbreviations and General Notes

Structural Plans (by structural unit)

Structural Details

Structural Pay Limits

Architectural Symbols, Abbreviations and Notes

Architectural Drawings

Mechanical Key Plans (if not on Plan and Profile)

Mechanical Symbols, Abbreviations and Notes

Mechanical Drawings

a. Plumbing

b. HVAC

Electrical and Train Control Key Plan

Electrical and Train Control Symbols, Abbreviations and Notes

Electrical Drawings

Train Control Drawings

Communication Drawings

CONTENT AND ORGANIZATION OF CONTRACT DRAWINGS

The drawing format for the general construction site plan shall utilize a full size sheet which shall be placed immediately after the cover sheet. It shall include the information pertinent to the general construction site.

The contract title must be specific. Identify major elements such as stations, parking lots, substation, etc., in the title.

The survey plot drawings should show soil boring locations and Metro horizontal and vertical control monuments. Small sketches showing the monument reference ties should be included on individual sheets. Tabulations of boring coordinates and monumentation data should also be shown on unused portions of the survey plot sheets.

The horizontal and vertical control (plan and profile) sheet should show the schematic ties between monuments and alignment control points (PIs, POTs, etc.) and other pertinent control information.

The standard horizontal curve geometry sheet should be expanded to include all civil abbreviations and symbols. The datum conversion table should be included on this sheet.

The use of a separate sheet as a drawing key plan is not required. Instead, a small schematic of the site should be inserted on each sheet where appropriate, with the area of the site covered by the particular sheet highlighted on the schematic.

Information currently shown on the structural and mechanical (drainage) key plans may also be included on the PP drawings. However, care must be taken not to overcrowd the PP drawings. The PP drawings should be the central reference plans for the major components of the section, thereby facilitating design review and encouraging coordination among disciplines during design and construction.

The plan and profile drawings should be supplemented by typical cross sections at reasonable scales (on separate sheets, if needed) taken at critical locations, such as curves, crossover areas, and transitions between different types of construction (i.e., tunnel to cut-and-cover). The cross sections should show fire lines, electrical cables (embedded or attached to channel inserts) handrails, panel boxes, lighting, etc. Care must be taken to indicate items as N.I.C. where appropriate. These sections would minimize the need for separate sections showing items pertaining to each discipline throughout the set of plans.

Alignment coordinates may be removed from the PP sheets and tabulated on a separate sheet.

Information shown, in addition to the current alignment data, should include:

Structural unit designation, stations, and IB & OB T/R elevations at the construction joints (if separate structural key plans are not provided).

Location of the safety walk.

Station location of the beginning and ending of structure widening with centerline track to wall dimensions. Where dimensions vary (on spirals) dimensions at start and ending of variation should be shown.

Major electrical system elements could be indicated, such as trip stations, divisions of AC power, tie breaker stations and substations. Provide separate key plans for electrical and train control items.

Screened topographic mapping is required for the plan and profile drawings.

Special trackwork designation and P.S. stations, floating slab limits, etc.

Separate structural plans need not be drawn for each unit when a typical plan may serve to define a number of units.

Contract drawings shall be prepared on electronic media files in accordance with the following requirements:

1) The Section Designer/Design Engineer is required to (or as specified by the Authority) provide all final drawing documents in Latest Release of AutoCAD drawing file. WMATA will specify prior to delivery which medium the Section Designer/Design Engineer shall use to provide this information. The digital medium shall be provided by the Section Designer/Design Engineer and become the property of WMATA.

These drawings are to be photographically reduced and offset printed to half-size for binding into contract books and subsequent distribution to bidders. Other than signatures, no free-hand entries are permitted. Letters and numbers on the body of the drawing shall not be less than one-eighth of an inch high. In drawings where a subdued background is required, the background shall be screened to a 50 percent density at 80 to 85 lines per inch.

Entries in pencil are not permitted for the final submitted drawings. Final entries must be in ink.

Figures 8 .1 and 8.2 illustrate the types and weights of lines, north points and section arrows which shall be used on contract drawings. Figure 8.3 explains title block and scale requirements.

Completed drawings shall become the property of the Authority. These drawings shall be complete with all revisions and shall represent, as closely as practicable, the complete system facilities.

Drawings modified by amendments prior to construction or by revision during construction shall be clearly marked to identify the detail changed. Amendment and revision numbers shall be noted and dated in the title block. Amendment numbers shall be placed in a 1/4 inch square e.g.

$\boxed{\text{A/1}}$ $\boxed{2}$ and immediately adjacent to the detail modified and to the top and right borders of the drawing. These squares shall be opposite the amendment or revision square in the detail modified.

The crossover alignment, including curve control points and curve data, is to be shown on the PP drawings.

The project coordinate system or a baseline and offset system should be used to locate and define curb lines and profile grade lines. Baseline shown for layout geometry may not necessarily be considered construction baseline. That should be left to the option of the construction contractor. All curb lines except small islands should have a top of curb or flowline included. Rigid mathematization of all profiles may not be consistent with construction practice. "Spline" profiles may be used.

Symbols used on the construction staging plans shall be uniform. These would include:

a. Precast concrete barrier (single and double)

b. Other standard barricades

c. Metro construction - current stage

d. Metro construction - completed in previous stages

f. Decking - current and completed

g. Temporary pavement

Show survey baseline on the survey plot drawings. Tie the cross sections on the plan to the alignment of the outbound track. Tie cross section to the survey baseline only if it is not practical to tie them to the centerline of the outbound track.

8.12.2 Drawing Numbering System

8.12.2.1 Route and Contract Numbers

Figure 8.4 indicates the general location of each route.

There are eleven routes in the regional rapid transit system with the following designations:

A - Shady Grove

B - Glenmont Route

C - Huntington Route

D - New Carrollton Route

E - Greenbelt Route

F - Branch Route

G - Addison Route

H/J - Franconia/Springfield Route

K - Vienna Route

I - L'Enfant - Pentagon River Crossing

N - Dulles Extension Route

Each of these routes has been subdivided into specific contracts. The contract number shall be shown on each drawing in the lower right corner in the box above the title block. Information drawings in each bid package shall also include the contract number. Contracts of each route have been stationed consecutively starting at the 0+00 system reference point for the particular route. The first digits of all contract drawing number shall indicate the route and contract number and will include the letter designation of the subsection (example: K7i). The contract number for a finish contract for this same design section will be preceded by the letter 'F" (example: FK7i). The Main heading in the title block of each drawing shall indicate the name of the route of which the particular contract is a part.

8.12.2.2 Drawing Type Designations

Drawing types will vary from contract to contract, and will include the following types of drawings, among others. The middle digit of the contract drawing number shall indicate the drawing type:

G - General Information

C - Horizontal and Vertical Control

SP - Survey Plots

SO - Soils & Geotechnical Information

R - Right-of-Way

PP - Plan and Profile

GR - Grading

X - Cross Sections

SC - Soil Erosion and Sediment Control

U - Utilities

P - Paving and Restoration

TM or MT - Maintenance of Traffic

S - Structural

A - Architectural

LA - Landscape Architecture

M - Mechanical

E - Electrical

TC - Train Control

CM - Communications

Other digits as required.

Drawings shall appear in the contract book in the sequence as set forth in Section II, Item R.

8.12.2.3 Drawing and Sheet Numbers

The last digits of the drawing number shall indicate the sequence in which the drawings were actually produced. When the drawings are assembled in the contract book, the drawing numbers need not appear in consecutive order throughout any one group of drawings. Order in the book shall be established by numbering each sheet in the sequence desired, with the sheet number preceded by a file number (M-number) supplied by the Authority. This is the final step in contract book preparation.

8.12.3 Cover Sheets

The cover sheets for the contract drawings shall include the following information in a format as indicated in Figure 8.15:

Information	Example
a. IFB Number	IFB-C-509
b. Design Section Designation	Section K-5c
c. Route Name	Vienna Route
d. Title of Project	North 25th Street Tie Breaker Station
e. Contract Number	1KOO53
f. Date of Advertisement	November 1, 1981
g. Designer	Polytech, Inc.

8.12.4 Standard Drawings

Information and details which are of a standard nature and are to be repeated on successive contracts have been detailed by the General Consultants on Standard Drawings. These drawings are numbered as follows:

Civil	ST-C
Utilities	ST-U
Structural	ST-S
Mechanical	ST-M
Electrical	ST-E
Train Control	ST-TC
Communications	ST-CM
Architectural	ST-A

Full-size electronic reproductions of standard drawings will be furnished to Designers at the pre-final review stage, upon request, for inclusion in the contract drawing books at the end of the appropriate section of drawings. Standard Drawings are not to be modified. If a portion is not needed, it may be crossed out.

8.12.5 Coordination and Review of Contract Drawings

8.12.5.1 Coordination

The WMATA Project Manager will coordinate the work of all Designers. Information from one Designer which affects other Designers will be coordinated between the Designers with copies to the Project Manager. In order to facilitate coordination and review of the work, periodic submissions of contract drawing prints are to be made by the Designers to the General Consultants. It should be stressed that review by the General Consultants shall not relieve the Designer of responsibility for accuracy of the design and adequacy of the drawings.

The Designer shall direct technical questions, correspondence and prints for review to the Project Manager who will be responsible for expediting a response to questions by the Designers and for the review of drawings and submittals.

Designers will require certain information regarding inserts, slots, sleeves, recess and duct locations, etc., for traction power, supervisory control, train control and other system contracts being developed by others. This information will .be forwarded by the General Engineering Consultant. Provision for these details shall be made on the contract drawings.

8.12.5.2 Reviews

Prints of all contract drawings produced by the Designer shall be submitted to the General Consultants each month. These prints will serve as a record of progress. Review submittals are defined in the Scope of Services for each particular contract. Monthly submittals shall be half-size prints and consist of all drawings. Review submittals shall be half-size prints and consist of all contract drawings produced by the Designer.

8.12.6 Approvals

Upon completion of the contract drawings, each drawing shall be sealed and signed by the Professional Engineer, Surveyor or Architect under whose direction the drawings were produced and who assumes full responsibility for all aspects of the design. The Professional Engineer, Surveyor or Architect shall be licensed in the jurisdiction where the work will be constructed.

Submit Adobe (.PDF) of contract drawings (design-bid-build) or Issued for Construction Drawings (design build) sealed and signed by a professional engineer or architect, as applicable, registered in the jurisdiction where the work will be performed for official record.

8.12.7 Types of Contracts

There are a number of types of contracts for which contract documents will be required. In general, structural contract should include the construction work performed by the heavy construction trades while finish contract should include the work performed by the building trades.

8.13 STRUCTURAL CONTRACTS

The following drawings shall be produced for a structural contract. Other drawings shall be included as required. The scales to be used and information to be shown on each type of drawings are listed below:

All rapid transit routes have been stationed from a preselected reference point, 0+00 at Metro Center and 0+00 on 7th Street, N.W., at Gallery Place Station.

For ease in orientation, drawings for contracts of the Shady Grove (A), Huntington (C), Vienna (K), Franconia/Springfield (H/J), L'Enfant Pentagon River Crossing (L) and Dulles Extension (N) Routes shall be drawing with stationing increasing from right to left on each sheet. Drawings for contracts of the Glenmont (B), Greenbelt (E), New Carrollton (D), Addison (G) and Branch (F) Routes shall have stationing increasing from left to right on each sheet.

The drawings shall appear in order of increasing stationing.

8.13.1 General Information

Scale: As required

General Information drawings shall be prepared for the following items:

8.13.1.1 Key Plan of System: **The base for this drawing will be furnished by the General Engineering Consultant.**

8.13.1.2 General Construction Site Plan

Scale: Appropriate to allow the construction site to fit on one sheet. If possible, the site plan and key plan of the system shall be shown on the same sheet.

8.13.1.3 Traffic and Construction Staging

Scale: Horizontal - As required

Information shown:

Traffic Staging, coordinated with and approved by local authorities

Traffic Detours, coordinated with and approved by local authorities

Construction Staging

Possible construction ramp and storage sites Street and sidewalk areas to be decked for duration of construction.

8.13.1.4 General Notes and Abbreviations

8.13.1.5 Index of Drawings

A complete index of drawing shall be included with the set of contract plans. The index shall include drawing numbers, titles and sheet numbers. A cross index by drawing number shall also be included.

8.13.1.6 Payment Limits

Drawings delineating payment limits shall be included as required.

8.13.2 Horizontal and Vertical Control

Scale:	Horizontal	1" = 200'
	Vertical	1" = 40'

Information shown:

Structural alignment and outline in relation to street system

Control line ties to track alignment

Coordinate system

Location of control points and benchmark

Top of rail profile and structure outline

Ground surface

Contract limits and type of construction

Benchmark, ties to horizontal control points and control point coordinates Control Survey Marker Detail (See Figure 8.17).

8.13.3 Right-of-Way

Scale: Horizontal 1" = 40'

Information shown:

Right-of-Way lines with distances and bearings

Centerline of tracks Outline of transit structure

Track centerline stationing and station equations

Relationship of right-of-way to property lines, street systems and where properties will be affected by construction

Reference ties by distance and bearing from the right-of-way to copper corners in the District of Columbia and other monuments in Maryland and Virginia.

Right-of-Way widths, both existing and proposed Curve data of right-of-

way curves

Parcel numbers, lot numbers, square numbers, subdivision names and patent or survey names

Names of property owners

Design section limits

Affected and adjacent vaults with their disposition

Construction fencing

All existing easements on the property

Total area of parcel or lot affected

Area of taking

Screentone (Zip-a-tone) See Legend of Right-of-Way, Figure 9.1

Coordinates

a. coppers

b. sufficient to re-establish right-of-way

c. PC and PT of curves

Parcel, lot, square and track boundary lines of affected properties with distances and bearings shown

Distances and bearings around proposed takings

Names and widths of abutting streets and highways

Encroachments on, over and across land to be purchased

PC and PT of right-of-way curves

Show outbound track centerline at intersections with property block or square lines

If land is part of larger tract, show larger tract

Note in the property disposition table buildings to be demolished.

Where one lot has two or more easements of same type, note areas of each on plan, and sum in property disposition table.

Legend

Coordinate Grid

Pavement limits, curb lines.

8.13.4 Survey Plots

8.13.4.1 Scale: 1" = 40'

8.13.4.2 General information to be shown:

All planimetric features of the entire area affected by Metro construction.

8.13.4.2.1 Streets and Railways - describe all surface elements.

8.13.4.2.2 Buildings - describe material of construction, height, and street number of buildings adjacent to construction.

8.13.4.2.3 Proposed Metro alignment and facilities - indicate by phantom outline.

8.13.4.2.4 Trees - species, size and location in accordance with the following guidelines:

8.13.4.2.4.1 It is the Authority's policy to remove as few trees as possible and to design surface features to allow as many natural features as possible to remain while screening the Metro facilities from the adjacent property owners.

8.13.4.2.4.2 Preparation of the Survey Plot sheets shall be undertaken to provide a record for restoration after construction and of preservation during design. If the trees are to be destroyed during construction and not replaced, their location on the drawings can be indicated graphically, either individually in clusters or in molts. In the event an area is to be partially cleared, the Designer shall attempt to save as much as possible of the natural growth worth saving, designing the Authority's structures and facilities in accordance with the location and Metro guidelines for landscaping, using not only the advice and counsel of the location jurisdictions, but also that of trained professionals.

8.13.4.2.4.3 The extent of the identification and location of trees necessary to satisfy the Contract shall be determined by the Designer and reviewed by the GEC, based upon an evaluation of the trees, their location, the requirements of Metro, the overall area, and anticipated public interest in the trees.

8.13.4.2.4.4 Soil boring locations

8.13.4.3 Topographic Data to be shown

8.13.4.3.1 Accuracy of elevations

8.13.4.3.1.1 Paved areas ± 0.01'

8.13.4.3.1.2 Unpaved areas ±0.1'

8.13.4.3.2 Cut-and-Cover Construction and Excavations - Provide ground elevation on a 50' (maximum) grid with supplementary elevations of all abrupt breaks in grade (i.e., top and bottom of curbs, etc.) over entire area affected by construction.

8.13.4.3.3 Tunnel Construction - Provide a minimum of five ground elevations at 50' intervals along centerline of construction. These elevations will be oriented perpendicular or radial to centerline of construction and shall be located as follows:

One midway between tunnel(s)	1
One at each centerline track	2
One 20' outside each centerline track	2
Total	5
One midway between tunnel(s)	(1)
One at each centerline track	(2)
One 20' outside each centerline track	(2)

8.13.4.3.4 At-Grade & Aerial Construction

Provide one-foot contour interval supplemented with spot elevations at critical points throughout all areas affected by construction.

8.13.5 Plan and Profile

Scale:	Horizontal	1" = 40'
	Vertical	1" = 20'
	Information shown: (See below)	

Horizontal and vertical alignment superimposed on street system and existing ground profile.

Outline of structure in plan and profile.

Horizontal and vertical alignment data.

Buildings, structures and other prominent physical features.

The preceding five sections of drawings comprise the Civil drawings. Abbreviations and legends shall conform to those given on Figures 8.5 and 8.6. If required, additional abbreviations may be used with approval of the General Engineering Consultant.

8.13.6 Utilities

Composite plans of all utilities shall be prepared to show the interrelationship of all existing and proposed utilities rearrangements and Metro structures in the contract area. Where utility facilities are above the proposed Metro tunnel and the intention is that they be maintained in place, a separate plan and profile is not required but pertinent information such as material or a typical cross section showing proximity to the tunnel should be included in the composite plans. In addition to the composite plan, in areas affected by construction, separate utilities plans and profiles must be prepared for:

Water Mains

Sanitary Sewers

Storm Sewers

Gas

Electric

Telephone

Communications

Cable TV

Utilities that are not congested may be combined in one drawing if it is acceptable by the approving agency.

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

Fire and Police Alarm Systems

Parks

U.S. Capitol Grounds

Street and Traffic Lights

Parking Meters

U.S. Steam Tunnels and Pipes

The structural outline on Composite and Detail Utility drawings shall be delineated with a shading medium (AutoCAD hatching).

All openings to the surface, such as vent shafts and dome reliefs, and all ancillary spaces, service areas, etc. shall be clearly shown and identified on the plans and profiles.

Refer to Utility Standard Drawing ST-U-14 for abbreviations, symbols and general notes to be used on these drawings.

In the preparation of composite and separate utility drawings, the Designer shall make a field survey to locate all visible utilities which shall, among other things, determine the following insofar as they may affect Metro design:

Location of all manholes, valve boxes, vaults, street and traffic signals and appurtenances, trees and other improvements.

Size and invert elevations of all pipes in sewer manholes.

Size, internal dimensions, cover and headroom of all manholes on duct lines belonging to electric, telephone, cable TV and telegraph companies and governmental agencies. The Designer shall not remove the covers nor enter any manholes without the prior approval of the owner, and in company with the owner's representative.

Overall dimensions and conformation of all duct lines in manholes on electric, telephone and other similar facilities. Depths, position in walls of manholes and the location of cables at manholes shall be determined for all affected duct lines.

Which cables, if any, are owned by AT&T, governmental agencies or are coaxial TV lines.

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

Should test pits be required, the Designer shall submit recommendation and estimate of cost for such work to the Authority for approval.

On composite plans, all utilities shall be designated as existing, proposed, previously abandoned, to be abandoned, to be maintained complete in place, etc., using the symbols shown on Standard Drawing ST-U-14. The size and type of each utility shall be indicated (S 12", E 6", etc.) by the use of the

appropriate abbreviation shown on the Standard Drawing. These drawings are not to be dimensioned but shall be drawn accurately to scale. The centerline of the utility will be used for scale reference.

Separate utility plans and profiles shall include information for all lines (existing, proposed, to be abandoned, etc.) of the particular facility, using the symbols on Standard Drawing ST-U-14.

Abbreviations on these drawings shall clearly indicate size, type, material of all lines (G 6" CI, W 12" CIPC, T 12 MTD (4x3), W 12" DILM) and pertinent data concerning facilities in manholes. The drawings shall be dimensioned to indicate depth and location of facility from curb, building line, or centerline of street and to demonstrate clearances with other utilities and structures. The center point of all new manholes shall be located from baseline approximately at right angles to each other. Similar information shall be included for existing manholes in areas affected by Metro that are to be retained in service. Designers shall consult, and coordinate at all stages of planning and design with the appropriate utilities and governmental agencies, and shall reach agreement with the respective owners before detailing drawings. Where designs are prepared by owners, the Designer shall ascertain that work is compatible with Metro and shall include the work on Metro plans appropriately labeled. The Underground Construction Office, Department of Highways and Traffic for the District of Columbia and appropriate agencies in adjoining jurisdictions, shall be apprised of proposals for handling utilities as they are developed. The Designer shall cooperate with these offices and owners to assure fully coordinated utilities rearrangements.

It is essential, particularly for cut-and-cover construction, that preparation of composite and separate utility drawings be started promptly. Necessary consultations with utility owners shall be initiated and work scheduled and prosecuted to assure that completion of the overall project is not delayed by poor utility planning.

It is the responsibility of Designers to submit plans and specifications at various stages of completion for review of the respective utility owners, including government agencies, and to secure and file with the Authority, letters of acceptance and approval by the owners. Upon completing design, the Designer shall submit a statement listing betterments and shall secure from each affected owner a firm estimate of work to be undertaken by the utility. After formal approval of plans, two sets of full-size prints shall be made available to each utility owner.

Insofar as applicable, all utility work shall conform to the standards of each utility owner and to the policies established, or as may be established by the Authority.

In the preparation of designs, the Designer shall consider the various ways in which utilities may be handled and the effect of these on the overall cost or other aspects of the project.

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

For those portions of Metro to be constructed in tunnel, or where utilities are sparse, composite drawings may suffice. Detail drawings may be omitted only if approved by the Authority.

Designs shall take into account and make allowance for subway decking and trench bracing systems.

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 compacted backfill. When circumstances justify, utilities may be permanently supported on concrete posts bearing on the roof of the Metro structure. Each posting, however, must be separately considered and approved by the Authority.

Preferred scales are shown herein for each type of utilities drawing. However, in areas of congested utilities and cut-and-cover construction, 1" = 10' or larger scale may be required for clarity. In areas of tunnel construction, 1" = 40' scale may suffice, with larger scale details at locations of fan shafts, vent shafts, station entrances and other similar features.

In addition to building and curb lines, subway structures, vaults and trees, plan sheets of detail drawings shall show only the pipes, ducts, etc., pertaining to the particular facility. Profiles shall show all utilities and interferences as well as Metro structures; they shall show depths below surface and the top and bottom envelope or cross section of all utilities, all drawn to scale.

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 Metro construction and if it is to be supported during construction.

8.13.6.1 Utilities - Composite Plan

Scale: 1" = 40'-0"

Information shown:

All utilities, abandoned (when of record), existing, to be abandoned, maintained, supported, restored, diverted and proposed.

Structure outline, building lines, sidewalks, curbs, trees, poles, public and private vaults, pipelines, tunnels, other surface and subsurface features.

Abandoned street car tracks, as shown in Figure 8.7, may still be in place and in some instances covered with bituminous pavement. A typical detail of these tracks shall be shown on the contract drawings and their location shown in street cross sections. Plan shall note clearly the existence of all tracks, defining their limits including crossovers and switches and shall indicate payment limits of any removal.

Service lines between utilities and adjoining properties must be investigated for maintenance of service but need not be indicated on the drawings unless required by the owner of utility to which service is connected. It should be noted on the drawings that service connections must be maintained by the Contractor.

Detailed dimensions and elevations of roof and floor of vaults affected by construction shall be shown on an appropriate utility plan.

The drawings shall not include utility work beyond the immediate vicinity of construction. As soon as the need for any such work is developed, such as in the case of rerouting, the matter shall be discussed with the General Engineering Consultant. Major utility work beyond the limits of construction will, unless directed otherwise by the Authority, be handled by the utility company concerned.

8.13.6.1.1 Water Mains, Sewers and Drainage Facilities

Scale:	Horizontal	1" = 40'
	Vertical	1" = 10'

Information shown:

Plan, profile and cross sections shall clearly indicate water mains, sewers, drainage lines, catch basins and appurtenances affected by construction, including facilities to be maintained, relocated, proposed, abandoned, etc.

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

Indicate and identify any related work to be designed and constructed by others.

8.13.6.2 Gas

The Washington Gas Company (WGCO) will prepare plans for any abandonment of gas mains, for the construction of any new or temporary mains and services, and for any connection or re-connections of gas mains and service. All such construction work will be normally performed by the WGCO, although some temporary relocation work may be performed by the Metro Contractor upon specific agreement with WGCO. Designs prepared by WGCO shall be placed on Metro drawings and marked "work to be done by others." The line symbols and abbreviations shall be made to conform with the standards shown on Utility Standard Drawing ST-U-14. Plans shall indicate staging of construction and clearly indicate which shall be "maintained complete in place" during Metro construction.

The Designer shall consult, as required, with WGCO to assure that proposed facilities are compatible with other existing and proposed utilities on Metro installations.

The transit system construction contractor will be required to excavate certain abandoned gas mains and to protect and support other lines. This work may be indicated on the drawings prepared by WGCO or on separate sheets, whichever is most practicable.

Scheduling of construction shall recognize the obligation of WGCO to provide uninterrupted service during the winter heating season.

8.13.6.3 Electric

Scale:	Horizontal	1" = 40'
	Vertical	1" = 10'

Information shown:

Construction of duct and vault structures may be performed by the owner or Metro, depending on the approval of the utility owner for each section. Installation and connection of cables will always be performed by the owner. Plan, profile and cross sections shall clearly indicate electric conduits, high voltage pipes, manholes and transformer manholes affected by construction. Indicate facilities to be "maintained complete in place," temporary wooden manholes to be constructed and maintained during construction, temporary wooden troughs to be provided and supported, abandoned ducts and manholes to be removed, special backfill for pipe conduit carrying high voltage cable, all by the Metro contractor.

All new ducts and manholes, removal of ducts and manholes on hot lines, transfer of cables to temporary troughs (see above) and other work by the owner shall be indicated.

Details of all non-standard manholes shall be included on plan drawings or on separate sheets. Each plan sheet shall include on that sheet a schedule of information concerning existing manholes and ducts (see above) and as shown by Figure 8.8.

Plans shall indicate which lines to be constructed by the owner will be completed prior to Metro construction as well as those installed at other designated stages.

When circumstances justify, proposed, maintained and restored utilities may be permanently supported on concrete posts tied to the roof of the Metro structure. Each posting, however, must be separately approved by the Authority.

Any work involving street lights and traffic signals and appurtenances may be included on these drawings (See Section 8.13.6.8).

8.13.6.4 Telephone, Telegraph and CATV

Scale:	Horizontal	1" = 40'
	Vertical	1" = 10'

Information shown:

Plan, profile and cross sections shall clearly indicate telephone, telegraph and cable television lines affected by transit construction and indicate facilities to be maintained, relocated, proposed, abandoned, etc.

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

Indicate any related work to be performed by others.

Each plan sheet shall include on that sheet a schedule of information concerning manholes and ducts as shown by Fig. 8.8.

Where new ducts are installed, all cables will be pulled and changeovers made by the affected telephone, telegraph, or cable television company.

Indicate which ducts, if any, may be maintained in place during construction and then permanently supported on compacted backfill or those temporarily supported in troughs during construction, then restored and permanently supported on compacted backfill. The method adopted shall be at the Contractor's option.

When circumstances justify, new, maintained and restored utilities may be permanently supported on concrete posts tied to the roof of the Metro structure. Each posting must be separately approved by the Authority.

Designers shall ascertain if telephone, telegraph or cable TV cables are affected and, after consultation with the owners, shall include the necessary work in the Metro design.

Work involving police and fire alarm systems may be included on these or separate drawings (See Section 8.13.6.5).

8.13.6.5 Fire and Police Alarm Systems

Scale:	Horizontal	1" = 40'
	Vertical	1" =10'

Information shown:

Location of alarm boxes and cable runs thereto.

Show facilities to be removed, temporarily relocated and restored and cables

to be supported.

Each plan sheet shall include information concerning existing manholes and ducts as shown by Figure 8.8.

Construction work affecting alarm boxes and the restoration of cable runs in the District of Columbia will be handled by District forces at no expense to the Contractor unless otherwise indicated on the drawings and/or specifications.

Suburban communities do not operate fire and police alarm systems.

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

8.13.6.6 Parks and Other Government Controlled Areas

Scale:	Horizontal	1" = 40'
	Vertical	1" =10'

Information shown:

Separate plans for each utility, as stipulated in the first paragraph of Section 8.13.6 shall be prepared where Metro crosses parks and other government controlled areas.

Plan, profile and cross sections shall indicate all facilities to be affected by Metro construction. Indicate facilities to be maintained, relocated, proposed, abandoned, etc. Drawings shall clearly identify facilities belonging to the controlling agency and those on the property owned by utility corporations and agencies normally operating in areas beyond limits of property. Work involving facilities of the controlling agency shall be in accordance with requirements for similar facilities beyond limits of controlled areas. Details of non-standard facilities shall be included on these drawings or on separate sheets.

8.13.6.7 U.S. Capitol Grounds

Scale: Horizontal 1" = 40'

Vertical 1" =10'

Information shown:

Separate plans for each utility, as stipulated in Section 8.13.6 shall be prepared where Metro crosses the U.S. Capitol Grounds.

Plan, profile and cross-sections shall indicate all facilities to be affected by Metro construction. Indicate facilities to be maintained, relocated, proposed, abandoned, etc. Drawings shall clearly identify facilities belonging to the Capitol and to utility corporations and other agencies normally operating in areas beyond the limits of the Capitol Grounds.

Work involving Capitol facilities shall be in accordance with requirements for similar facilities beyond limits of the Capitol Grounds.

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

8.13.6.8 Street Lights and Traffic Signals

Scale: Horizontal 1" = 40'

Vertical 1" = 10'

Information shown:

Plans shall show all street lights and traffic signals in the affected area: those maintained in service, to be temporarily relocated and restored, temporary installations and new installations; also cable and duct runs, as well as control appurtenances.

Generally all such work will be performed by governmental agencies with their own contract or power company forces, at no cost to the Contractor.

The Contractor shall be responsible for and handle any work involving lights owned by private parties. These may be located on either public or private property.

8.13.6.9 U.S. Steam Tunnels & Pipes

Scale: Horizontal 1" = 40'

Vertical 1" = 10'

Information shown:

Plan, profile and cross sections shall clearly indicate steam tunnels and pipe lines affected by Metro construction including facilities to be maintained, relocated, abandoned, constructed, etc. Profiles, sections and details of any special structures shall be included.

Details of any permanent supports shall be included. Plans and construction schedule shall take into account the need to supply steam to U.S. Government buildings, including the Pentagon, at all times.

8.13.6.10 Parking Meters

Scale: Horizontal 1" = 40'

Information shown:

Drawings shall indicate parking meters affected by Metro construction and disposition to be made by the District of Columbia, or other local jurisdictions. The Contractor is to remove, store and reinstall posts; the meter heads will be removed and replaced by the local jurisdictions without cost to the contractor.

8.13.7 Paving and Restoration

Scale: Horizontal 1" = 40'

Vertical 1" = 10' (if required)

Information shown:

Plan shall show structure outline, street lines, sidewalks, curbs, alleys, catch basins, vaults, and other surface features affected by Metro construction. Typical sections, existing and proposed elevations, cross sections or cross section information, type of pavement, curbs and other details for areas to be repaved or restored shall be shown. Elevations of street surfaces to be matched shall be indicated. The pay limits of areas to be constructed or restored shall be clearly defined. They shall include a reasonable area outside the limits of excavation, approximately 15 feet, and also any areas damaged by utility relocation. A note should be added to the effect that the final limits of restoration shall be determined by the extent of damage to existing surfaces. Provide interface details as required to maintain integrity.

When restoration does not extend beyond roadway limits and does not involve any restoration or replacement of curbs, plans shall include centerline profile and elevations at intervals of 50' and breaks in grade, shall show original and proposed elevations at point on profile and at edge of restoration. Existing elevations at flow line shall be included.

When restoration involves replacement of curbs, plans shall include centerline profile, as well as profiles at each curb line showing flow line or top of curb.

When restoration includes adjoining sidewalk with or without curb, plans shall show areaways, window wells, doorways, Metro gratings and other pertinent surface features together with existing and proposed elevations in sufficient detail to clearly indicate slope and warping of sidewalk to assure that areas are properly drained.

Show rates of grade for the flow lines with control elevations at the tangent points of the street corners or fillets, and at points to be matched.

Breaks in grade in excess of 0.50% require a vertical curve. Both breaks in grade and vertical curves should be properly noted.

Show pavement marking and striping, and provide details.

When existing catch basins located in curb returns and their connecting pipes are to be removed and replaced or replaced and maintained, it is preferable that they be relocated on the tangent a minimum of 5'-0" off the PCs or PTs of the curb returns, provided no extra cost is involved.

Locate and note trees to be removed by the Contractor.

Unless notified to the contrary by the General Engineering Consultant, disturbed areas shall be restored to rough grade to match the adjoining properties, alleys and streets.

Unless otherwise shown, all work shall conform to conditions existing at the start of construction and to applicable local standards.

Street lights, traffic signals, and police and fire alarm facilities affected shall be indicated. Restoration will be handled by others as set forth in Section 8.13.7 (this section) and shall be noted on drawings. Restoration of all areas within the construction right-of-way and adjoining properties shall be indicated. Details of restoration for each property will be dependent upon the terms of the acquisition agreements.

Contraction and construction joints shall be prepared for both rigid pavement and sidewalk.

Drawings shall include plans showing pavement and surface restoration in park areas and the grounds of the U.S. Capitol.

8.13.8 Soils and Geotechnical Information

Scale:	Horizontal	1" = 40'
	Vertical	1" = 10'

Information shown:

Boreholes shall be located on the survey plot drawings and numbered according to the soils report prepared by the Authority's General Engineering Consultant. Reference shall be made to separate soils drawings upon which should be reproduced without alteration, the borehole logs are presented by the General Engineering Consultant. Reference shall also be made to more complete information contained in soils reports.

8.13.9 Structural

8.13.9.1 Key Plan of Structure

Scale:	Horizontal	1" = 40'
	Vertical	1" = 10'

Information shown:

The plan and profile drawings should be used as the key plan unless separate structural key plans are required to avoid loss of clarity. The number of each structural unit shall be given along with the number of the first drawing upon which it is detailed. The station at each contraction joint between structural units shall be given. The position of the safety walk shall be clearly shown.

In plan, for open cut or cut-and-cover construction, controls for maximum vertical distance between points of support for excavation shall be shown over the length of the project. Critical areas for excavation support shall be noted. See Standard Specification Section

In profile, the ground surface at the centerline of structure, the outline of structure, and the track profile grade line shall be shown. If the profile grade lines of adjacent tracks are not the same, separate profiles of each track shall be shown. The elevation shall be shown to the nearest one hundredth of a foot for top of low rail at each contraction joint. Grades and vertical curves shall be indicated.

8.13.9.2 Detail Drawings

Scale: ¼” = 1'-0" (general)

Information shown:

Each structural unit shall be completely detailed in plan and elevation and shall show adequate details for construction and for the detailing of reinforcing steel by the Contractor. Where possible, a unit shall be complete on one drawing.

It is preferred that not more than one unit be detailed on one drawing; however, where dissimilarities between units are minor, varying dimensions may be tabulated.

The Designer shall include in the structural drawings loading diagrams and design criteria for the design of temporary retaining and deck structures. Horizontal soil pressures and allowable bearing values shall be recommended by the Designer and coordinated with the General Engineering Consultant.

8.13.9.3 Numbering of Structural Units

Units shall be numbered according to line and station. The number shall be based upon the approximate station to the centerline of the unit. The number need only be based on station to the nearest 10 feet. For example, a typical 50' long structural unit on the Rockville Route having stations of 16+00 and 16+50 at contraction joints would be numbered A162. Similarly, a unit between stations 238+45 and 238+95 would be numbered A2387.

Drawings of structural units shall be arranged in the contract drawing book in numerical order by unit number. When a station is reached, the architectural functional plans prepared by the Designer shall be inserted for the general information of the contractor preceding details of structural units in station.

8.13.9.4 Underpinning Plans

Reference should be made to the subsection relating to "Support of Existing Structures" in Section 15 of these criteria.

The scale of underpinning drawings shall be selected to suit the particular building being underpinned. Drawings shall be complete in detail and shall clearly describe and indicate the method of underpinning to be used.

8.13.10 Architectural

8.13.10.1 General Plan Drawings and Design Drawings

Scale: 1" = 20', 1/8" = 1', ½" = 1', 1-½" = 1'

Information Shown:

The General Architectural Consultant will prepare General Plan Drawings and Design Drawings for all stations. General Plans for each station will include configuration of all spaces, materials and finishes. The drawings will include dimensioned plans, control elevations, sections and details. Design Drawings will include standard details to be used as shown on the General Plan drawings. These General Plans will be furnished to the Designer as a guide to development of the architectural drawings for the construction contracts. Applicable standard details from the architectural Design Drawings shall be included on the Designer's plans utilizing the nomenclature or standard reference as shown on the architectural designs.

8.13.10.2 Detail Drawings

Scale: Site Plans:	1" = 40'
Plans and Sections:	1/8" = l'
Details:	½" = 1', 1½" = 1', 3" = 1'

Overall plans, sections showing all exits, mezzanines and key surface features on one drawing:

Scale: 1" = 20'

Information Shown:

The Designer shall prepare for each station construction bid documents based upon the General Plan drawings and Design Drawings. These bid documents shall include all information required for the structural contract, the subsequent application of architectural finish elements and electrical and mechanical items in a separate finish contract. Drawings shall fully coordinate all aspects of the structural contract with architectural finishes, and stage contract items.

8.13.11 Mechanical

The following minimum of mechanical items are required in the structural contract drawings:

8.13.11.1 Key Plan of Drainage, Plumbing, Ventilation and Air Conditioning

Scale:	Horizontal	1" = 40'
	Vertical	1" = 20'

Information Shown:

The plan and profile drawings should be used as the key plan unless separate mechanical key plans are required to avoid loss of clarity. Locations of escalators and elevators, water supply entrances to structures, drainage discharge from structures, fan shafts, emergency access shafts, vent shafts, manholes, track drains, ejector pits, and recesses in ceilings of train tunnels for jet fans and piping crossovers shall be indicated. Provisions for chilled water and control air piping to enter structures shall be included. Structural unit numbers shall be indicated. The drainage profile shall be shown; indicate top of rail elevations, stations at manholes and drainage pipe invert elevations at manholes.

8.13.11.2 Detail Drawings

Scale: 1/8" = 1' (General)

Information Shown:

8.13.11.2.1 Details of drainage pump installations.

8.13.11.2.2 Details of drainage installations in the tunnels and structural units.

8.13.11.2.3 Temporary drainage pumps (where used) and their installation in wet wells.

8.13.11.2.4 Details shall include, both in plan and elevation, all buried or other piping and ductwork inaccessible to the finish contractor.

8.13.11.2.5 All pipe and ductwork (or air passages) to grade or connected to utilities from structures.

8.13.11.2.6 Details in plan and elevation of all pipe sleeves, duct sleeves, and other openings in walls, floors and ceilings required in the finish contract.

8.13.11.2.7 All necessary inserts and support points for equipment, ductwork, piping and pipe anchors.

8.13.11.2.8 All necessary access openings, panels, doors and hatches in structural work so as to facilitate installation and servicing of all elements.

8.13.11.2.9 Vent shafts, fan shafts and emergency access shafts shall be designed and detailed to accommodate future dampers, and fans, which will be included in the finish contract. Frames and gratings at grade shall be shown in the structural drawings.

8.13.11.2.10 Floor drains, condensate drains, etc., encased in structure.

8.13.11.2.11 All ductwork and pipework, constructed in the structural contract shall be terminated at points where continuation under the finish contract is feasible. The limit of such work shall be clearly shown and identified.

8.13.11.2.12 Terminations of all pipe work and ductwork shall be adequately capped to prevent entry of water, dirt, and vermin.

8.13.11.2.13 Details in plan and elevation of all escalator support structures, clearances and necessary service access provisions in structural work.

8.13.11.2.14 Jet fan installations, including mounting details.

8.13.11.2.15 All other details determined by the Designer to be necessary for the structural contractor.

8.13.12 Electrical, Communications and Train Control

The following Electrical, Communications and Train Control drawings will be prepared for inclusion in the structural or combined contracts. All structural requirements to provide for the installation of Electrical, Communications and Train Control equipment shall be shown on these drawings.

Symbols and General Notes Drawing

Key Plan and Schedule of embedded items.

Detail drawings with section views and expanded plans

of congested areas

Conduit Schedule

Standard Plans

These plans divide the task into two general areas. The Key Plans and Schedule shall define all requirements between stations while the Detail Drawings and Conduit Schedule shall illustrate structural requirements in all remaining areas such as stations, ancillary rooms, power substations, vent and fan shafts, and tie breaker stations.

8.13.12.1 Symbols and General Notes Drawing

Information shown:

All abbreviations and symbols employed as well as all notes of a general nature shall be shown. Abbreviations and symbols shall agree with those presented in Figures 8.9 through 8.12. Should additional symbols or abbreviations be necessary the Designer shall include them. Such symbols shall conform to NEMA, IEEE, EIA and AAR standards.

8.13.12.2 Key Plan and Schedule

Scale: 1" = 40'

Information shown:

A plan view of the structure divided into numbered structural units shall be shown. The plan shall indicate the type of structure and location of walkway with sufficient stationing points shown for reference.

A schedule indicating locations of recesses, slots, sleeves and embedded conduit for all electrical, train control and communications equipment between stations shall be shown on each key plan. This schedule shall be divided into the following subsections:

8.13.12.2.1 Item No. (items shall be sequentially numbered)

8.13.12.2.2 Unit No. and Description (each item shall have a code number and description name).

8.13.12.2.3 Structural Unit No. (each item shall be specifically located by the Structural unit number).

8.13.12.2.4 Stationing (each item located within a structural unit shall be further **located by the actual stationing of the item).**

8.13.12.2.5 Drawing No. (a drawing number shall indicate where the details of the item may be found).

8.13.12.2.6 Detail (the detail letter shall indicate the specific detail of the abovementioned drawing that applies to the item).

8.13.12.2.7 Inbound Track (indicates track location).

8.13.12.2.8 **Outbound** Track (indicates track location).

8.13.12.2.9 Note (indicates number of note if special information is required.) Section views and details necessary to clearly define all items listed on said schedule shall be shown on the Detail Drawings and shall be adequately cross-referenced. All information to be included on the schedule not under the control of the Designer will be provided by the Authority.

The Designer shall furnish the Authority all documentation specified in contract

8.13.13 Detail Drawings

Scale: 1/8" = 1'

Information Shown:

Architectural drawings of the station areas, traction power substations, tie breaker stations, ancillary rooms and all other structural areas not covered in the Key Plans shall be used to show the location of all embedded conduits or raceways, recesses, slots, sleeves, and channels. The requirements for Electrical, lighting and power systems shall be shown on separate drawings. The requirements for Fire and Intrusion Alarm, Communications and Train Control shall be shown on the same drawings. Section views and details shall be added by the Designer to clearly illustrate all areas of conduit congestion, or to define details necessary for installations. Locations of communication equipment marked by the Authority will be given to the Designer for his use in including this information on his plans.

8.13.14 Conduit Schedule

A schedule separating the conduit requirements for Electrical, Fire and Intrusion, Communications and Train Control facilities shall be included with each set of drawings and shall be divided into the following sections:

8.13.14.1 Conduit Number (Each conduit shall be sequentially numbered and prefixed in a manner to clearly distinguish between Electrical, Train Control and Communications conduits).

8.13.14.2 Drawing Number (The number of the plan on which conduit is shown shall be listed).

8.13.14.3 Size and Type (The size and material type of conduit shall be specified).

8.13.14.4 End Points (The two points connected by the conduit shall be specified and listed in "FROM", "TO" columns).

8.13.14.5 Type of Service (The type of service for which the conduit is required shall be specified, i.e., A.C., including voltage: CCTV, P.A. SYSTEM).

8.13.14.6 Remarks (List here any special information required).

Information relating to items not under the control of the Designer will be provided by the Authority.

8.13.15 Standard Plans

The Authority will provide standard drawings to define certain repetitive items required throughout the system. Additional standard drawings as necessary to facilitate installation within the area of a section shall be produced by the Designer. All standard drawings applicable to the contract section shall be included with the contract drawings.

8.14 COMBINED CONTRACTS

The Combined Contracts will provide for the execution of all work usually associated with the buildings trades and will include architectural construction, finishes, mechanical and electrical work. In some instances light structural work may be included. The work will generally be applied to structures constructed by others in previous construction contracts, the following drawings will prepared for a finish and combined contracts. Other drawings shall be included as required.

8.14.1 General Information

Scale: As Required

General information drawings shall be prepared for the following items:

8.14.1.1 Key Plan of System

The base for this drawing will be furnished by the Authority.

8.14.1.2 General Construction Site Plan

Scale: Appropriate to fit on one sheet. If possible the site plan and key plan shall be shown on the same sheet.

8.14.1.3 Key Plan of Structure - The key plan of structure drawings from the structural contract shall be reproduced and included in the finish contract drawings, with titles, notes, and other information revised as necessary.

8.14.1.4 Index of Drawings - A complete index of drawings shall be included with the set of contract plans. The index sheet shall include drawing numbers, titles and sheet numbers, and shall be arranged in sections by sheet numbers. A cross index by drawing number shall also be included.

8.14.1.5 General Notes and Abbreviations

8.14.2 Architectural

Scales: Site Plans:	1" = 40' or as required
Overall Station Plans:	1" = 20'
Plans and Sections:	1/8" = 1"
Details:	½" = 1', 1½" = 1', 3" = 1'

The Designer shall prepare a complete set of architectural drawings, including the following types of drawings:

8.14.2.1 Master Key Plan, identifying rooms and areas, with finish schedule, showing the full extent and limits of the finish contract

8.14.2.2 Station Plans, showing separate levels on individual sheets, at 1" = 20'

8.14.2.3 Tunnel Plans, where work is required in tunnel areas, at 1/8" = 1"-0'.

8.14.2.4 Service Room Plans and Elevations, showing floor plan, reflected ceiling plans, elevations, at 1/8" = 1' or ¼" = 1'. A small key plan identifying the general location of the room shall be shown on each service room sheet.

8.14.2.5 Platform Plans, at 1/8" = 1'

8.14.2.6 Mezzanine Plans, at 1/8" = 1'

8.14.2.7 Train Room Plans and Elevations

8.14.2.8 Entrance Plans and Elevations

8.14.2.9 Passageway Plans

8.14.2.10 Detail and Schedule Sheets, showing flooring and wall finishes, tile details, stonework, doors, folding gates, railings, registers, gratings, fixtures

The following architectural items are stage contract items and shall be furnished and installed in separate construction contracts which will be prepared by others.

8.14.2.11 Kiosk

8.14.2.12 Fare Collection Facilities

8.14.2.13 Graphics

8.14.2.14 Escalators / Elevators

8.14.2.15 Public Address System

8.14.2.16 Closed Circuit Television System

Provisions are to be included in the finish contract for installation of these items by others.

8.14.3 Mechanical

8.14.3.1 Key Plan of Drainage, Plumbing, Ventilation, Air Conditioning and Escalators

Scale:	Horizontal	1" = 40'
	Vertical	1" = 20'

Information shown:

The key plan of mechanical drawings from the structural contract shall be reproduced and revised as necessary to include: locations of escalators and elevators, water supply entrances to structures, drainage discharges from structures, primary ventilating fans, vent shafts, sewage ejectors and manholes. Locations of chilled water piping, control of air piping and water supply piping (if any) in train tunnels. Structural unit numbers shall be indicated. The drainage profile shall indicate top of rail elevations, stations at manholes and drainage pipe invert elevations at manholes. All work completed in structural contract shall be indicated as existing by symbols and/or notes.

8.14.3.2 Detail Drawings

Minimum Scale: 1/8" = 1'-0"

Information Shown:

8.14.3.2.1 Details of factory packaged drainage pumps.

8.14.3.2.2 Non-typical drainage installations in the tunnels and structural units and connections to wet wells and effluent channels or piping.

8.14.3.2.3 Details in plan and in elevation of all piping for the following services:

8.14.3.2.3.1 Drainage, sanitary

8.14.3.2.3.2 Drainage, other than sanitary

8.14.3.2.3.3 Water supply, hot and cold

8.14.3.2.3.4 Chilled water

8.14.3.2.3.5 Condensate piping

8.14.3.2.3.6 Condenser water piping

8.14.3.2.3.7 Fire protection

8.14.3.2.3.8 Control air

Line drawings in diagrammatic perspective form shall be submitted for illustration.

8.14.3.2.4 Details of all plumbing fixtures together with all connections to services.

8.14.3.2.5 Details in plan and in elevation of all ductwork, air shafts and air tunnels, for the following services:

8.14.3.2.5.1 Primary ventilation

8.14.3.2.5.2 Secondary ventilation

8.14.3.2.5.3 Air conditioning

8.14.3.2.5.4 Heating

8.14.3.2.5.5 Exhaust air

8.14.3.2.6 Details in plan and in elevation of all equipment, appurtenances and controls for the following services:

8.14.3.2.6.1 Drainage, sanitary

8.14.3.2.6.2 Drainage, other than sanitary

8.14.3.2.6.3 Water heating

8.14.3.2.6.4 Air conditioning

8.14.3.2.6.5 Heating, electric resistance

8.14.3.2.6.6 Primary ventilation

8.14.3.2.6.7 Secondary ventilation

8.14.3.2.6.8 Control air

8.14.3.2.6.9 Fire protection

8.14.3.2.6.10 Escalators

8.14.3.2.6.11 Ladders for fan shafts, vent shafts, emergency access shafts and pumping station access shafts

8.14.3.2.6.12 Grating and miscellaneous metals

8.14.3.2.7 All other mechanical details necessary to complete the finish or combined contracts.

8.14.4 Electrical

Installation requirements of Electrical wiring and equipment for finish or combined design shall be shown on the following set of plans:

8.14.4.1 Symbols and General Notes Drawing

8.14.4.2 Running Structure Plans, including section views and details

8.14.4.3 Detail Drawings, including section views, expanded plans, and one-line diagrams

8.14.4.4 Panelboard Schedules

8.14.4.5 Standard and Design Plans

These plans divide the electrical finish design task into two general areas. The running structure plans shall define electrical requirements for trackside areas between stations while the detail drawings shall illustrate the requirements in all remaining areas such as stations, traction substations, tie breaker stations, ancillary rooms, fan and vent shafts, and pumping stations.

8.14.4.6 Symbols and General Notes Drawing

Information shown:

All abbreviations and symbols employed as well as all notes of a general nature shall be shown. Abbreviations and symbols shall agree with those presented in Figures 8.9 through 8.12. Should additional symbols or abbreviations be necessary the Designer shall include them. These symbols and abbreviations shall conform to NEMA and IEEE standards.

8.14.4.7 Running Structure Plans

Scale: 1" = 40'

Information shown:

A plan view of the structure including at-grade areas, with sufficient stationing points to locate between station platforms, all track side normal and emergency luminaries, associated wiring, junction boxes and circuitry details shall be shown.

A similar plan view of the structure with sufficient stationing points to locate all other finish design electrical facilities between station platforms shall also be shown. Said facilities shall include emergency trip boxes including blue light and receptacle, electrical receptacles, combination transformer and panel boxes, and all associated wiring, junction boxes and circuitry details.

Section views, tabulations and details necessary to clearly define any item presented on either of the running structure plans shall also be shown and shall be adequately referenced.

8.14.4.8 Detail Drawings

Scale: 1/8" = 1'-0"

Information shown:

Architectural drawings of the station areas, traction power substations, tie breaker stations, ancillary rooms and any other structural areas not covered in the running structure plans shall be used to show the location of all finish design electrical facilities. Said facilities shall include all switchboards, panelboards, junction boxes, cable raceways, normal and emergency luminaries, signs, switches, receptacles, transformers, control or disconnect equipment, and grounding facilities, as well as all feeds for heating, ventilating, and pumping equipment, escalators, ticket vending and collection equipment, communications and train control equipment.

The detail drawings shall identify each room or space and show the calculated foot candle level for each such room or space, as well as the location of all ductwork sufficient for train control and communication facilities. The detail drawings shall also include a one-line diagram of facilities from the incoming power service through all subpanel boards.

Section views and details shall be added by the Designer to clearly illustrate all features of the electrical facilities in a manner to permit installation of a complete, coordinated, electrical lighting, power, and wiring system within the limits of the contract.

8.14.4.9 Panelboard Schedule

Information Shown:

A panelboard schedule showing all main and subpanel boards shall include the following information.

8.14.4.9.1 Panel designation

8.14.4.9.2 Panel mounting, either surface of flush

8.14.4.9.3 Size and type of mains

8.14.4.9.4 Voltage

8.14.4.9.5 Complete feeder circuit breaker information

8.14.4.9.6 Circuit designations or description

8.14.4.9.7 Wire or cable information as necessary to provide fully detailed installation data

8.14.4.10 Standard and Design Plans

The Authority will provide Standard and Design Drawings to define certain repetitive items required throughout the system. Additional or modified standard drawings as necessary to facilitate installations within the area of a section shall be produced by the Designer. All standard drawings applicable to the contract section shall be included with the contract drawings.

8.14.5 Other Drawings

The Designer shall prepare drawings additional to those listed herein as required to complete the design work.

8.15 INFORMATION TO BE SUPPLIED BY THE AUTHORITY

Each Designer will receive from the Authority copies of each of the following:

Manual of Design Criteria

Guide Specifications

General Plans (Half-size)

Design Drawings (Half-size)

Standard Drawings (Half-size)

Additional information listed in the Designer Scope of Services.

In addition, each Designer will be supplied with a comprehensive soils report

8.15.1 General Plans

Two sets of half-size general plans will be furnished by the GEC. The Designer shall utilize these in accordance with the requirements of his specific contract. In all cases the information shown on the General Plans shall be verified by the Designer before using the information on contract drawings. General Plans are considered preliminary drawings subject to further study by the Designer.

8.15.2 Design Drawings

Design drawings are sample solutions and shall be adapted by the Designer to fit the specific design circumstances. Not all design problems are shown on the Design Drawings.

Included in the Design Drawings are Architectural Standard Details which shall be incorporated into the work by the Designer as applicable.

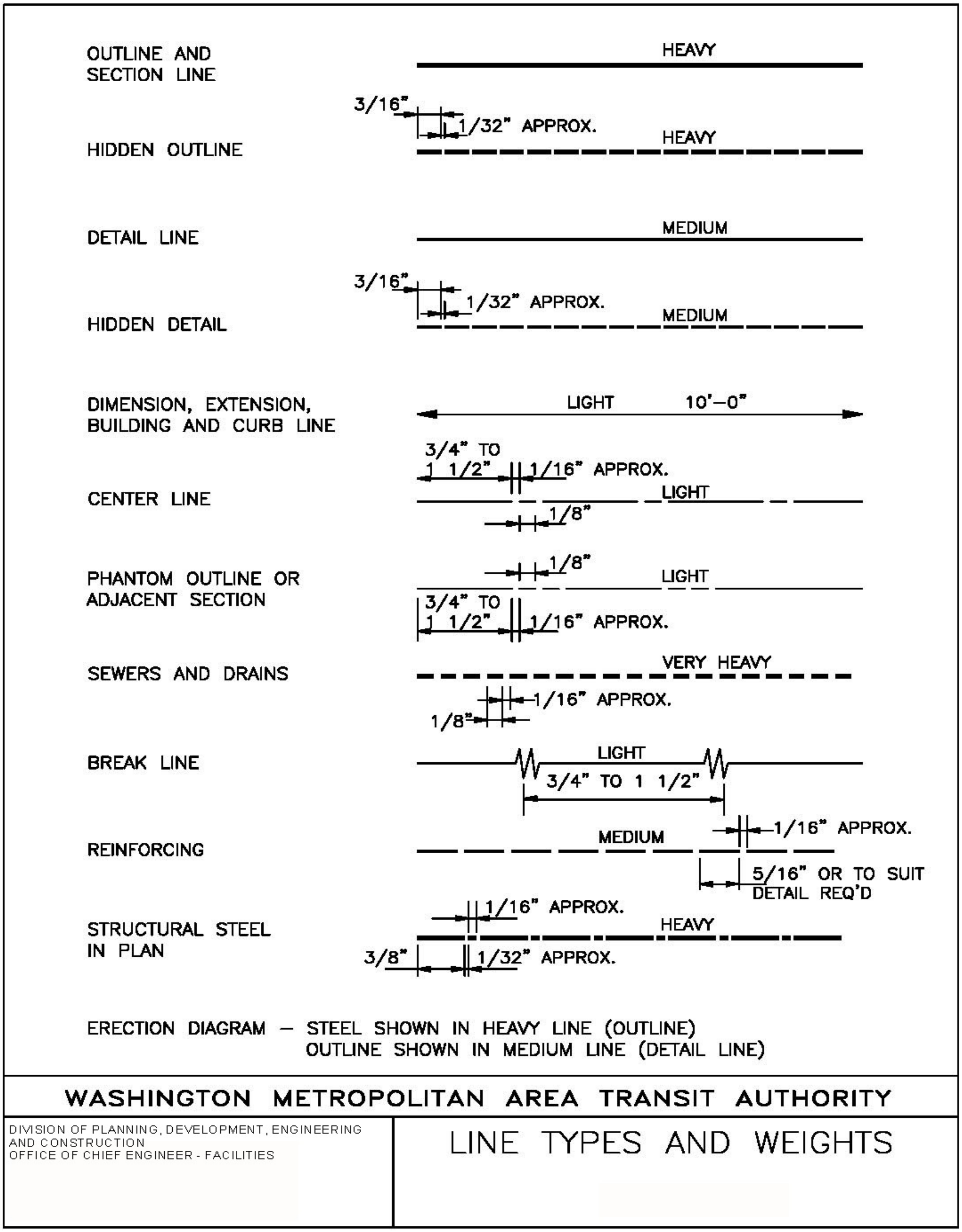
8.15.3 Standard Drawings

Standard Drawings are system wide standards which are to be inserted into the contract documents by the Designer as appropriate. The half-size books include copies of all Standard Drawings; the Designer shall select from this book those standards appropriate to the section and request full-size reproducibles of these from WMATA, at the prefinal submittal stage. The Designer shall include the full-size reproducibles with the final submittal of contract documents.

8.15.4 Additional Information

8.15.4.1 One reproducible set of 1" = 40' scale planimetric survey manuscripts will be made available to the Designer. For areas designed after 1989, digital copies of the topography (in AutoCAD format) may also be available. The data on these surveys must be verified and supplemented by field surveys carried out by the Designer as required.

8.15.4.2 Other information as listed in the Scope of Services for each particular contract.


OUTLINE AND SECTION LINE
HEAVY
3/16"
1/32" APPROX.
HIDDEN OUTLINE
HEAVY
DETAIL LINE
MEDIUM
3/16"
1/32" APPROX.
HIDDEN DETAIL
MEDIUM
DIMENSION, EXTENSION, BUILDING AND CURB LINE
LIGHT
10'–0"
3/4" TO 1 1/2"
1/16" APPROX.
CENTER LINE
LIGHT
1/8"
1/8"
PHANTOM OUTLINE OR ADJACENT SECTION
LIGHT
3/4" TO 1 1/2"
1/16" APPROX.
SEWERS AND DRAINS
VERY HEAVY
1/16" APPROX.
1/8"
BREAK LINE
LIGHT
3/4" TO 1 1/2"
REINFORCING
MEDIUM
1/16" APPROX.
5/16" OR TO SUIT DETAIL REQ'D
1/16" APPROX.
STRUCTURAL STEEL IN PLAN
HEAVY
3/8"
1/32" APPROX.
ERECTION DIAGRAM – STEEL SHOWN IN HEAVY LINE (OUTLINE)
OUTLINE SHOWN IN MEDIUM LINE (DETAIL LINE)
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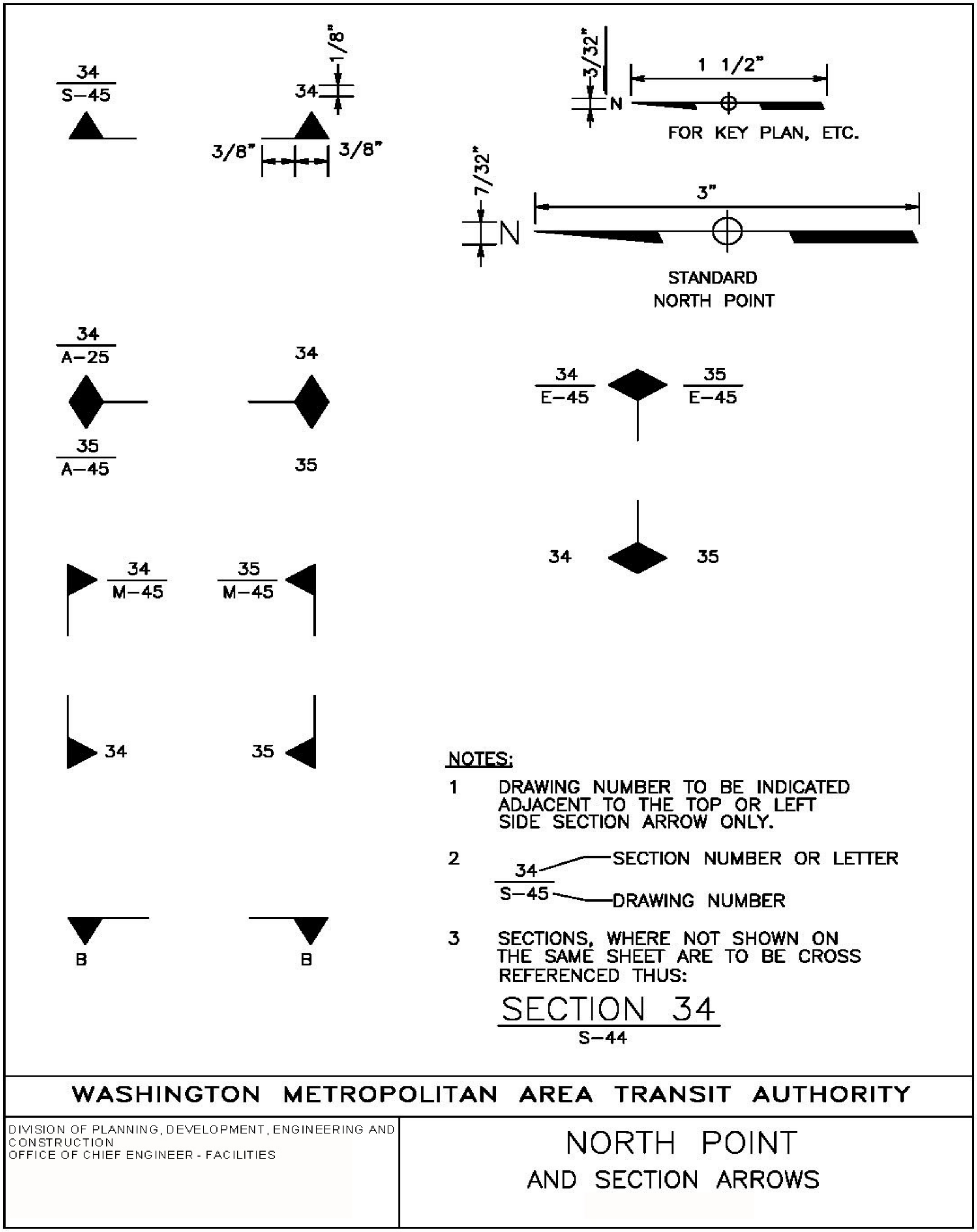
OFFICE OF CHIEF ENGINEER - FACILITIES
LINE TYPES AND WEIGHTS

FIGURE 8.1


34
S–45
1/8"
34
3/8"
3/8"
3/32"
N
1 1/2"
FOR KEY PLAN, ETC.
7/32"
N
3"
STANDARD
NORTH POINT
34
A–25
35
A–45
34
35
34
E–45
35
E–45
34
35
34
M–45
35
M–45
34
35
B
B
NOTES:
1 DRAWING NUMBER TO BE INDICATED ADJACENT TO THE TOP OR LEFT SIDE SECTION ARROW ONLY.
2 34 SECTION NUMBER OR LETTER
S–45 DRAWING NUMBER
3 SECTIONS, WHERE NOT SHOWN ON THE SAME SHEET ARE TO BE CROSS REFERENCED THUS:
SECTION 34
S–44
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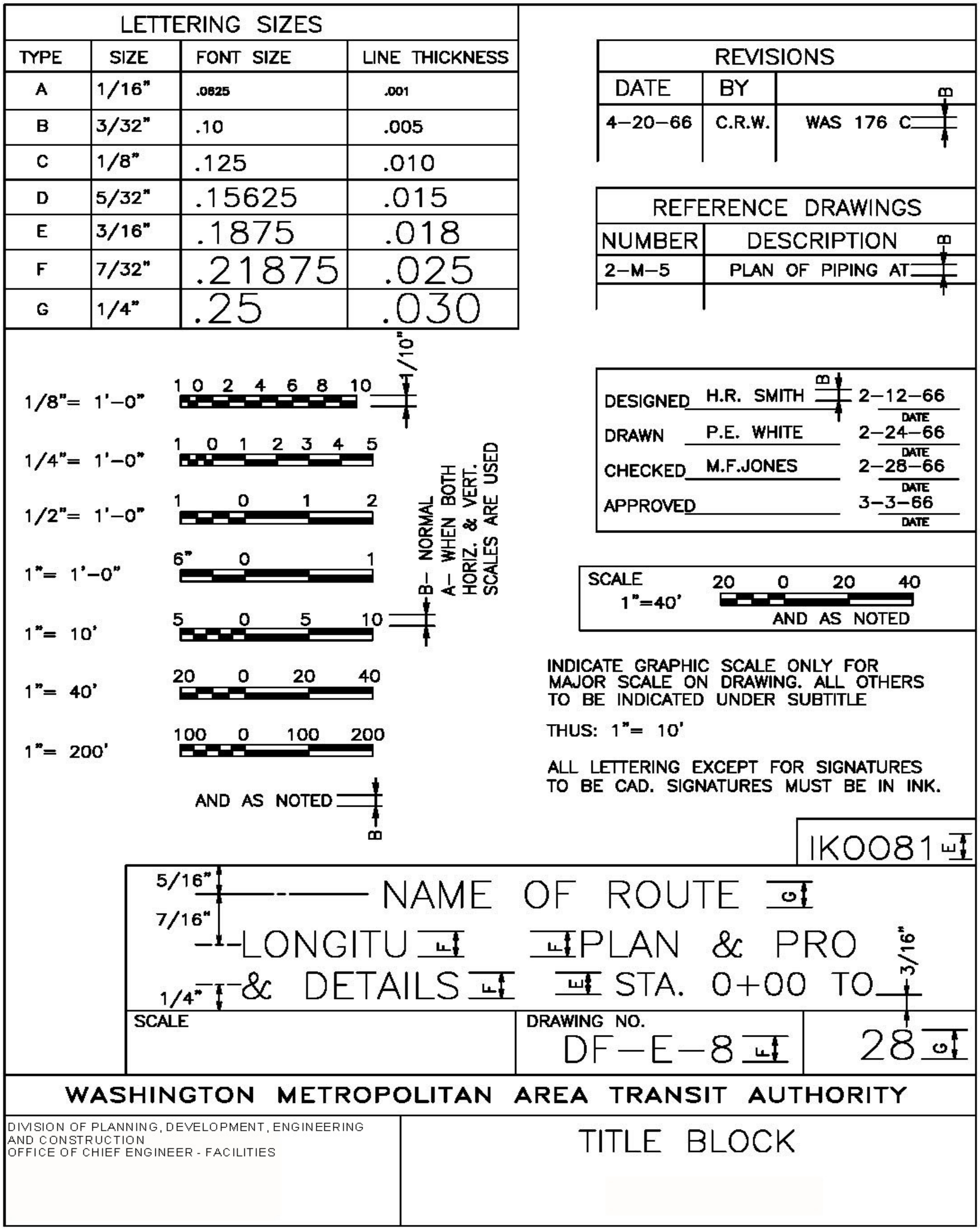
NORTH POINT
AND SECTION ARROWS

FIGURE 8.2


LETTERING SIZES
TYPE SIZE FONT SIZE LINE THICKNESS
A 1/16" .0625 .001
B 3/32" .10 .005
C 1/8" .125 .010
D 5/32" .15625 .015
E 3/16" .1875 .018
F 7/32" .21875 .025
G 1/4" .25 .030
REVISIONS
DATE BY
4-20-66 C.R.W. WAS 176 C
REFERENCE DRAWINGS
NUMBER DESCRIPTION
2-M-5 PLAN OF PIPING AT
1/8"= 1'-0"
1 0 2 4 6 8 10
1/4"= 1'-0"
1 0 1 2 3 4 5
1/2"= 1'-0"
1 0 1 2
1"= 1'-0"
6" 0 1
1"= 10'
5 0 5 10
1"= 40'
20 0 20 40
1"= 200'
100 0 100 200
AND AS NOTED
1/10"
B- NORMAL
A- WHEN BOTH HORIZ. & VERT. SCALES ARE USED
DESIGNED H.R. SMITH 2-12-66
DRAWN P.E. WHITE 2-24-66
CHECKED M.F.JONES 2-28-66
APPROVED 3-3-66
DATE
SCALE 1"=40' 20 0 20 40 AND AS NOTED
INDICATE GRAPHIC SCALE ONLY FOR MAJOR SCALE ON DRAWING. ALL OTHERS TO BE INDICATED UNDER SUBTITLE
THUS: 1"= 10'
ALL LETTERING EXCEPT FOR SIGNATURES TO BE CAD. SIGNATURES MUST BE IN INK.
IK0081
5/16"
7/16"
1/4"
3/16"
NAME OF ROUTE
LONGITU PLAN & PRO
& DETAILS STA. 0+00 TO
SCALE
DRAWING NO.
DF-E-8
28
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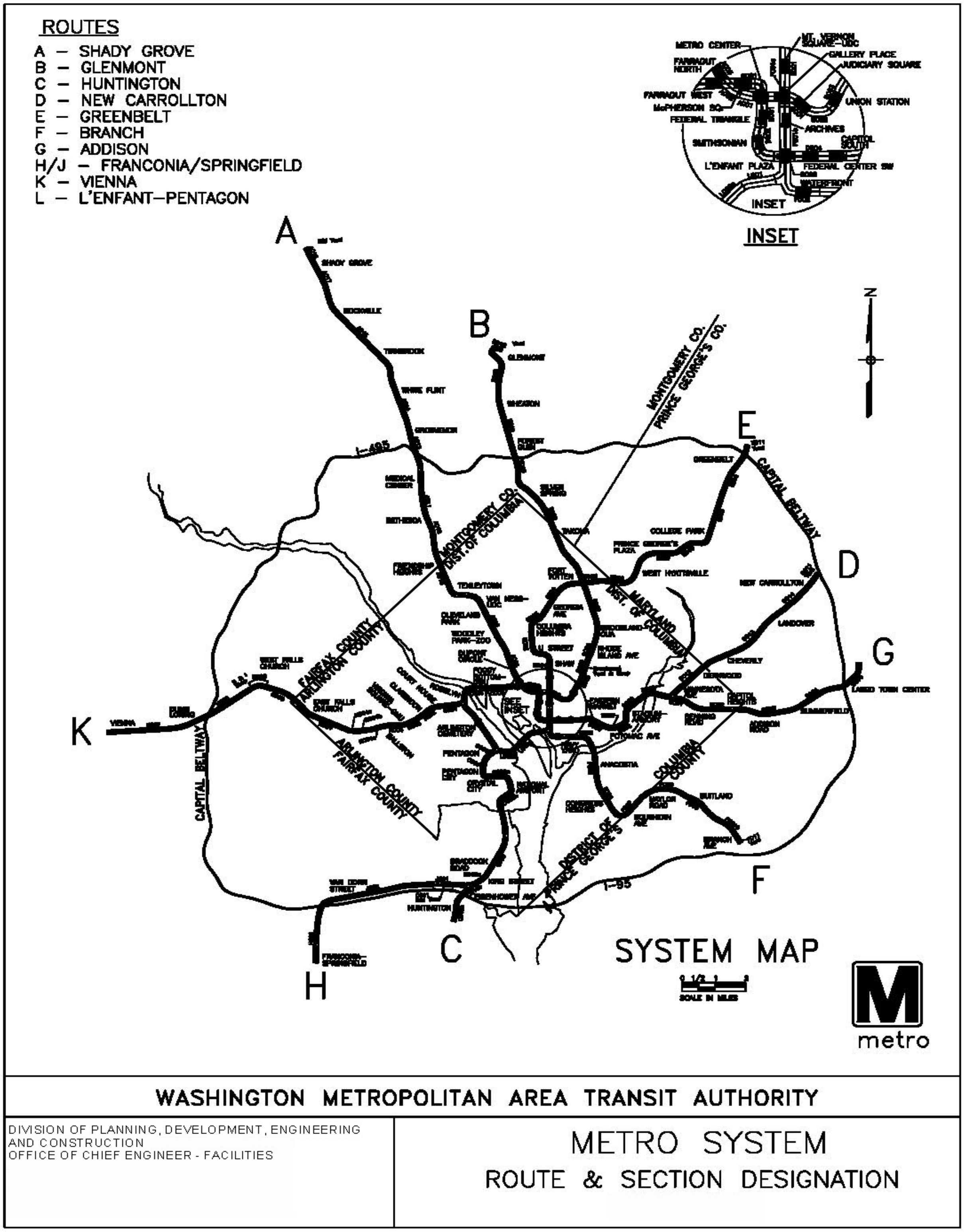
TITLE BLOCK

FIGURE 8.3


ROUTES
A – SHADY GROVE
B – GLENMONT
C – HUNTINGTON
D – NEW CARROLLTON
E – GREENBELT
F – BRANCH
G – ADDISON
H/J – FRANCONIA/SPRINGFIELD
K – VIENNA
L – L'ENFANT–PENTAGON
INSET
A
B
C
D
E
F
G
H
K
SYSTEM MAP
metro
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METRO SYSTEM
ROUTE & SECTION DESIGNATION

FIGURE 8.4

AHD.	AHEAD
A.R.E.A.	AMERICAN RAILWAY ENGINEERING ASSOCIATION
A.R.E.M.A.	AMERICAN RAILWAY ENGINEERING AND MAINTENANCE—OF—WAY ASSOCIATION (FORMERLY A.R.E.A.)
BK.	BACK
B.&O.	BALTIMORE AND OHIO
BL	BASELINE
B.M.	BENCH MARK
CL	CENTERLINE
CONST.	CONSTRUCTION
EL.	ELEVATION
EQN.	STATIONING EQUATION
5 STY.	FIVE STORY
G.P.S.	GLOBAL POSITIONING SURVEY
H.F.	HEEL OF FROG
HORIZ.	HORIZONTAL
INV.	INVERT
MEZZ.	MEZZANINE
M.O.	MID ORDINATE
M.P.H.	MILES PER HOUR
N.G.S.	NATIONAL GEODETIC SURVEY
P.C.C.	POINT OF COMPOUND CURVE
P.O.C.	POINT ON CURVE
P.I.T.O.	POINT OF INTERSECTION OF TURNOUT
P.R.C.	POINT OF REVERSE CURVE
P.S.	POINT OF SWITCH
P.O.T.	POINT ON TANGENT
P.V.C.	POINT OF VERTICAL CURVE
P.V.I.	POINT OF VERTICAL INTERSECTION
P.V.T.	POINT OF VERTICAL TANGENT
PROP.	PROPOSED
R.O.W.	RIGHT OF WAY
RTE.	ROUTE
STD.	STANDARD
STA.	STATION
ST.	STREET
TAN.	TANGENT
T/R	TOP OF RAIL
VERT.	VERTICAL
V.C.	VERTICAL CURVE

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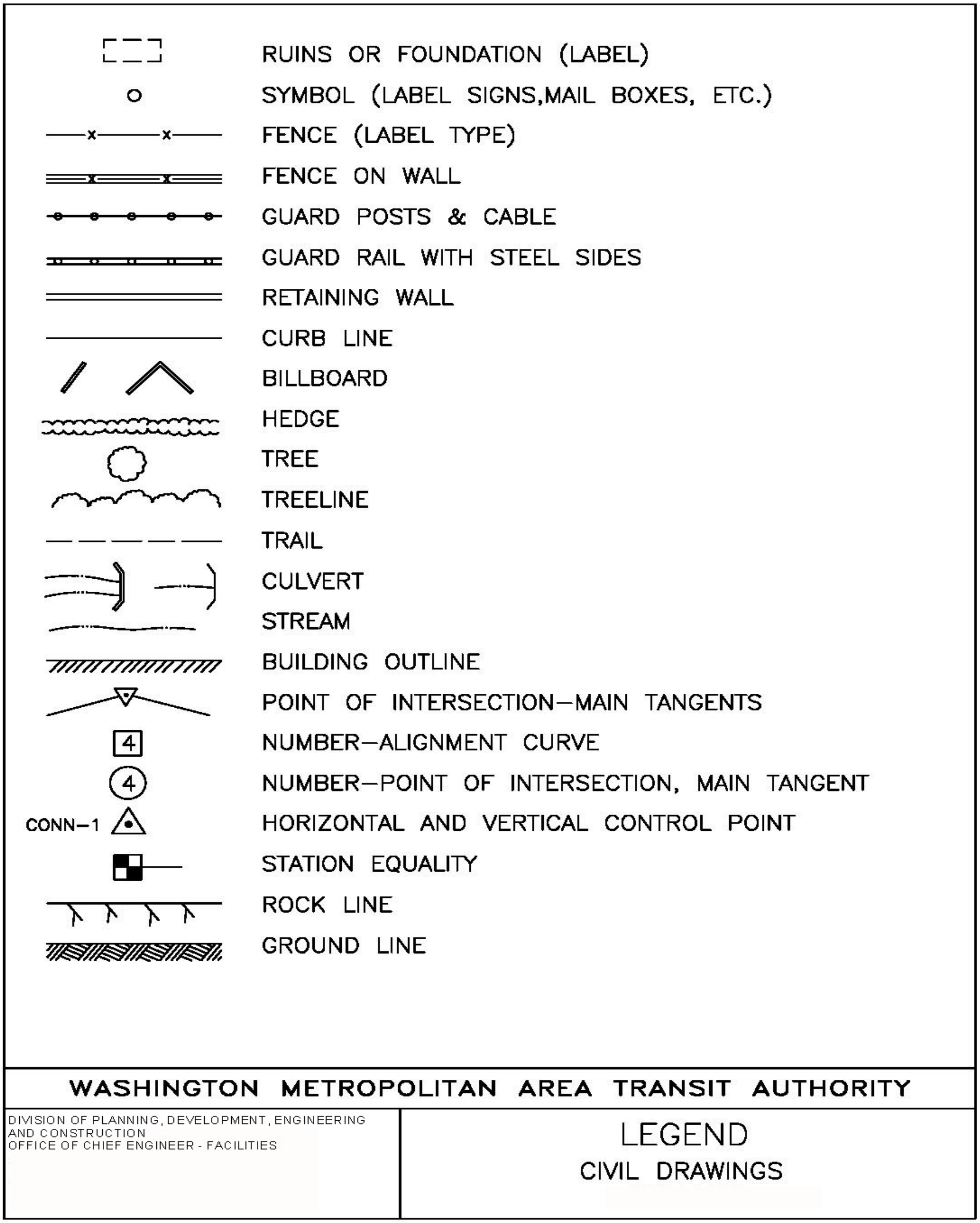
ABBREVIATIONS
CIVIL DRAWINGS

FIGURE 8.5


RUINS OR FOUNDATION (LABEL)
SYMBOL (LABEL SIGNS,MAIL BOXES, ETC.)
FENCE (LABEL TYPE)
FENCE ON WALL
GUARD POSTS & CABLE
GUARD RAIL WITH STEEL SIDES
RETAINING WALL
CURB LINE
BILLBOARD
HEDGE
TREE
TREELINE
TRAIL
CULVERT
STREAM
BUILDING OUTLINE
POINT OF INTERSECTION–MAIN TANGENTS
4
NUMBER–ALIGNMENT CURVE
4
NUMBER–POINT OF INTERSECTION, MAIN TANGENT
CONN–1
HORIZONTAL AND VERTICAL CONTROL POINT
STATION EQUALITY
ROCK LINE
GROUND LINE
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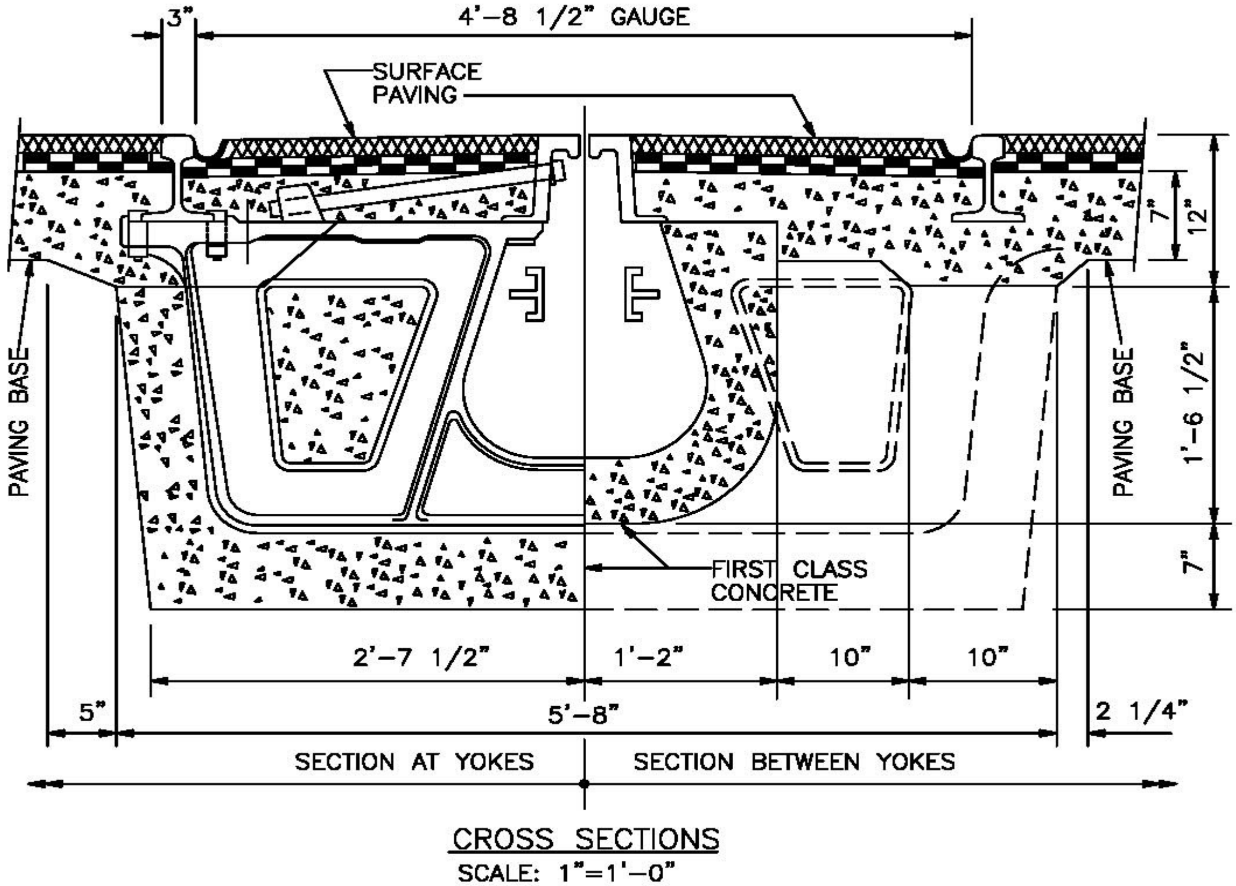
AND CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
LEGEND
CIVIL DRAWINGS

FIGURE 8.6



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TYPICAL STREET CAR
TRACK CROSS SECTION

FIGURE 8.7

DATA FOR EXISTING MANHOLES AND DUCTS

M.H. (1)	INSIDE DIM. L x W x HEAD ROOM	TOP OF COVER TO FLOOR	LOOKING EAST (2)			LOOKING WEST			LOOKING NORTH			LOOKING SOUTH		
			TOP	BOT.	SEC.	TOP	BOT.	SEC.	TOP	BOT.	SEC.	TOP	BOT.	SEC.
144	8'x 9'x 10'-6"	11'-10"	3'-6"	4'-3"		3'-0"	4'-8"		2'-8"	3'-8"		3'-6"	5'-6"	

1. AS IDENTIFIED IN PLANS.
2. DIMENSIONS FROM INSIDE TOP OF M.H. TO TOP AND BOTTOM OF DUCTBANK.

DIMENSIONS AND INDICATED SECTIONS ARE TYPICAL.

BY MEANS OF APPROPRIATE SYMBOLS AND LEGEND INDICATE DUCTS OCCUPIED BY CABLES, TYPE OF CABLE AND OWNERSHIP (C&P, AT&T, CO-AXIAL TV, DISTRICT OF COLUMBIA, PEPCO, ETC.)

DATA TO APPEAR ON EACH DETAIL SHEET FOR ELECTRIC AND TELEPHONE.

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UTILITY MANHOLE
CHART

FIGURE 8.8

CONDUIT OR CABLE TURNING AWAY OR DOWN	
CONDUIT OR CABLE TURNING UPWARD	
CONDUIT CAPPED OR CABLE DEAD ENDED	
JUNCTION OR PULL BOX	JB
TOGGLE SWITCH, 1 POLE	S_1
TOGGLE SWITCH, 2 POLE	S_2
TOGGLE SWITCH, 3 WAY	S_3
SWITCH, SPECIAL (NOTE REQUIRED)	S
DUPLEX FLUSH RECPTACLE 25A 125V WITH WEATHERPROOF SPRING COVER	C
PUSH BUTTON AS FOR MOTOR CONTROL	PB
DUPLEX FLUSH RECEPTACLE 15A 125V	
SINGLE HEAVY DUTY FLUSH RECEPTACLE 125V WEATHERPROOF SPRING COVER	
EMERGENCY BLUE LIGHT, INCANDESCENT	B
EMERGENCY WHITE LIGHT, (TUNNEL), INCANDESCENT	E
EMERGENCY EXIT LIGHT INCANDESCENT	X
INDICATES NUMBER AND SIZE OF WIRES, SIZE CONDUIT HOME RUN TO PANEL AND BREAKER DESIGNATION	#10-3/4 NP_1
SURFACE CONDUIT OR CABLE	
BURIED OR CONCEALED CONDUIT	

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OFFICE OF CHIEF ENGINEER - FACILITIES

SYMBOLS & ABBREVIATIONS
ELECTRICAL DRAWINGS 1 OF 4

FIGURE 8.9

FLUORESCENT LAMP FIXTURE

FLUORESCENT RECESSED TROFFER

FLUORESCENT FIXTURE NO.1

FLUORESCENT FIXTURE NO.2

INCANDESCENT FIXTURE

INCANDESCENT BRACKET FIXTURE

INCANDESCENT RECESSED FIXTURE

INCANDESCENT EXPLOSION PROOF FIXTURE

MERCURY VAPOR LIGHTING FIXTURE INDOOR

MERCURY VAPOR LIGHTING FIXTURE OUTDOOR

ANCHOR POINT–CONTACT RAIL

EXPANSION JOINT–CONTACT RAIL

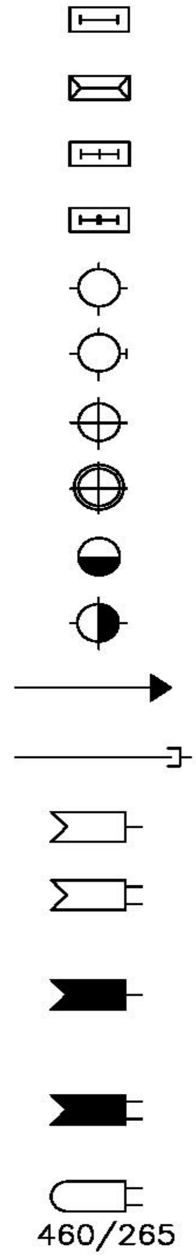
13.2 KV POWER CO. SERVICE, 1 INCOMING LINE

13.2 KV POWER CO. SERVICE, 2 INCOMING LINES

13.2 KV SERVICE FROM TRACTION POWER SUBSTATION, 1 INCOMING LINE

13.2 KV SERVICE FROM TRACTION POWER SUBSTATION, 2 INCOMING LINES

OTHER VOLTAGE SERVICE (SPECIFY)



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SYMBOLS & ABBREVIATIONS
ELECTRICAL DRAWINGS 2 OF 4

FIGURE 8.10

TIE BREAKER STATION	B
BREAKER, A.C.	
BREAKER–STARTER COMBINATION–A.C.	
PANEL, DISTRIBUTION "NP"	
RELAY OR CONTACTOR–REQUIRES NOTE	R
STARTER, MOTOR	
SWITCHBOARD, A.C.	
SWITCH–WALL, LOCK–TYPE	S,L
TRANSFORMER, DRY–(CAP & VOLTS AS SHOWN)	
EMERGENCY TRIP SWITCH	
SWITCH, SAFETY	
SWITCH, PHASE SELECTOR	
AMMETER	A
VOLTMETER	V
WATTHOUR METER	WH
POTENTIAL TRANSFORMER	PT
CURRENT TRANFORMER	CT
SWITCH, TEST	TS

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SYMBOLS & ABBREVIATIONS
ELECTRICAL DRAWINGS 3 OF 4

FIGURE 8.11

EJECTOR, SEWAGE	
ESCALATOR	
FAN, EXHAUST	
HEATER, INFRA–RED	H
THERMOSTAT, STATION	
PUMP, MOTOR DRAINAGE	
SHAFT, VENT	
TANK, HOT WATER HEATER	HW
THERMOSTAT, TUNNEL	T
SUBSTATION	SS
TOKEN, VENDING MACHINE	TV
TURNSTILE	
TRANSFER MACHINE	TR
CHILLED WATER PLANT	
SHAFT, FAN	

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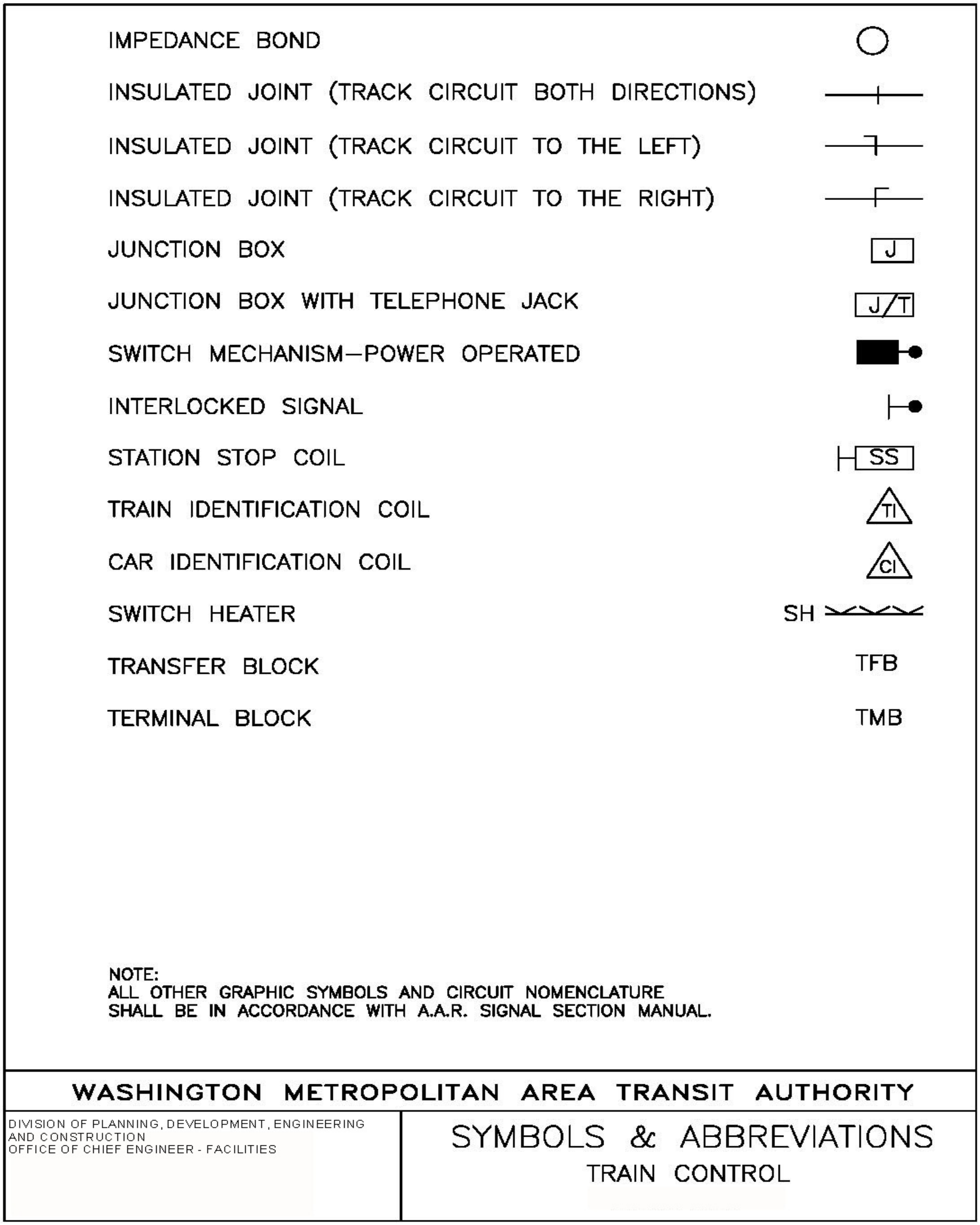
SYMBOLS & ABBREVIATIONS
ELECTRICAL DRAWINGS 4 OF 4

FIGURE 8.12


IMPEDANCE BOND
INSULATED JOINT (TRACK CIRCUIT BOTH DIRECTIONS)
INSULATED JOINT (TRACK CIRCUIT TO THE LEFT)
INSULATED JOINT (TRACK CIRCUIT TO THE RIGHT)
JUNCTION BOX
J
JUNCTION BOX WITH TELEPHONE JACK
J/T
SWITCH MECHANISM—POWER OPERATED
INTERLOCKED SIGNAL
STATION STOP COIL
SS
TRAIN IDENTIFICATION COIL
TI
CAR IDENTIFICATION COIL
CI
SWITCH HEATER
SH
TRANSFER BLOCK
TFB
TERMINAL BLOCK
TMB
NOTE:
ALL OTHER GRAPHIC SYMBOLS AND CIRCUIT NOMENCLATURE
SHALL BE IN ACCORDANCE WITH A.A.R. SIGNAL SECTION MANUAL.
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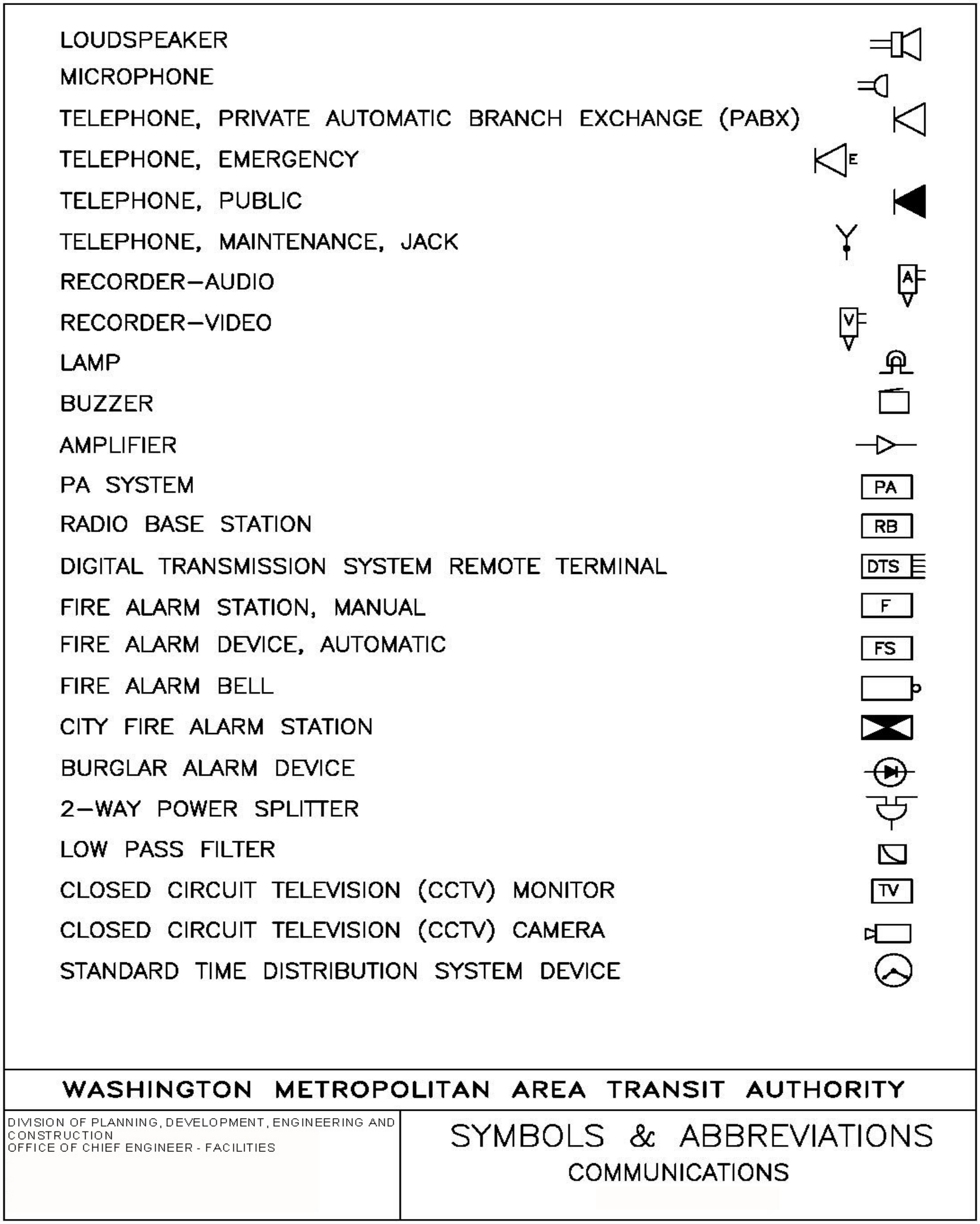
AND CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
SYMBOLS & ABBREVIATIONS
TRAIN CONTROL

FIGURE 8.13


LOUDSPEAKER
MICROPHONE
TELEPHONE, PRIVATE AUTOMATIC BRANCH EXCHANGE (PABX)
TELEPHONE, EMERGENCY
E
TELEPHONE, PUBLIC
TELEPHONE, MAINTENANCE, JACK
RECORDER—AUDIO
A
RECORDER—VIDEO
V
LAMP
BUZZER
AMPLIFIER
PA SYSTEM
PA
RADIO BASE STATION
RB
DIGITAL TRANSMISSION SYSTEM REMOTE TERMINAL
DTS
FIRE ALARM STATION, MANUAL
F
FIRE ALARM DEVICE, AUTOMATIC
FS
FIRE ALARM BELL
CITY FIRE ALARM STATION
BURGLAR ALARM DEVICE
2—WAY POWER SPLITTER
LOW PASS FILTER
CLOSED CIRCUIT TELEVISION (CCTV) MONITOR
TV
CLOSED CIRCUIT TELEVISION (CCTV) CAMERA
STANDARD TIME DISTRIBUTION SYSTEM DEVICE
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
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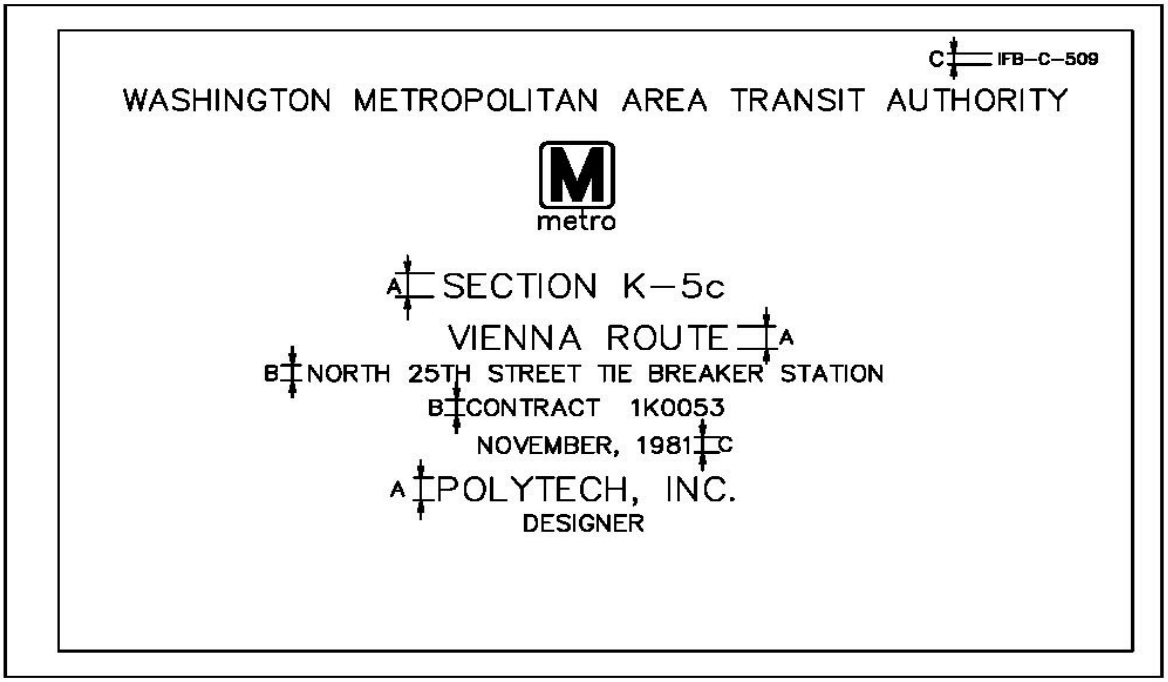
OFFICE OF CHIEF ENGINEER - FACILITIES
SYMBOLS & ABBREVIATIONS
COMMUNICATIONS

FIGURE 8.14



TYPICAL EXAMPLE

DESIGNATION	FONT SIZE	FONT STYLE
A	.72"	
B	.425"	
C	.35"	

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	FORMAT FOR CONTRACT DRAWING COVER SHEET

FIGURE 8.15

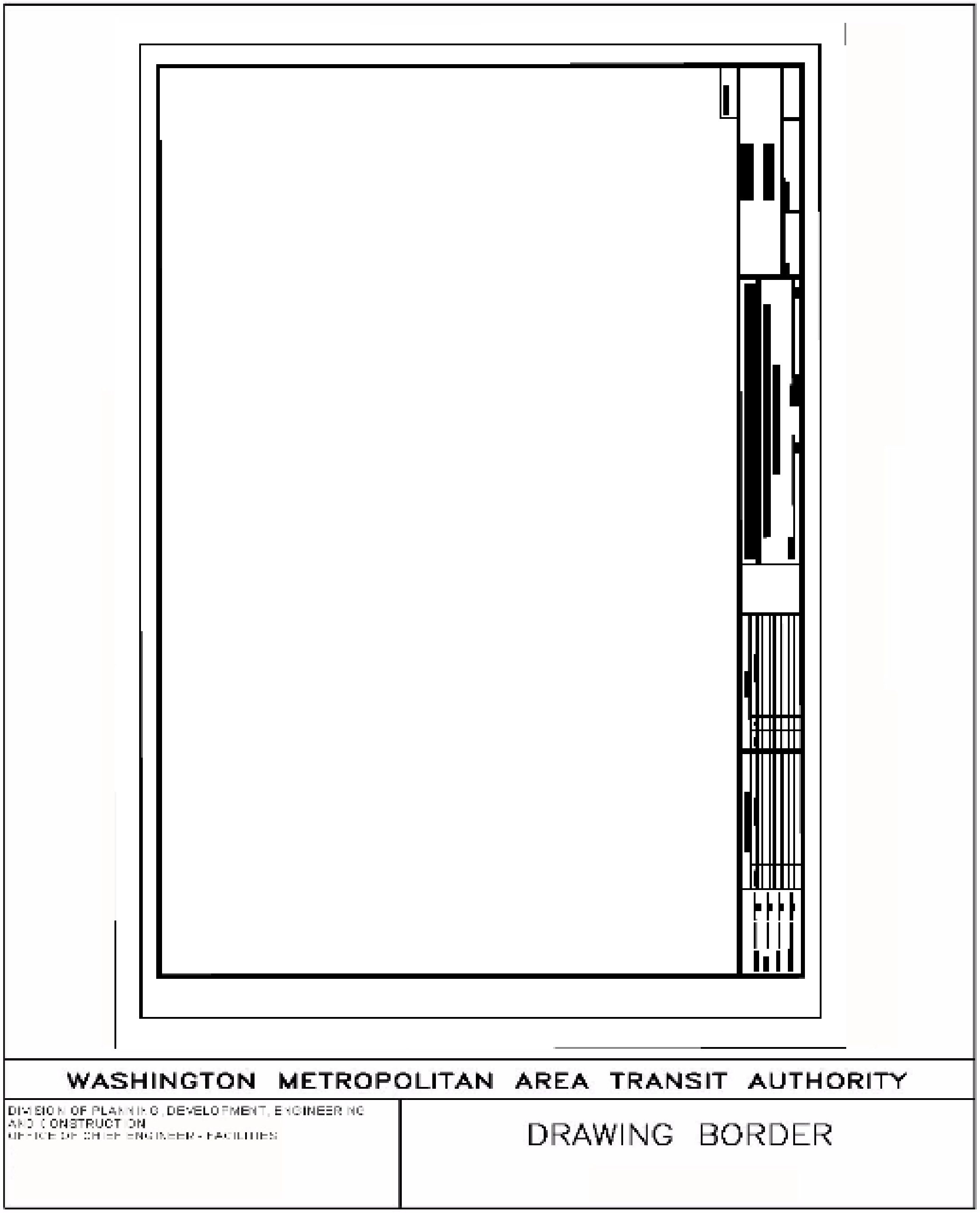

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DRAWING BORDER

FIGURE 8.16

SECTION 9 RIGHT-OF-WAY

9.1 GENERAL

9.1.1 Policy

Right-of-way is defined as the composite or total requirement of all real property interests and uses, both temporary and permanent, needed to construct, maintain, protect, and operate the Metro system.

WMATA's policy is to certify for acquisition the minimum right-of-way sufficient to construct, operate, and maintain the bus and rail transit system. The right-of-way plans together with the detailed property disposition and verified limits tables approved by the WMATA Office of Chief Engineer Infrastructure Services (CENI) are used by the WMATA Office of Property Development and Management (LAND) as a basis for acquisition of property interests. LAND will make the final determination of the quantum of the estate in the land to be acquired.

For permanent easements, the Section Designer/Design Engineer shall determine a right-of-way envelope which encompasses all the requirements of permanent facilities and structures, drainage, future maintenance requirements, access roads, fire protection, utilities, rock bolts, structural supports and any other permanent improvements or projections necessary for the construction, operation and maintenance of the system.

The right-of-way envelope is influenced by the topography, drainage, ditches, retaining walls, service roads, utilities, the type of structure and the slopes required.

The limit of right-of-way shall be shown as an unbroken line which delineates the right-of-way with simple curves and connecting tangents. Chords maybe used in lieu of large radius curves.

9.2 RIGHT-OF-WAY STAGING

The Section Designer/Design Engineer shall identify the minimum limits of the right-of-way during the design of the first or "structural" contract developed for a design section. Any subsequent contracts should identify additional or new right-of-way outside the limits of the first contract required for that contract.

The first contract should identify the right-of-way that will be available for the first contract, the portion of right-of-way that will be made available for any sequential contracts, and when in the construction phase one contractor will make the right-of-way available for another contractor.

The contract drawings for the second contract, need only identify the work areas that the second contractor will have available. The complete set of right-of-way drawings need not be inserted in subsequent contract drawing sets.

9.3 DEFINITIONS OF RIGHT-OF-WAY EASEMENTS

9.3.1 Permanent Surface Easement

A permanent surface easement shall provide sufficient space for the construction, operation, protection and maintenance of the Metro facility at the ground surface. The recommended easement width must incorporate basic track width, drainage, supporting slopes and utilities. Typical examples of permanent surface easements are sites for stations, traction power substations, chiller plants, vent and fan shafts, and other at-grade structures, in addition to at-grade tracks.

9.3.2 Permanent Surface Easement with an Upper Limit

A permanent surface easement with an upper limit shall provide space for the transit structures and for their future maintenance. This easement is applicable where structures such as a railroad or highway pass over or building structure built over Metro facilities. The easement shall have definite upper and lateral limits. A lower limit shall be described only when required. Typical examples of stations, elevators and entrances with canopies.

9.3.3 Permanent Underground Easement

A permanent underground easement shall encompass the total Metro facility located beneath the surface of the ground. It shall have definite upper and lateral limits. Lower limits shall be described only where special limiting features exist.

9.3.4 Permanent Aerial Easement

A permanent aerial easement shall completely envelop the aerial portion of the Metro facility, with lower and lateral limits. An upper limit shall be described only where special limiting features exist.

9.3.5 Utility Easement

A utility easement shall provide space for the relocation of existing utilities or the installation and maintenance of required or relocated utilities.

9.3.6 Construction Easement

A construction easement is a temporary easement or short term lease that provides sufficient space to allow for the temporary use of property by the Contractor during construction.

9.3.7 Slope Easement

A slope easement is a permanent surface easement for a cut or fill side slope to the tracks. A slope easement can be made revertible to the adjacent property owner if acceptable provisions are made for future support of the slope.

9.3.8 Drainage Easement

A drainage easement is a permanent surface easement for drainage of water along a prepared course.

9.3.9 Electric Grounding Grid Easement

The electric grounding grid at substations and tie breaker stations should be designed to be located within the permanent surface easements at the station. If such an arrangement is unworkable, then the grounding grid shall be located in an identifiable grounding grid easement. The grounding grid location should be monumented.

9.3.10 Access Easement

As access easement is a defined path for ingress and egress in someone's property.

9.4 DRAWING DETAILS

Right-of-way drawings shall be 1" = 40' scale showing the relationship of the right-of-way to the street system and properties affected by construction. All existing topographic features shall be screened on the base sheets.

Show property lines and delineate affected parcel ownership along the right-of-way. When a property appears on more than one sheet of the right of-way plans, the total area of the easement required shall be shown in the Property Disposition Table on the first sheet on which the property appears. The property shall be listed in the property disposition table on each sheet on which it appears and shall be cross referenced to the sheet which delineates the area of the easement.

The right-of-way drawings shall have a designated grid system and north arrow reflecting the appropriate datum of WMATA's project grid or related USC&GS datum as appropriate for the area concerned (see Figure 11.1).

9.4.1 Format

All right-of-way plans shall conform to the format established in the most current WMATA Right-of-way Design Drawings and Contract Drawing Standards.

9.4.2 Graphic Symbols

Graphic symbols used to describe easements shall be uniform and shall conform to the standard right-of-waylegend (see FIGURE 9.I). Each sheet shall contain a legend describing only the symbols used on that sheet. The edge of each easement shall be marked with a neat line to mark the limit of the easement and to aid in distinguishing it from existing facilities or other easement symbols. The street system shall be clearly shown and identified by street names as well as Federal, State and/or County route numbers.

9.4.3 Centerline

The right-of-way plans shall show the centerline of the tracks and the outline of the structure, in addition to the limits of right-of-way which describes the right-of-way envelope. Stationing and station equations shall be shown in addition to contract limits. The beginning and ending points for curves and spirals on the centerline of both tracks shall be shown, as well as the dimension between tangent track centerlines. Show the outbound centerline stationing at property lines.

9.4.4 Contractors' Work Areas

Delineate on the drawings the property required for the contractors' use and show the limits of any additional easements, temporary or permanent, that are required to accommodate access, temporary roads, drainage and utilities. Show all structures that require razing prior to construction. Show temporary fencing or barriers around contractors' work areas. Determine the property owners of record affected by the above limits and show the property dispositions in table form with areas involved by type easement required.

Coordinate all of the requirements for the contractors' work areas at each end of the design section. The contractor's work areas for one design section shall not cross over into the adjacent section. If construction staging allows the use of an area in an adjacent design section, its use must be coordinated with WMATA and the adjacent Section Designer/Design Engineer to avoid contractor confusion and claims.

9.4.5 Property Surveys in the District of Columbia

In the District of Columbia, the right-of-way envelope shall be dimensionally tied to existing copper corners. Copper corners, which are generally offset from the square corners or property lines, can only be established by the D.C. Surveyor, or a surveyor registered in D.C. After establishing a copper, the surveyor then prepares and records a plat showing the relationship between the established copper and the property line. Ties from the proposed limit of right-of-way to the property lines are also required.

The following procedure is to be followed when requesting copper corners:

9.4.5.1 The General Plans shall be reviewed by the Section Designer/Design Engineer to determine the location of the copper corners needed to complete the design.

9.4.5.2 A search of the District of Columbia's survey records shall be conducted to determine the exact field location of each existing copper in the affected area.

9.4.5.3 A field check shall be made to determine the accuracy of all coppers located based on the copper locations taken from the D.C. survey records.

9.4.5.4 Coppers located and verified by the field check may be used in the design.

9.4.5.5 If additional copper corners are required to complete the right-of-way design, the Designer will contact the D.C. Surveyor's office to obtain a list of Registered Surveyors who can provide services on behalf of the D.C. Surveyor's office.

9.4.5.6 The designer shall establish the location of the coppers and or boundary lines with respect to the Metro grid and place the coordinate values on the plats prepared and signed by the D.C. Surveyor or a surveyor registered in the District of Columbia. Plats with the coordinated copper corners shall be used in the design and the coordinated values of the copper corners shall be shown on the right-of-way plans. (It is emphasized that copper corners be requested as early as possible to avoid delay in design.) When calculating areas of required rights-of-way, each square affected by the right-of-way envelope must be considered separately.

9.4.5.7 Written descriptions shall be in the D.C. meridian and shall include measured and record distances as well as a reference to WMATA's coordinate system. This reference shall include a WMATA datum reference as well a WMATA POB coordinate and bearing.

9.4.6 Property Surveys in Maryland and Virginia

- The WMATA right-of-way envelope on the plans shall be described by bearings and distances, ensuring that the pertinent portions of all tracts, subdivisions, U. S. lands, parcels, and other areas which are affected by the envelope are similarly described. Coordinates (and elevations for WMATA acquisitions having vertical limits) further describing the right-of-way limits and existing property corners shall be shown on the plans. Coordinates shall be provided for all angle and curve points along the limits of right-of-way. Properties that are affected by WMATA's right-of-way shall be shown in their entirety. Smaller scale (e.g. 1" = 200') schematic or property mosaic drawings may be used.

- The surveyor shall prepare plats of survey for recordation in accordance with the requirements found in Section 9.4.7 and the minimum technical standards of the appropriate jurisdiction. The final plats shall comply with the requirements of the jurisdiction in which the property is situated. It is required in Arlington County (and strongly recommended for other jurisdictions) that the surveyor submit the plats to the County (or City) having jurisdiction for their approval and comments. The plats shall be coordinated with WMATA prior to their submittal to the County (or City). Final plats shall be certified by a Land Survey or registered in the applicable jurisdiction.

- In 1974, the National Geodetic Survey (formerly the United States Coast and Geodetic Survey) adjusted the values of the horizontal control coordinates of all first order Triangulation Stations in Maryland and Virginia. WMATA mapping and control was generally based on the NAD27 1971 field geographic positions and coordinate values of these stations. One small section of WMATA's mapping and control (A-14 to A-17) was based upon NAD27 1974 adjustment. In either case, the Section Designer/Design Engineer shall include on the right-of-way plans, and on the plats of recordation, a note that describes the coordinate datum and adjusted values which are the basis for the coordinates shown. Survey consultants performing surveys for WMATA shall endeavor to use the NAD27 1971 and 1974 positions where historically these positions have been used in the past. NAD83 1991 positions shall be used for all extensions beyond the 103 Mile System. Adjustment of existing control shall be limited to avoid complications due to the differences of accuracy, and its relationship to previously set rail centerline control points and right-of-way monuments.

9.4.7 Plat of Survey Requirements

9.4.7.1 A surveyor performing any boundary survey for WMATA shall follow the minimum technical jurisdictional requirements and the WMATA technical standards during the performance of the work. Deviation from these requirements shall require WMATA approval.

9.4.7.2 All original plats of boundary surveys shall be provided on durable reproducible film, drawn at a jurisdictionally approved suitable scale clearly indicating the compiled results of the field work, computations, research, and record information.

9.4.7.3 All plats shall be submitted to WMATA in the latest AutoCAD® and Portable Document Format (PDF) file formats. PDF files shall include seal and signature of the surveyor of record. All legal descriptions shall be submitted to WMATA in the latest MicrosoftWord® and Portable DocumentFormat(PDF)file formats. All plats and legal descriptions shall include separate area closure sheets output from the computational software showing computed coordinates, bearing and distances, areas and closure error for each parcel and shall be submitted as an ASCII text and Portable Document Format (PDF) file formats.

9.4.7.4 All plats and legal descriptions shall be signed and sealed by the record surveyor.

9.4.7.5 Plats may not be smaller than 8 ½ x 11 inches. Plats shall be prepared in multiples of 8 ½ x 11 inches or 8½ x 14 inches. Tic marks shall be placed on the plat to indicate the matched corners of the multiple plats. The scale of the plat shall be 1 inch = 100 feet or smaller. Excess blank space shall be avoided.

9.4.7.6 Dimensions, bearings, or angles, including sufficient data to define curves, shall be neatly and legibly shown with respect to each property boundary line and or WMATA's acquisition lines. Tables of dimensions, bearings and angles shall be avoided.

9.4.7.7 All bearings shall be shown in a clockwise direction.

9.4.7.8 Building street address numbers, as displayed on the premises, or so noted if no numbers are displayed.

9.4.7.9 Markers shall be labeled as "found" or "set", with a brief description of the marker and relevant reference markers, if any, along with their positions in relation to the corner.

9.4.7.10 Natural or artificial features, where relevant, such as building lines, fences, water courses, streets, curb lines, pavement lines and visible utilities, shall be labeled, dimensioned, and referenced to the nearest property boundary line or represented by a symbol on the plat in its proper location. Each symbol shall clearly indicate what is represented or shall be labeled for identification either individually or in a separate key of symbols or legend.

9.4.7.11 A statement indicating the origin and method of determination of the bearings shall be made on each plat, and the origin of the bearings shall include a reference to the WMATA approved local coordinate system with the controlling station names listed along with coordinate values.

9.4.7.12 Separate intricate details, blowups, or inserts may be used for clarity. They shall be properly referenced to the portion of the plat where they apply, particularly in areas of encroachment or where lines of possession do not conform to the deed lines, and or where a comparison of adjoining deeds indicates the existence of a gap or overlap.

9.4.7.13 When record bearings or angles or distances differ from measured bearings, angles or distances, both the record and measured bearings, angles, and distances shall be clearly indicated. If the record description fails to form a mathematically closed figure, the surveyor shall so indicate.

9.4.7.14 Cemeteries and burial grounds found by the surveyor within the premises being surveyed shall be noted on the plat.

9.4.7.15 All evidence of monuments found beyond the subject tract, on which establishment of the corners of the subject tract are dependent, along with their application related to the survey shall be indicated.

9.4.7.16 Different line weights or delineating letters or numbers shall be used to clearly show the limits of the survey.

9.4.7.17 Easements and other physical encumbrances shown on the title shall be included on each plat along with all data necessary to establish or reestablish the location of the lines and the area of a strip or parcel of land designated on a tract of land for the specific use and benefit of others.

9.4.7.18 Upper and lower easement elevations and geometric delineation of easements required shall be shown on all plats.

9.4.7.19 WMATA structure lines and WMATA right-of-way lines shall be shown on all corresponding plats.

9.4.7.20 Permanent property interests required by WMATA shall be plainly and precisely identified on all corresponding plats.

9.4.7.21 The character of any and all evidence of possession shall be stated and the location of such evidence carefully given in relation to both the measured boundary lines and those established by the record. An absence of notation on the survey shall be presumptive of no observable evidence of possession.

9.4.7.22 Flood zone designation with proper annotation based on Federal Emergency Management Agency Flood Insurance Rate Maps or the state or local equivalent, by scaled map location and graphic plotting only shall be shown on each plat.

9.4.7.23 The name of owner(s) will be shown with references to include deed book & page, square number, block & lot number, parcel number, section number, name of subdivision and recording information, as appropriate, or if not in a subdivision, Town/City and County. In addition, taxi identification number shall be shown on all plats.

9.4.7.24 Adjoining properties will be shown and shall with references to include deed book & page, square number, block & lot number, parcel number, section number, name of subdivision and recording information, as appropriate, or if not in a subdivision, Town/City and County. In addition, tax identification number shall be shown on all plats.

The distance from the appropriate corner or corners of the surveyed property to the nearest right of way line, if the surveyed property does not abut a right of way.

9.4.7.25 The name of any street, highway or other public or private way abutting the surveyed property, and the width and location of the travelled way relative to the nearest boundary line of the surveyed property.

Visible evidence of physical access (such as, but not limited to, curb cuts and driveways) to any abutting streets, highways or other public ways.

The location and character of vehicular, pedestrian or other forms of access by other than the apparent occupants of the surveyed property to or across the surveyed property, including, but not limited to driveways, alleys, private roads, sidewalks and footpaths observed in the process of conducting the survey.

Without expressing a legal opinion as to ownership or nature, the location and extent of any potentially encroaching driveways, alleys, and other ways of access from adjoining properties onto the surveyed property observed in the process of conducting.

Evidence of access to and from waters adjoining the surveyed property, such as paths, boat slips, launches, piers and docks observed in the process of conducting the survey.

9.4.7.26 Improvements such as any fixed permanent features including buildings, sheds, detached garages, structures, and fences shall be shown on each plat. The type of building construction shall be noted as brick, frame, steel, concrete, etc. All improvements shall be dimensioned (including number of stories and projections into public space) and shown on the plat. If no buildings exist a note shall be placed on the plat stating "No buildings".

9.4.7.27 Driveways and alleys on or crossing the property shall be shown. Where there is evidence of use by other than the occupants of the property, the surveyor must so indicate on the plat or map. Where driveways or alleys on adjoining properties encroach, in whole or in part, on the property being surveyed, the surveyor must so indicate on the plat or map with appropriate measurements.

9.4.7.28 A statement as to whether or not a current title report has been furnished to the surveyor along with title report number.

9.4.7.29 Building restriction line(s) per restrictive covenant, if shown on the record subdivision plat.

9.4.7.30 All measured and record boundary line distances of parcels surveyed shall be shown.

9.4.7.31 Date of plat certification (signing & sealing)

9.4.7.32 Path & filename (digital)

9.4.7.33 Survey contractor's project filename & number

9.4.7.34 WMATA survey request number (if applicable)

9.4.7.35 WMATA task order number (if applicable)

9.4.7.36 WMATA line & section number (if applicable)

9.4.7.37 CENI parcel number

9.4.7.38 LAND parcel number

9.4.7.39 QA review by signature block

9.4.7.40 Date of field survey

9.4.7.41 Revision date(s)

9.4.7.42 Name of surveyor

9.4.7.43 Survey company name

9.4.7.44 Survey company address and the phone number

9.4.7.45 Client's name (survey prepared for)

9.4.7.46 Title of survey

9.4.7.47 Title report reference

9.4.7.48 Classification of the survey(urban, suburban, rural, mountain and marshland)

9.4.7.49 Scale of drawing

9.4.7.50 Basis of bearings

9.4.7.51 Datum (NAD83 or other datum approved by WMATA)

9.4.7.52 Gridlines / grid ticks

9.4.7.53 Coordinate station names

9.4.7.54 Coordinate station values for base control

9.4.7.55 Coordinate station scale factor(s)

9.4.7.56 North arrow

9.4.7.57 Legend

9.4.7.58 Signature, seal, printed license number of the surveyor & date block

9.4.7.59 Property description & location

9.4.7.60 Vicinity map

9.4.7.61 Land area for each parcel (acreage)

9.4.7.62 Point of commencement/point of beginning

9.4.8 Deliverables

9.4.8.1 In addition to the right-of-way drawings, plats of survey and written metes and bounds descriptions of the proposed permanent easements shall be prepared by the Section Designer/Design Engineer. Digital and hard copies shall be submitted to WMATA in the required format. The plats shall show both the record and the measured distances and bearings. Area closure sheets shall also be submitted.

9.4.8.2 Fee interests are normally taken from railroad companies, in lieu of permanent surface easement. Therefore, plats of railroad property where WMATA will require permanent surface easement shall be prepared to show fee takings. (The right-of-way plans shall still show permanent surface easement in the railroad properties.)

9.4.9 Curve Data

9.4.9.1 The Section Designer/Design Engineer shall reduce all spirals to circular curves at the limit of right-of-way. Circular curves are the only type of curves acceptable for recording purposes. Curve data shall be shown on the right-of-way plan sheet on which the curve appears in a table of curve data. Tangent sections shall be used in lieu of curves to show the limits of the right-of-way when curves are extremely flat.

9.4.10 Right-of-way for Aerial Structures

9.4.10.1 In determining right-of-way needs when dealing with aerial structures the Section Designer/Design Engineer may use as a guide a horizontal distance of twenty-five feet (25'-0") from the centerline of the nearest track to the right-of-way line. This should provide sufficient space for fire protection and maintenance. Consideration shall be given to the location of adjoining buildings and property limits which could govern the extent of the right-of-way limits.

9.4.10.2 The upper elevation of an aerial easement shall be a plane parallel with the datum, the upper elevation controlled by the highest point of the Metro structure. The upper elevation plane shall be stepped as necessary to prevent excessive takings. The steps shall be co-located with property lines, or other land features acceptable in land description practice. A lower limit will be required in most cases. Typical examples are a railroad passing under the WMATA facilities, or where the Metro passes over Federal Aid Highways, parking lots, or other facilities. Future requirements of access for maintenance purposes from ground elevation shall be considered in designing aerial rights-of-way.

9.4.10.3 Within the aerial easement area the following rights are obtained as a minimum:

9.4.10.3.1 Support rights for foundations, piers and other structural members.

9.4.10.3.2 The right of unobstructed and unimpaired use of the aerial envelope.

9.4.10.3.3 The right to prevent the transfer of loads to any part of the structure or foundations.

9.4.10.3.4 Access rights for periodic inspection and maintenance of the structure and footings.

9.4.10.3.5 The right to prevent the storage of flammables, explosives or other hazardous materials under the aerial envelope.

9.4.10.3.6 The right to install utilities beneath the surface of the ground within the easement area.

9.4.10.3.7 The right to use the area of the aerial easement as a contractor's work area during construction.

9.4.10.3.8 In property owned by the National Park Service (NPS) or by the General Services Administration (GSA), the areas for all easements required below the aerial easement shall be defined in the normal way.

9.4.10.3.9 In designing the WMATA right-of-way, the Section Designer/Design Engineer shall take the above criteria into consideration and any existing local, state and Federal requirements.

9.4.11 Continuous Right-of-way

Even though WMATA may not require acquisition of public space, all plans shall show the right-of-way envelope as being continuous crossing public as well as private space.

9.4.12 Isolated Right-of-way

The easement areas supporting all new construction such as fan and vent shafts, substations, escalators, and chiller plants shall be geometrically delineated as is the right-of-way envelope, with ties shown where the location is not contiguous to the right-of-way.

9.4.13 Underground Vaults

Underground vaults (found mainly in the District of Columbia) that will be influenced by WMATA construction shall be shown and their disposition noted. The vaults shall be labeled in accordance with the following categories:

9.4.13.1 Category "A" are those vaults which must be physically removed during construction.

9.4.13.2 Category "B" are those vaults which lie within the influence line of construction, but may not require physical removal.

9.4.13.3 The influence line may generally be considered to project upwardly on a 1:1 slope from a point two feet (2') below the lowest point of excavation nearest the property line. Vaults not in Category "A" but within the influence line could experience cracking and utility lines may be subject to rupture. The owner may be required to abandon use of vaults designated Category "B" during construction.

9.4.14 Multilevel Easements

Multilevel easements maybe required by WMATA at station entrances located in buildings. In such instances the Section Designer/Design Engineer shall prepare a separate detail drawing showing the interests on each floor level. The following points shall be adhered to:

9.4.14.1 Each floor level affected by the WMATA facility shall be so noted and separately illustrated. The area required on each level should be shown on each level of the detail, with the sum of the areas shown in the property disposition table for that property.

9.4.14.2 Each type of easement on a floor level shall be properly dimensioned and symbolized. All footing and column locations shall be shown.

9.4.14.3 The elevations of each floor easement shall be given and referenced to the project datum. Elevations shall normally be from the underside of the floor structure to the underside of the next higher floor structure.

9.4.14.4 Access to each level of the easements must also be included in the design.

9.4.15 Explanatory Notes

Explanatory notes shall be used, where applicable, to aid in clarification of right-of-way takings.

9.4.16 Construction Easements

9.4.16.1 Construction easements are temporary easements that are normally required only during construction. These easements do not need the detailed definition of permanent easements, as an agreement (lease) is normally entered into with the property owner. It is essential, however, that the Contractor be able to accurately locate the extent of the easement in the field. Thus, distances and ties to existing features are important.

9.4.16.2 If the proposed easement is isolated from the WMATA right-of-way, ties or coordinates sufficient to locate the easement in the field should be shown on the plans.

9.4.16.3 Where WMATA facilities will be built by cut-and-cover construction, a construction easement is required over the permanent underground easement that will envelope the structure. The area of the construction easement is to be noted in the property disposition table with an asterisk, which refers to a note of explanation: "* INCLUDES AREA ABOVE PERMANENT UNDERGROUND EASEMENT", placed above the Property Disposition Table. Plats are not required for construction easements, except in the event of condemnation. Plats used for condemnation are required to show construction easements by bearings and distances.

9.5 RIGHT-OF-WAY LIMITS

The Section Designer/Design Engineer shall concurrently evaluate the right-of-way requirements for access, drainage, utilities, embankments, grades, alignments, and interfaces. The following criteria are provided as a guide for establishing the right-of-way limits. All right-of-way limits shall be defined as horizontal or vertical planes. The dimensions given herein are for general conditions and are to be modified where good sense, engineering, physical limitations, or real estate requirements dictate. The right-of-way limits will not always be concentric or parallel with the centerline of the tracks. Special attention shall be given to property takings, with the intent of avoiding takings where it is possible without adversely affecting the composite requirements of the Metro system. This may be accomplished by reducing or increasing the distance from the centerline of the tracks to the right-of-way limits or by stepping the limits around a certain property. The Section Designer/Design Engineer shall establish the right-of-way limit to include the security fence and its support structure. Right-of-way limits should be developed which will allow minor adjustments as the design is refined.

The following distances are offered as a guide in establishing the final right-of-way requirements early in the design. Right-of-way widths at stations are based on 40'-6" track centers. Use of wider track centers will require additional right-of-way widths.

9.5.1 At-Grade Structure (See Figure 9.2)

Upper Limit: Normally, an upper limit is not required. When an upper limit is required, the limit shall be described by the elevation of horizontal planes, stepped as required, locating the steps at existing property lines or prominent topographical features. The minimum distance from the top of the high rail to the horizontal plane is eighteen feet (18').

Lateral Limits: The Section Designer/Design Engineer shall establish the right-of-way limits taking into account all requirements that apply to the alignment. The following distances shall be used as a guide:

9.5.1.1 Normal at-grade section, five feet (5') from the toe or top of slope.

9.5.1.2 Normal at-grade section with a drainage interceptor ditch, five feet (5') from the outside edge of the interceptor ditch.

9.5.1.3 Restrictive and retained sections as approved by CENI.

Lower Limit: When required, the lower limit shall be defined in a manner similar to the upper limit, using a minimum distance of fifteen feet (15') below the top of low rail or fifteen feet (15') below the lowest flow line of adjacent drainage channels, whichever is lower.

9.5.2 Aerial Structure (See Figure 9.2, Figure 9.10 and Figure 9.11)

Lateral Limit: Single track minimum fifty feet (50') total; double track on fourteen feet (14') centers, sixty four feet (64') total. A lateral distance of twenty five feet (25') from the centerline of each track is to be maintained on wider track centers.

Lower Limit: A lower limit will normally be required under the aerial structure. The limit will vary from 1' to 4' below the bottom of the structure. The limit is delineated by elevations of horizontal planes, stepped as required, locating the steps at existing property lines or prominent suitable topographical features. For clearance requirements see Section 11.11.

Upper Limit: An upper limit is generally not required; however, if required, the upper limit should be set at eighteen feet (18') above the top of the high rail.

9.5.3 Rock Tunnel (See Figure 9.2, Figure 9.7, Figure 9.8 and Figure 9.9)

Dimensions given in the aforementioned figures and following paragraphs are minimum distances. Actual dimensions may increase due to the conditions of the rock.

Upper Limit: The limit of the right-of-way is described by elevations of horizontal planes, stepped as required, locating the steps at existing property lines or prominent suitable topographical features. As a guide, a horizontal plane shall be used that is thirty five feet (35') above the top of the high rail for single track, forty feet (40') for double track, and seventy feet (70') at stations.

Lateral Limit: Vertical planes shall be used that are thirty feet (30') from the centerline of the nearest track. In station areas, use sixty feet (60') from the centerline of the station.

Lower Limit: Lower limits are normally not prescribed for rock tunnels. Where used, the lower limit shall be configured in a like manner to the upper limit, using a distance of fifteen feet (15') below the top of the low rail.

9.5.4 Earth Tunnel (See Figure 9.2 and Figure 9.6)

Upper Limit: The limit of the right-of-way is described by elevations of horizontal planes, stepped as required, locating the steps at existing property lines or prominent suitable topographical features. As a guide, a horizontal plane twenty five feet (25') above the top of the high rail shall be used.

Lateral Limit: Fifteen feet (15') from the centerline of the nearest track.

Lower Limit: Where required by local jurisdictions or field conditions, a lower limit shall be configured in a manner similar to the upper limit using a distance of fifteen feet (15') below the top of the low rail.

9.5.5 Cut and Cover (See Figure 9.2, Figure 9.3, Figure 9.4 and Figure 9.5)

Upper Limit: Twenty five feet (25') above the top of the high rail for single track, double track or triple track, and forty feet (40') at stations. The limit is delineated by elevations of horizontal planes, stepped as required, locating the steps at existing property lines or prominent suitable topographical features.

Lateral Limit: Fifteen feet (15') from the centerline of the nearest track. In station areas, forty feet (40') from the centerline of the stations.

Lower Limit: Where required by local jurisdiction or field conditions. A lower limit shall be configured in a manner similar to the upper limit using a distance of fifteen feet (15') below the top of the low rail.

9.5.6 Storm Drainage

Local requirements shall be adhered to where applicable. If there are no applicable local requirements, then the following shall apply:

9.5.6.1 Open Ditches

A minimum strip ten feet (10') wide is required for ditches where the design requires surface drainage. (See standard drawings for other ditch dimensions and slopes.) A two foot (2') wide clean-out shelf is required where the ditch is unpaved.

Back and Front Slopes: In soils, a maximum back or front slope of21/2:1 shall be used. Where soil conditions would require excessive maintenance of a 21/2:1 slope, use a suitable flatter slope.

9.5.6.2 Underground Drainage

Widths of public easements for underground drainage systems shall be approved by the local approving agency.

9.5.7 Stations

All station platforms are 600' long, with ancillary rooms as an additional requirement. Station platforms shall be shown on the plans with stationing at each end of the platform. Right-of-way dimensions are delineated in paragraphs 9.5.1, 9.5.2,9.5.3, 9.5.4, and 9.5.5.

9.5.8 Projections in Public Space or Public Street Right-of-way

The Section Designer/Design Engineer shall submit to WMATA a written list of projections into public space which must be removed to accommodate the construction of the metro facilities. This list should be submitted as soon as possible, but no later than the intermediate review submittal.

The projections list shall identify the type of projection, the location of the projection by square and lot number or by the tax assessor's designations, the street address, and the owner's name and address. Types of projections include vaults, fire escapes, signs, display windows, awnings, footings, foundations, and stairways.

9.5.9 Escalator Requirements

In addition to the structural, mechanical and electrical requirements for escalator space, the requirements for pedestrian circulation space to and from the escalators must be satisfied. A fifteen feet (15') wide longitudinal walking strip on either side of the finished escalator portal is required. A twenty feet (20') distance from the newels at the top and bottom of the escalator must also be preserved for pedestrian circulation. Exterior escalators require overhead protection from the elements. See standard canopy design drawings DD-A-CP-001 though DD-A-CP-008. Provide a minimum 15'-0" maintenance easement above the top of the canopy structure. The minimum head room above the escalator is twelve feet (12'-0") for escalator truss removal.

9.5.10 Substations

At-grade substations require an access road that is a minimum of eighteen feet (18') wide, with a twenty feet (20') long parking area and a turnaround sufficient fora WB-50 vehicle. The requirement for land will vary with the type of substation. The substation area should be contiguous to the limit of right-of-way for the transit way, where possible, with a five feet (5') maintenance space between the limit of right-of-way and the face of the substation structure.

Underground substations require an underground easement extending out ten feet (10') from the outside face of the structure.

Provision shall be made for permanent right-of-way for the electrical and communications cable ducts between the substation and the tracks.

The electric grounding grid at substations shall be located within the permanent surface easement at the substation. If such an arrangement is unworkable, then the grounding grid shall be located in an identifiable grounding grid easement. The grounding grid location should be monumented.

9.5.11 Tie Breaker Stations

At-grade tie breaker stations require an access road that is a minimum of eighteen feet (18') wide, with a twenty feet (20') long parking area and a turnaround sufficient for a WB-50 vehicle. The requirement for land varies with the type of tie breaker station. The tie breaker area should be contiguous to the limit of right-of-way for the transit way, where possible, with a five feet (5') maintenance space between the limit of right-of-way and the face of the tie breaker structure.

Underground tie breaker stations require an underground easement extending out ten feet (10') from the outside face of the structure.

Provision shall be made for permanent right-of-way for the electrical and communications cable ducts between the tie breaker station and the tracks.

The electric grounding grid at tie breaker stations shall be located within the permanent surface easement at the tie breaker station. If such an arrangement is unworkable, then the grounding grid shall be located in an identifiable grounding grid easement. The grounding grid location shall be monumented.

9.5.12 Vent and Fan Shafts

Vent and fan shafts shall be located in public space where possible. The gratings shall not exceed forty percent (40%) of the sidewalk width. When located on private property, the limit of right-of-way shall be five feet (5') from the outside face of the structure. Access to the shaft is required from the public street right-of-way.

9.5.13 Chiller Plants

At-grade chiller plants require five feet (5') from the face of the structure to the limit of the right-of-way. Suitable access is required.

Chiller plants require additional space for the cooling tower when the cooling tower is located beside the mechanical plant instead of on top of the plant building. When chiller plants are located on existing buildings, a pipe and conduit chase shall be provided and required easements delineated on the right-of-way plans.

9.5.14 Fencing

All construction sites and contractor's areas shall have temporary fencing and suitable barricades where required to protect pedestrians and vehicles. It shall be noted on the plans that the contractor is required to fence only the area he will need to conduct his operations. The fencing will generally follow the limit of a construction easement. Contractor work areas in public space will be indicated by the limit of the construction fence. Dimensions of fencing may be scaled.

9.5.15 Monumentation

9.5.15.1 The objective of WMATA's monumentation is to provide a broad network of survey control, right-of-way and boundary monuments from which WMATA's real property interests can accurately be identified.

9.5.15.2 Definitions

9.5.15.2.1 Survey control monument

A Metro monument consisting of a brass or bronze disc inscribed "METRO-CONTROL SURVEY", as shown on Standard Drawings ST-C-SURV-002, ST-C-SURV-003 and ST-C-SURV-004. These are geodetically established, geo-referenced monuments placed within Metrorail corridors. This is the primary survey control used to design and construct the Metrorail system.

9.5.15.2.2 Right-of-way monument

A Metro monument consisting of a brass or bronze disc inscribed "METRO-RIGHT-OF-WAY", as shown on Standard Drawings ST-C-SURV-002, ST-C-SURV-003 and ST-C-SURV-004.These are geo-referenced monuments which document the boundary as determined by a registered surveyor.

9.5.15.2.3 Boundary monument

A steel rebar rod with aluminum cap inscribed "Metro - Property Monument," as shown on Standard Drawings, ST-C-SURV-002, ST-C-SURV-003 and ST-C-SURV-004, are to be used to mark a corner or point on a boundary line. The registered surveyor setting the monument is to inscribe the cap with their registration number, WMATA Real Estate parcel number and point number, and comply with all jurisdictional regulations.

9.5.15.2.4 Witness post

A fiberglass flexible post about six feet in length (one and one-half to two foot burial depth) used to mark a survey control, right-of-way or boundary monument located in open space, and provide an easily visible identifying reference to the monument. Witness posts may also be used to locate points on property lines when the line is not readily identifiable. See Standard Drawings ST-C-SURV-002, ST-C-SURV-003 and ST-C-SURV-004 for details of the decal that is to be applied to all witness posts.

9.5.15.3 Local Regulations

9.5.15.3.1 Right-of-way monuments shall be installed at property corners to mark the WMATA right-of-way when jurisdictional regulations require it.

9.5.15.3.2 Where jurisdictional regulations require a boundary monument to mark property acquisitions or divisions in property, the local regulations shall govern. If jurisdictional regulations do not require monuments to be set, then WMATA policies shall apply. Refer to Section 9.5.15.4.

9.5.15.3.3 The monumentation for the right-of-way of WMATA facilities shall be accomplished in such a manner that the right-of-way lines can be readily re-established by a registered surveyor.

9.5.15.4 Design Considerations

9.5.15.4.1 It is WMATA policy to monument all Metro right-of-way in such a manner that the right-of-way line can be readily re-established on the ground by a registered surveyor currently licensed to practice in the appropriate jurisdiction. In order to have consistency among the many surveys made, or that will be made in the future, the Metro control survey network shall be considered the basis for all Metro right-of-way monumentation.

9.5.15.4.2 Right-of-way monuments shall be installed at property corners to mark the WMATA right-of-way. Right-of-way monuments shall be installed at all station entrances, on property lines adjacent to public spaces, and on property lines considered to be sensitive, as directed by WMATA. Setting the WMATA right-of-way lines shall be accomplished only after careful consideration has been given to adjacent property lines.

9.5.15.4.3 Coordinate values on boundary survey plats are to be shown in the applicable state plane system. Coordinate values on right-of-way plans are to be based on the project coordinate system in District of Columbia and Maryland and for part of the Huntington Route in

Virginia. Coordinates in Virginia, except for part of the Huntington Route, are to be based on the Virginia State Plane Coordinate System, North Zone. State plane NAD83, 1991 coordinate values shall be utilized for various parts of the E-Route and the extension of the Outer G-Route.

9.5.15.5 Location of Monuments and Markers

9.5.15.5.1 It is WMATA's policy to set all property corners and to mark all underground utilities within the Metrorail right-of-way.

9.5.15.5.2 WMATA's control survey network shall be considered the basis for WMATA's right-of-way monumentation. Right-of-way monuments shall be set at angle points, at the beginning and ends of curves, and at intermediate points at intervals of not greater than 1000 feet.

9.5.15.5.3 Right-of-way monuments shall be placed where they would not normally be disturbed by WMATA maintenance operations, private grass cutting, future construction, and where their use would not create a hazard for the public or surveyors.

9.5.15.5.4 Boundary monuments shall be set in accordance with local laws, ordinances and regulations. Boundary monuments will not be set in the District of Columbia as this is the prerogative of the Surveyor, D.C.

9.5.15.5.5 Right-of-way monuments shall be set at Metrorail station entrances to define the limits of the WMATA surface property interests. Brass or other disks shall be used to mark the corners.

9.5.15.5.6 Control survey monuments shall be set following construction of WMATA concrete structures.

9.5.15.6 Monumentation of surface, underground, aerial and utility rights-of-ways

9.5.15.6.1 Surface right-of-way:

Right-of-way monuments shall be located outside of the WMATA security fence.

9.5.15.6.2 Underground right-of-way:

Right-of-way monuments shall not normally be used to mark WMATA underground occupancy of public space. On WMATA property, survey control monuments shall be set in readily accessible places such as entrances, dome relief curbs, elevator openings, and fan and vent shafts' concrete structures.

9.5.15.6.3 Aerial right-of-way:

Right-of-way monuments shall not normally be used to mark these rights-of-way.

9.5.15.6.4 Utility right-of-way:

All underground utility lines will be marked in accordance with Standard Drawing ST-U-66.

9.5.16 Underpinning Construction Easements

The Section Designer/Design Engineer shall provide detailed plans of the right-of-way necessary for the underpinning required by the design. Separate drawings showing the easements required for the construction contractor shall be prepared and referenced in the Property Disposition Table under "Remarks". The underpinning detail shall show the dimensions of the easements and tie the easements to the WMATA right-of-way, the property line, and the supporting columns of the structures. All footing and column locations shall be shown. Proposed access to the work areas through the building and location of dust walls shall be shown (see Section 15.7).

9.5.17 Street Closings

Provide separate drawings showing the areas of public property to be closed and utilized for WMATA. These drawings shall be prepared in accordance with all local requirements. The local plat requirements generally conform to the requirements for subdivision plats.

9.5.18 Utility Easements

Utility easements shall be treated as rights-of-way. Bearings and distances along the centerline shall be shown as well as the lengths and widths of the easements, and ties to the limits of right-of-way. All easements and clearances shall be in accordance with the Federal, State, local, and utility regulations and policies. All easements for new or relocated utilities shall be described by a metes and bounds description based upon the required plat.

9.5.19 Elevators

Provide direct access from elevators to public space. The access shall be a minimum of fifteen feet (15') wide, in addition to the space required for the queuing area. Provide for access to machine rooms, hoistways, elevator pits, etc., as required by the applicable code. Direct access to the elevator machine room shall be provided. Right-of-way for required utility services to the elevators shall be provided in accordance with the local jurisdiction requirements

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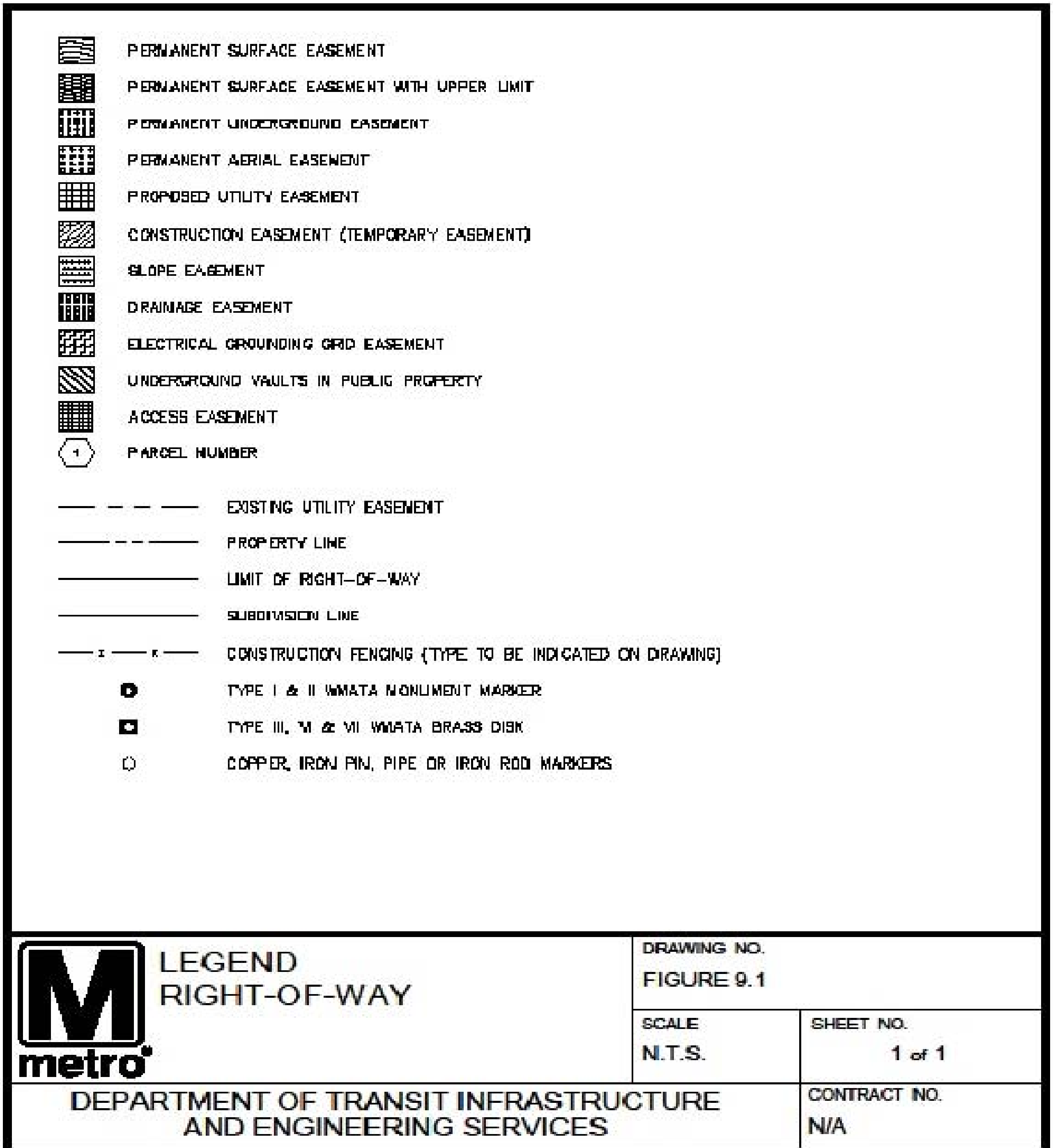
FIGURE 9.1



DEC. 2016

TYPE CONSTRUCTION	AT GRADE		CUT & COVER	EARTH TUNNEL	ROCK TUNNEL	AERIAL
TYPE EASEMENT (PERMANENT)	SURFACE	SURFACE WITH UPPER LIMIT	UNDERGROUND	UNDERGROUND	UNDERGROUND	AERIAL
UPPER LIMIT	N/A	18' ABOVE T/R 13' ABOVE T/R UNDER BRIDGES	SINGLE TRACK–25' ABOVE T/R DBL. OR TRPL.–25' ABOVE T/R STATIONS–40' ABOVE T/R	25' ABOVE T/R	1. SINGLE TRACK 35' ABOVE T/R 2. DOUBLE TRACK 40' ABOVE T/R 3. AT STATION 70' ABOVE T/R	18' ABOVE T/R
LOWER LIMIT (WHERE REQUIRED BY JURISDICTIONS)	15' BELOW T/R		15' BELOW T/R STATIONS–20' BELOW T/R	15' BELOW T/R	15' BELOW T/R	VARIES 1' TO 4' BELOW BOTTOM OF STRUCTURE
LATERAL LIMITS	EXCLUSIVE ROW VARIES (SEE DESIGN DRAWINGS) RESTRICTIVE ROW AS APPROVED (SEE DESIGN DRAWINGS)		15' FROM ℄ NEAREST TRACK 40' FROM ℄ STATIONS	15' FROM ℄ NEAREST TRACK	30' FROM ℄ NEAREST TRACK 60' FROM ℄ STATIONS	SINGLE TRACK 50' DOUBLE TRACK 25' FROM ℄ EACH TRACK

NOTES:

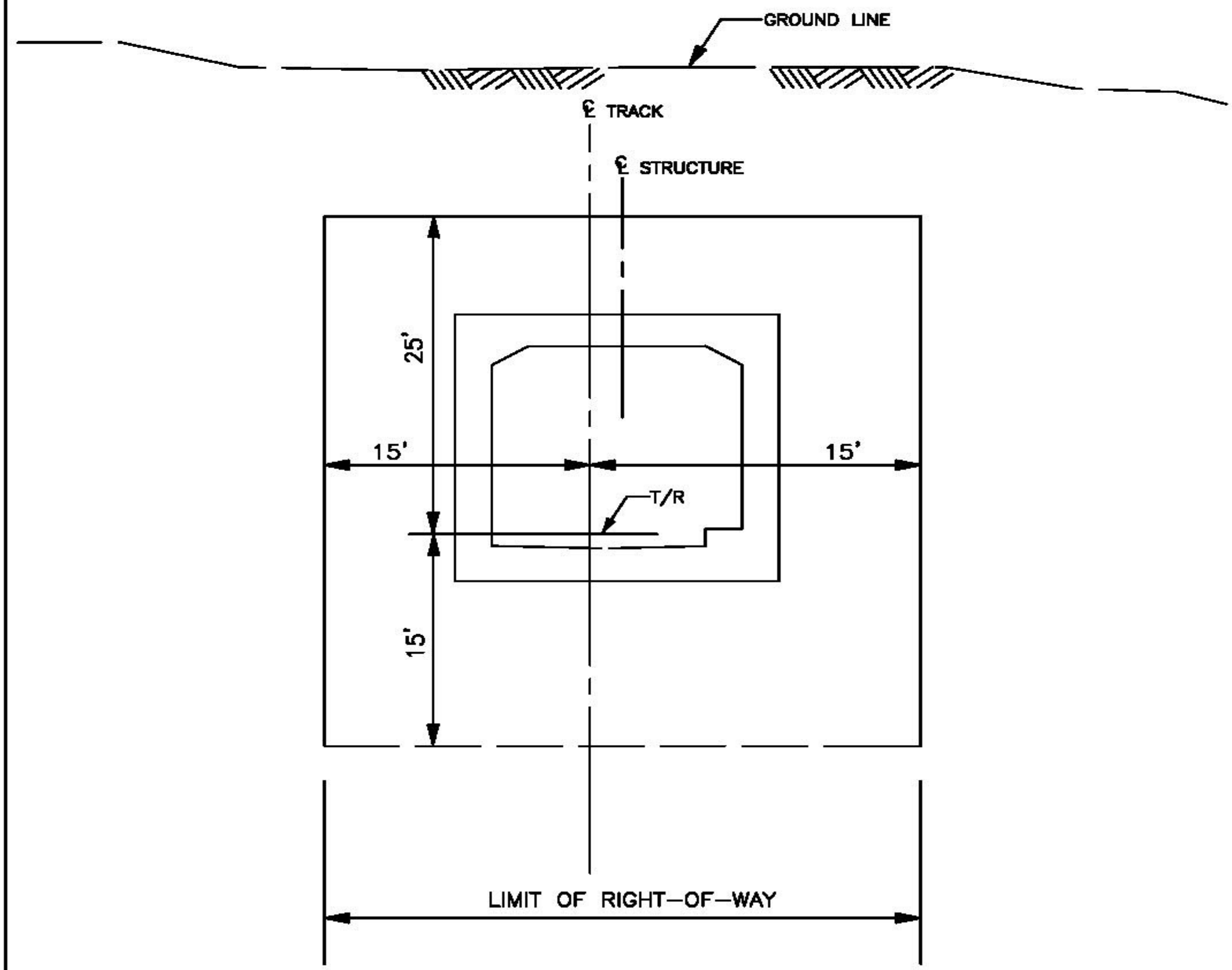
1. DISTANCES SHOWN ARE MINIMUM, AND ARE TO BE INCREASED WHERE ENGINEERING REQUIREMENTS SUCH AS ROCK BOLTS, SERVICE ROADS OR DRAINAGE DICTATE ADDITIONAL NEEDS.
2. ALL LIMITS OF RIGHT–OF–WAY ARE TO BE VERTICAL OR HORIZONTAL PLANES.
3. FOR UNDERGROUND EASEMENTS, WHERE THE DISTANCE SPECIFIED FOR THE UPPER LIMIT EXTENDS ABOVE THE GROUNDSURFACE, USE THE GROUND SURFACE AS THE UPPER LIMIT.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES

MINIMUM RIGHT–OF–WAY

FIGURE 9.2



WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	TYPICAL ROW CUT & COVER – SINGLE TRACK

FIGURE 9.3

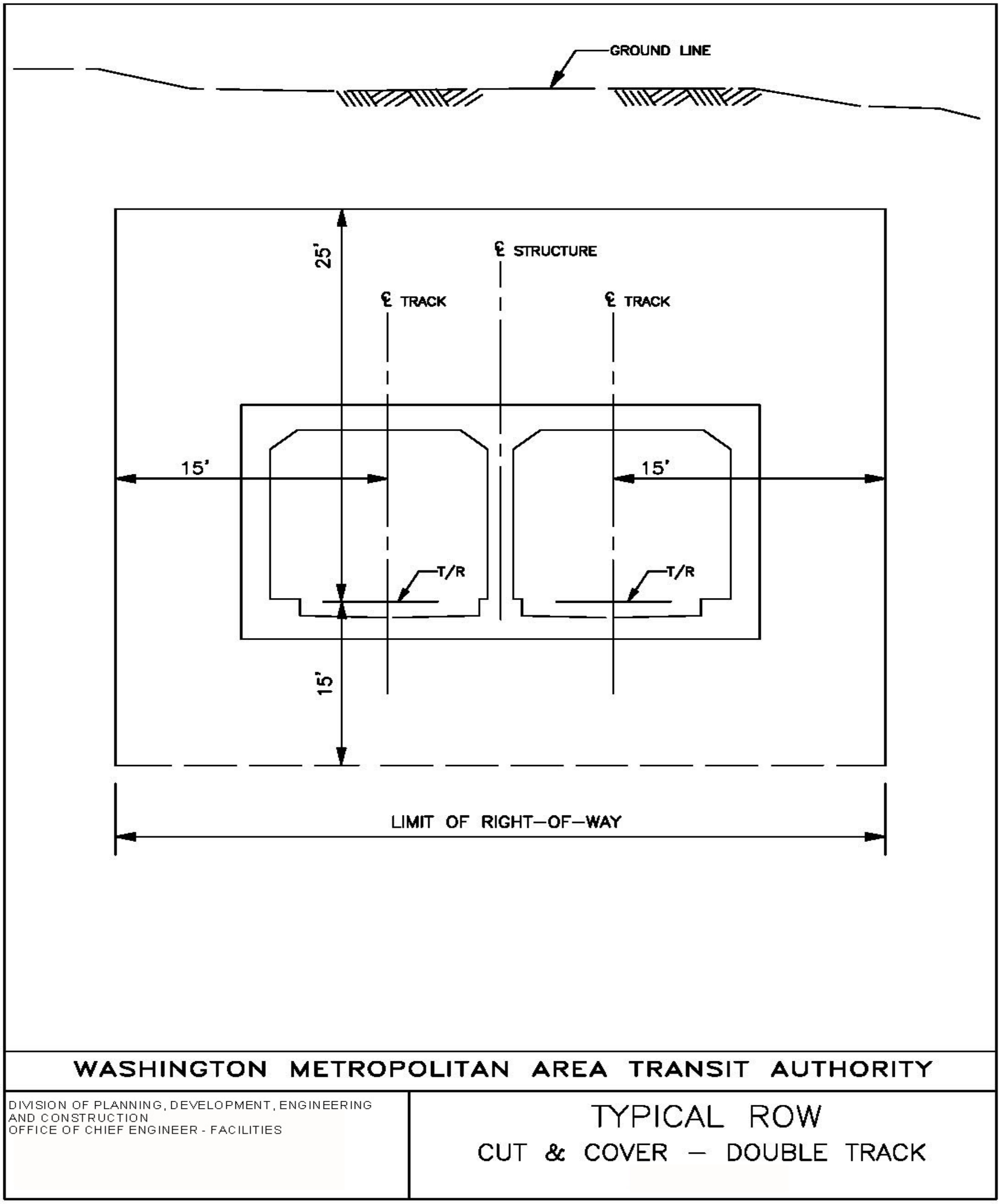
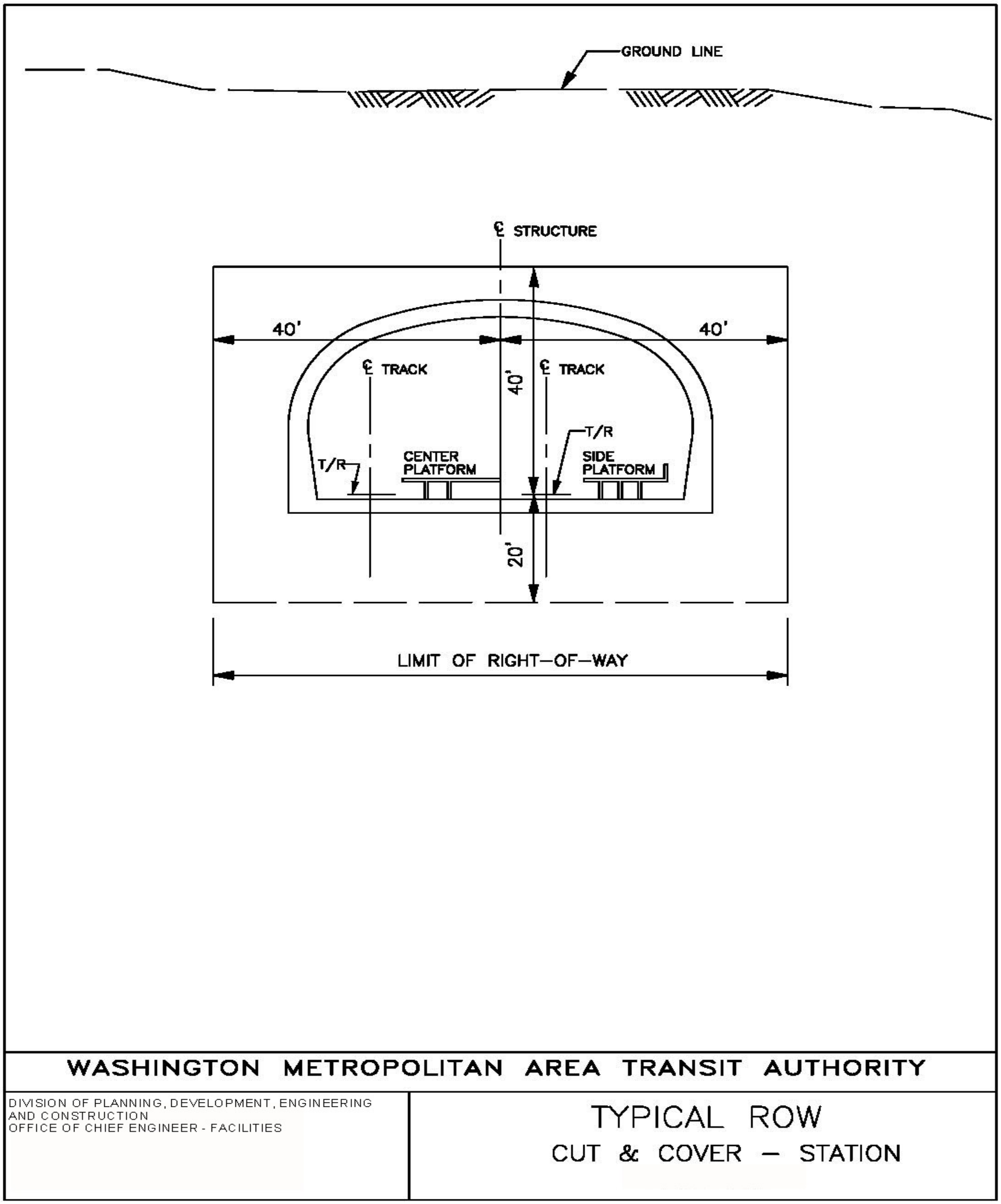

GROUND LINE
25'
℄ STRUCTURE
℄ TRACK
℄ TRACK
15'
15'
T/R
T/R
15'
LIMIT OF RIGHT–OF–WAY
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING
AND CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
TYPICAL ROW
CUT & COVER – DOUBLE TRACK

FIGURE 9.4


GROUND LINE
℄ STRUCTURE
40'
40'
℄ TRACK
℄ TRACK
40'
T/R
T/R
CENTER PLATFORM
SIDE PLATFORM
20'
LIMIT OF RIGHT-OF-WAY
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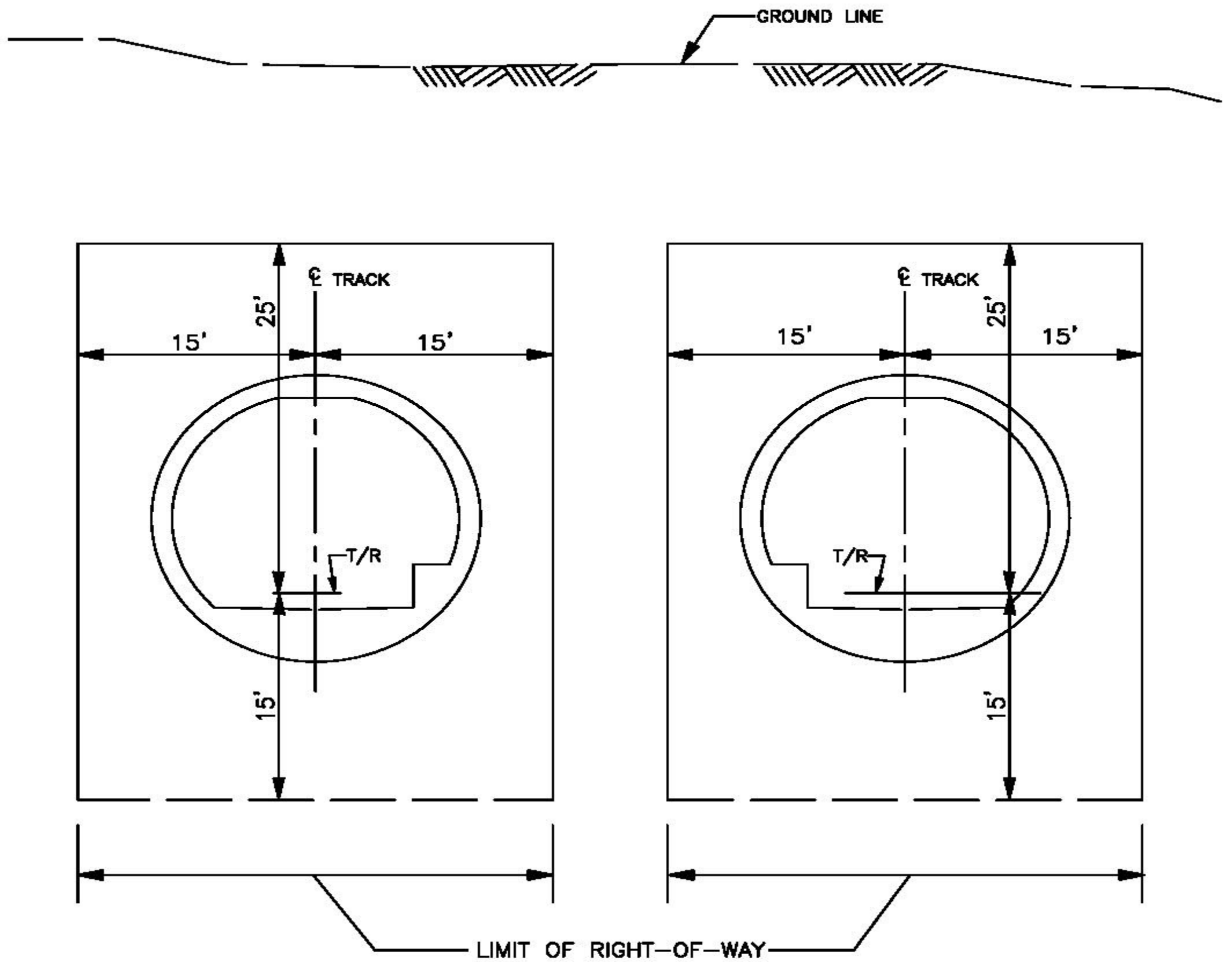
OFFICE OF CHIEF ENGINEER - FACILITIES
TYPICAL ROW
CUT & COVER – STATION

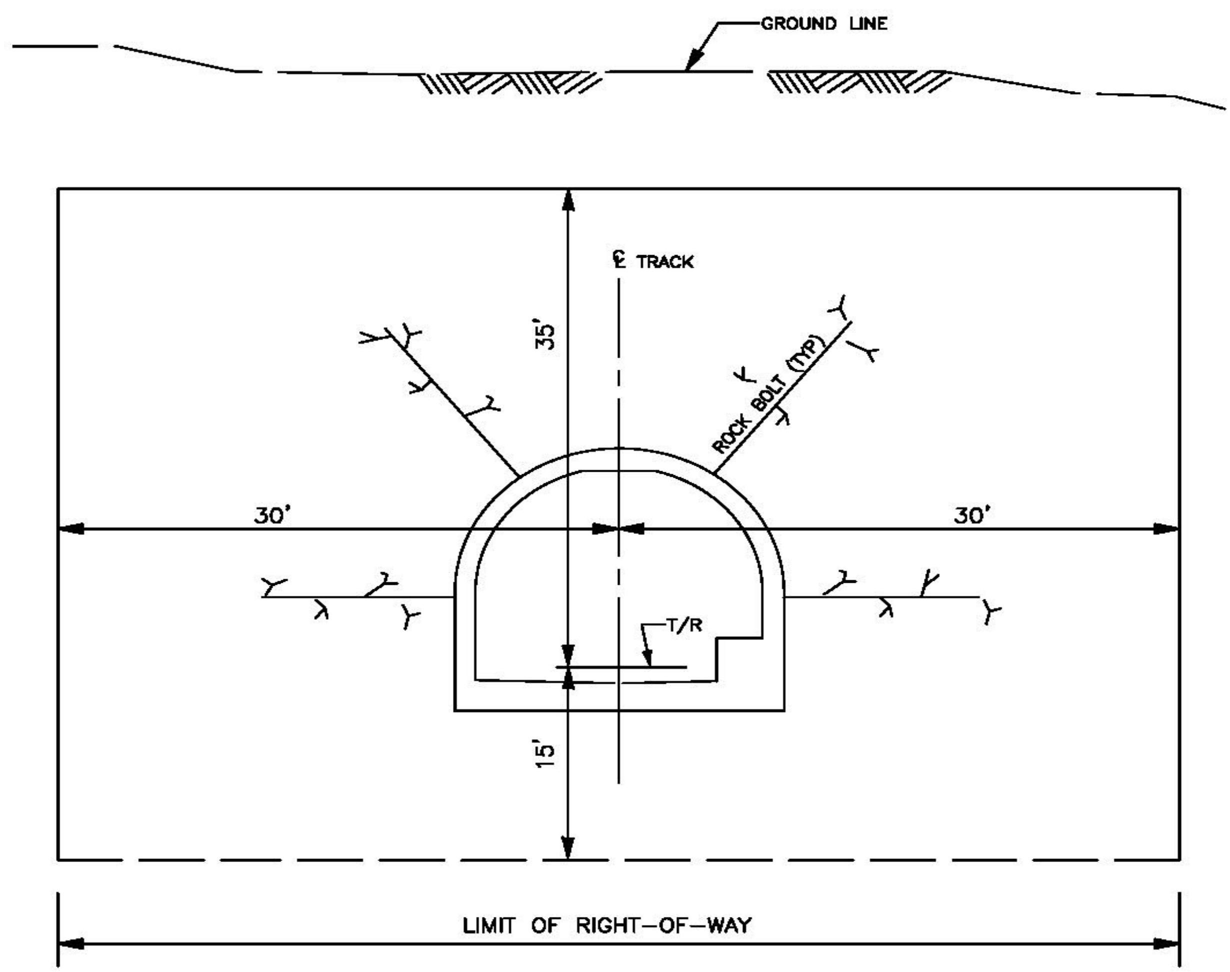
FIGURE 9.5



NOTE: WHERE CENTERLINES OF TRACKS ARE 35 FEET OR LESS, OR R.O.W. LIMITS BETWEEN TUNNELS OVERLAP, THE R.O.W. LIMIT BETWEEN TUNNELS NEED NOT BE DEFINED.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	TYPICAL ROW EARTH TUNNEL

FIGURE 9.6



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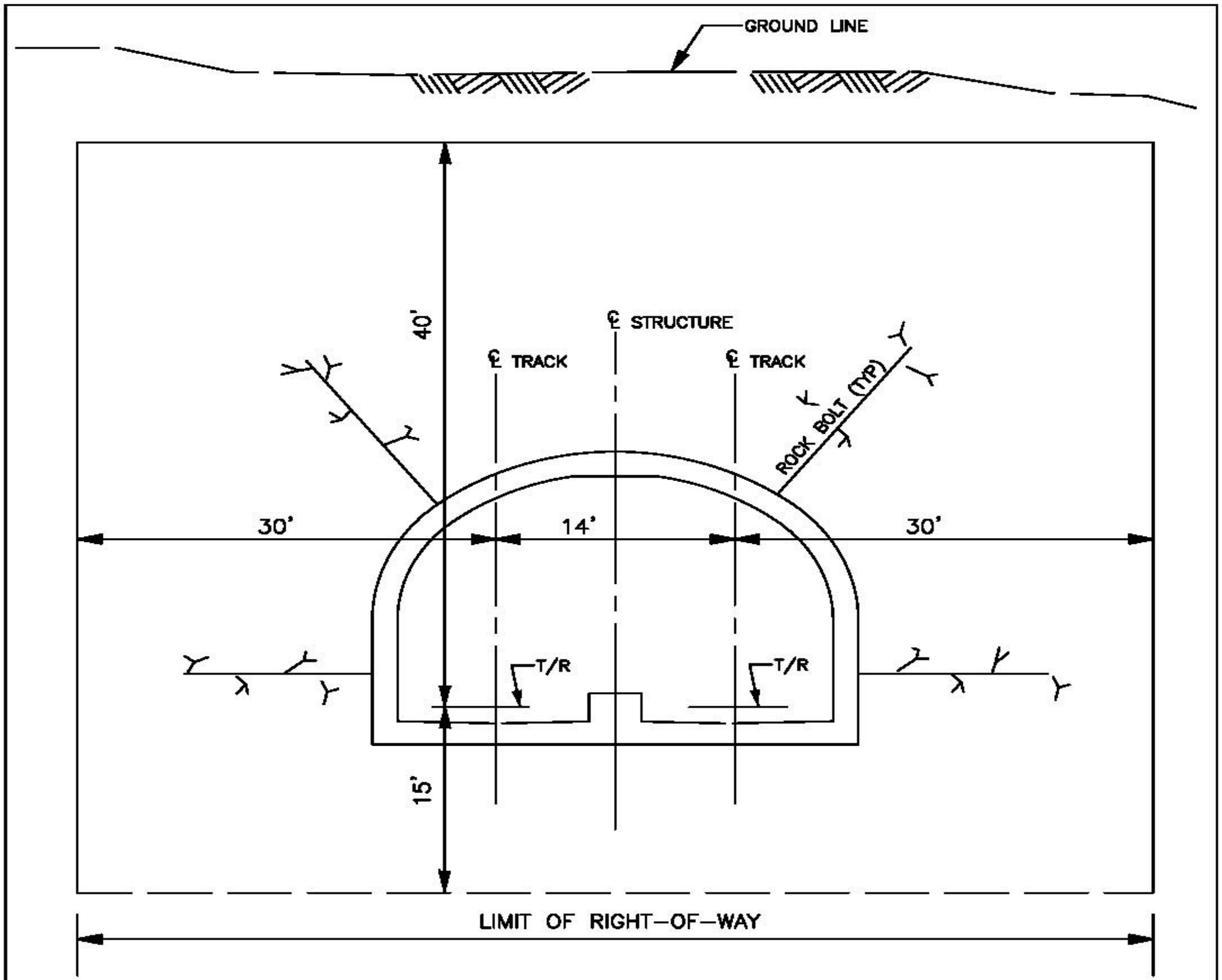
OFFICE OF CHIEF ENGINEER - FACILITIES

TYPICAL ROW
ROCK TUNNEL – SINGLE TRACK

FIGURE 9.7



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AND CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES

TYPICAL ROW

ROCK TUNNEL – DOUBLE TRACK

FIGURE 9.8

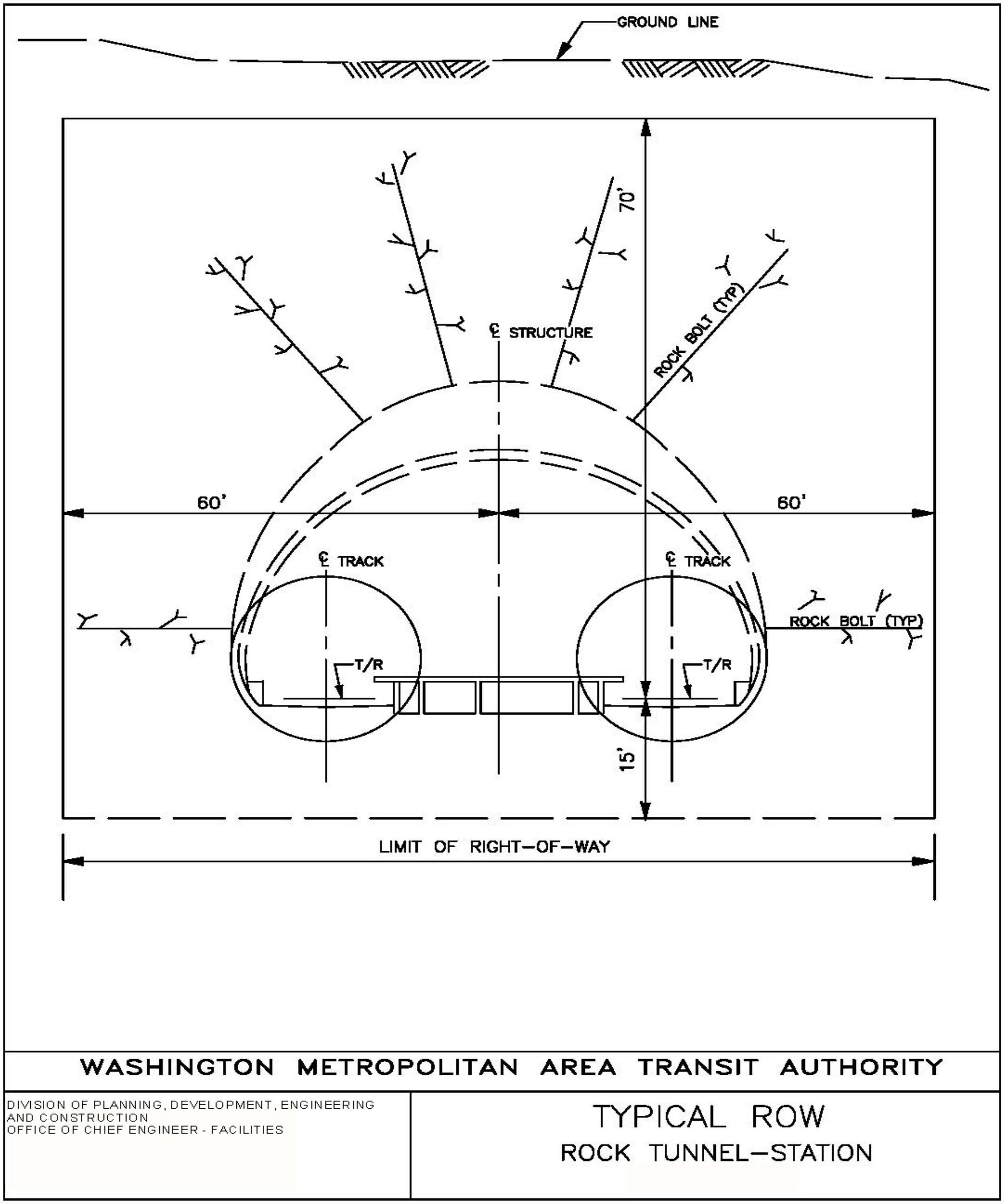
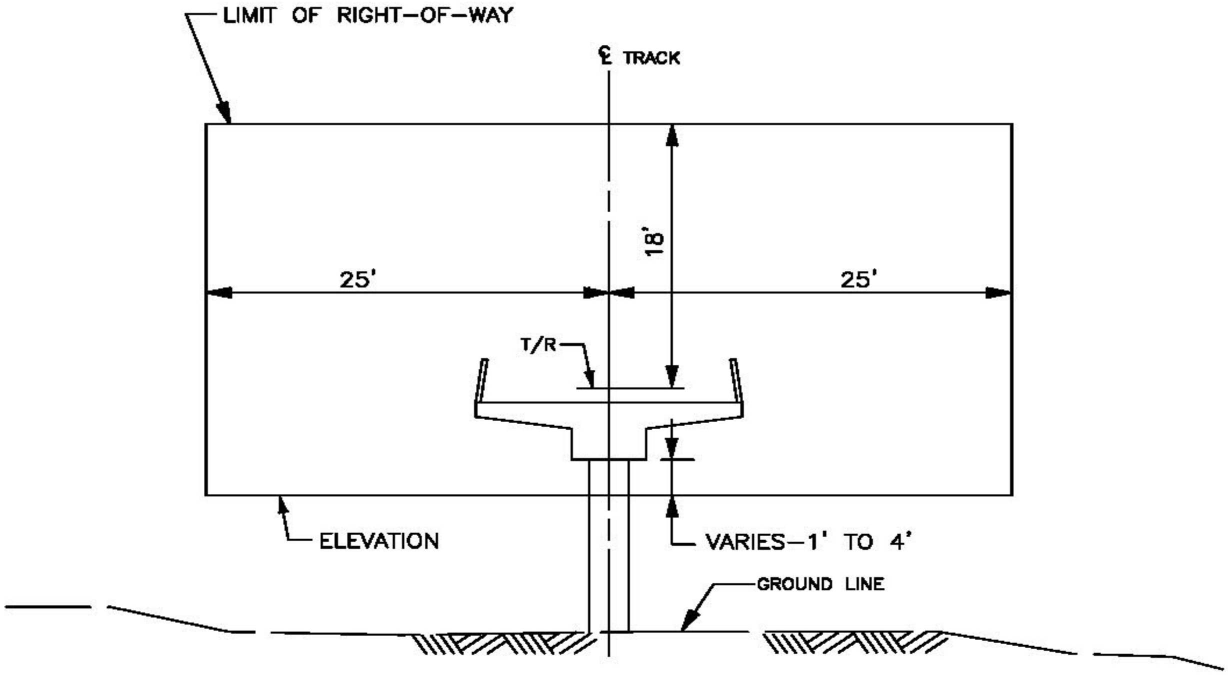

GROUND LINE
70'
℄ STRUCTURE
ROCK BOLT (TYP)
60'
60'
℄ TRACK
℄ TRACK
ROCK BOLT (TYP)
T/R
T/R
15'
LIMIT OF RIGHT—OF—WAY
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
TYPICAL ROW
ROCK TUNNEL—STATION

FIGURE 9.9

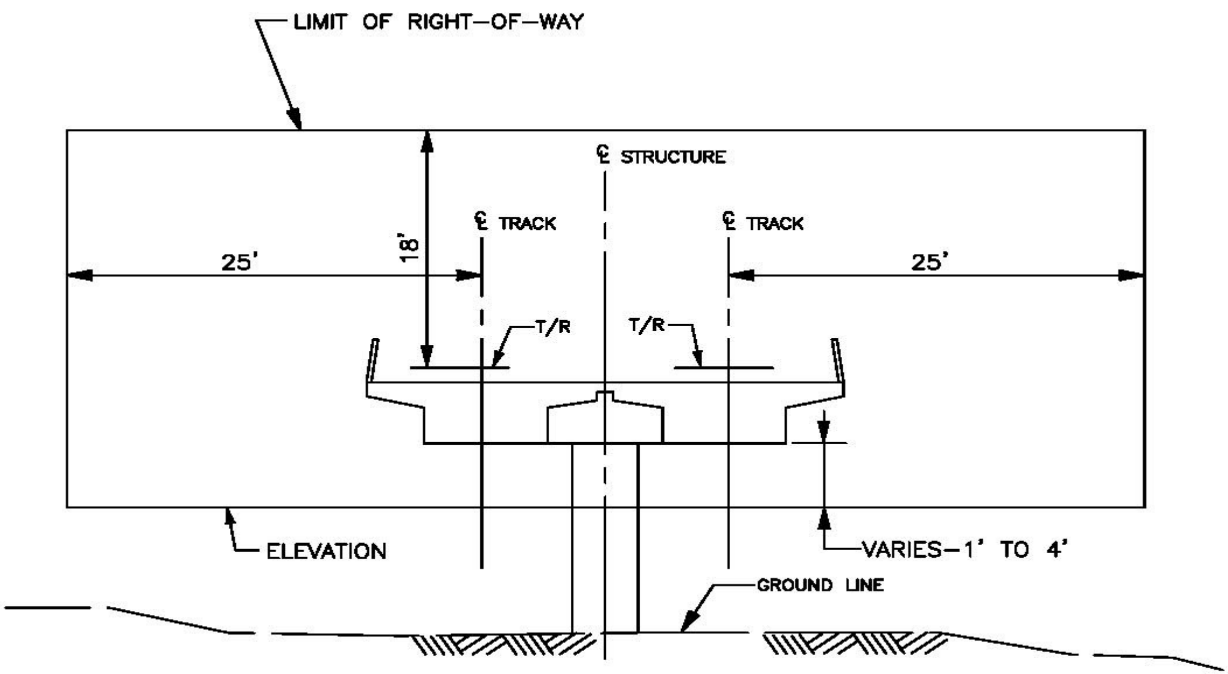


WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES

TYPICAL ROW
AERIAL-SINGLE TRACK

FIGURE 9.10



WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	TYPICAL ROW AERIAL–DOUBLE TRACK

FIGURE 9.11

SECTION 10 - (RESERVED FOR FUTURE USE)

SECTION 11 - CIVIL

11 .1 GENERAL

This section establishes the basic design criteria for geometrics, trackwork, and clearances for the Washington Rail Rapid Transit System. Determination of riding comfort relative to super elevation is based on the AREMA ride index scale. The index factor used in these criteria varies from 0.0, desirable, to a maximum of 1.5, as defined in the Proceedings of the American Railway Engineering Association Joint Committee Report, "Passenger Ride Comfort on Curved Track" published in the proceedings of the Fifty Fourth Annual Convention of the Area, Volume 56, 1955.

11.1.1 Minimum Criteria

The terms "Desirable Minimum", "Acceptable Minimum", and "Absolute Minimum" are used to denote WMATA order of preference for track alignment selections. Desirable Minimum" will be considered WMATA's preferred design limits.

1) "Acceptable Minimum" will be considered WMATA's design minimum when restrictions prevent the use of Desirable Minimum. The Basis of Design Report should highlight any locations where Acceptable Minimum design criteria have been used, but no specific WMATA approval is required.

2) "Absolute Minimum" represents the physical operating limits of the rail vehicle or other equipment. The Basis of Design Report shall highlight any use of Absolute Minimum design criteria and provide a detailed explanation of why it was not possible to use either the Acceptable Minimum or Desirable Minimum criteria. Any use of Absolute Minimum criterion is considered conditional until accepted in writing by WMATA.

3) The terms "Desirable Maximum", "Acceptable Maximum" and "Absolute Maximum" will appear in some locations within the following criteria and shall be interpreted as recited above for Minimum criteria.

11.2 SURVEY CONTROL

In 2009, WMATA adopted a Low Distortion Projection (LDP) Coordinate System in an attempt to have one coordinate system for use in a WMATA Enterprise GIS. All new projects beyond the 106 mile system shall use the WMATA 2009 LDP.

11.2.1 Horizontal Control

WMATA's Office of the Chief Engineer Infrastructure is responsible for selecting the appropriate base control for use in establishing all future WMATA control points to be used for design or construction purposes.

In general, all new horizontal control points established will be related to the new WMATA 2009 Low Distortion Projection (LDP) Coordinate System and North American Datum of 1983, as defined by the National Geodetic Survey. On all future projects horizontal control points shall be installed by the designer/contractor at a maximum spacing of 1000 feet and be inter-visible with adjacent control points. All horizontal control points shall have an elevation component.

Originally, project survey control points were established from U.S.C. & G.S. Triangulation Stations. In April, 1974, the National Geodetic Survey (formerly U.S.C. & G.S.) announced that all triangulation stations in the United States, except Washington, D. C., were read justed. Since there are significant changes in the final values, a note has been affixed to the final design plans stating, "The Grid Coordinates and Horizontal Control Values are based on U.S.C. & G.S. 1971 Field Geographic Positions and Coordinate Values." The geodetic reference system used initially by WMATA was North American Datum of 1927 (NAD27)and National Geodetic Vertical Datum of1929 (NGVD 29).Even though WMATA uses the aforementioned note on their Survey Control drawings, please remember that 1971 is the adjustment version of the NAD27 reference system with one exception. One small section of WMATA's mapping and control (A-14 to A-17) was based upon NAD27 1974 adjustment.

The original horizontal and vertical control for all 103 mile alignments has been based on survey control points established under the direction of WMATA as follows:

- Survey control points in the District of Columbia and Maryland and for part of the Huntington Route in Virginia are based on the Maryland State Plane Coordinate System (NAD27 / NGVD29), adjusted for scale and elevation to project grid, and herein referred to as WMATA Project Coordinates. The method for coordinate conversion from WMATA Project Coordinates (in DC and MD) to Maryland State Plane Coordinates (NAD27) is as follows: multiply the WMATA Project Coordinates (in DC and MD) by 0.9999430.

- Survey control points in the Commonwealth of Virginia, with the exception of part of the Huntington Route, were based on the Virginia State Plane System (NAD27 / NGVD29).

To convert WMATA Project Coordinates (in DC and MD) to Virginia State Plane Coordinates (NAD27), convert WMATA Project Coordinates to Maryland State Plane coordinates (NAD27), then convert Maryland State Plane Coordinates to geographical positions (latitude and longitude)as outlined in U.S. Department of Commerce Coast and Geodetic Survey

Manual of Plane Coordinate Projection Tables for Maryland, Special Publication No. 292, then, convert the geographical positions to Virginia State Plane Coordinates as shown in U.S. Department of Commerce Coast and Geodetic Survey Manual of Plane Coordinate Projection Tables for Virginia, Special Publication No. 293.

For a map showing the designation of various coordinate systems by Metro Route see Figure 11.1 entitled "Metrorail System Design Datums".

Traverses in the WMATA Project Coordinate system shall be connected to traverses in the Virginia state plane coordinate system as follows:

- Huntington (C) Route shall be connected to the existing Pentagon traverse as shown on Figure 11.2.
- Vienna (K) Route shall be connected to the existing Pentagon traverse as shown on Figure 11.3.
- The 3 mile Largo Extension of the Blue Line was based on Maryland State Plane Coordinate System (NAD83 / NGVD29).
- In 2002, the 23 mile Dulles Extension (Silver Line) consisting of Phase I and Phase
- II sections were assigned WMATA Project Coordinates that were based on Virginia State Plane Coordinate System (NAD83 (HARN) / NAVD88). The method for coordinate conversion from WMATA Project Coordinates (in VA) to Virginia State Plane Coordinates (NAD83) is as follows: multiply the WMATA Project Coordinates (in VA) by 0.9999537345.
- In 2010, the E Line test track between College Park and Greenbelt Metro Stations was moved to the WMATA 2009 Low Distortion Projection (LDP) with a geodetic datum of NAD 83 (NSRS2007) epoch 2002.00. The North American Vertical Datum of 1988 (NAVD 88) is specified as the vertical datum
- In 2012, Dulles Extension Phase II section was moved to the WMATA 2009 Low Distortion Projection (LDP) with a geodetic datum of NAD 83 (NA2011) epoch 2010.00. The North American Vertical Datum of 1988 (NAVD 88) is specified as the vertical datum, which is consistent with the original 2002 control.

11.2.2 Low Distortion Projection (LDP) Coordinate System Definition

The WMATA Coordinate System was designed such that linear distortion is minimized throughout the existing and proposed WMATA service area. The magnitude of linear distortion does not exceed 20 parts per million (0.1 foot per mile) along WMATA rail lines at the topographic surface of the Earth or in tunnels. Therefore actual "ground" distances measured between points will equal grid "maps" distances between the same points to within ±0.1 foot per mile everywhere within the WMATA system.

The approximate WMATA system hub was used for the WMATA Coordinate System central meridian. Although this essentially minimizes convergence angles for the existing WMATA system, it does not minimize convergence angles for proposed additions to the system.

Linear unit: U.S. survey foot (sft)

Note: 1 sft = 1200 / 3937 meter? 0.304 800 609 601 219 202 438 meter 1 sft = 1.000 002 international feet

Geometric reference system (geodetic datum): North American Datum of 1983 (NAD 83) 2009 Datum realization (datum tag): National Spatial Reference System of 2007 (NSRS2007)

Note: NSRS2007 was one of the recent realizations of NAD 83 and is based on the National Geodetic Survey (NGS) 2007 National Readjustment. This readjustment was constrained to the NGS Continuously Operating Reference System (CORS) network as defined at time 2002.00 (January 1, 2002), which is denoted as NAD 83 (CORS96). Therefore NAD 83 (2007) can be considered functionally equivalent to NAD 83 (CORS96) for the design area of the WMATA Coordinate System.

NAD 83 (2007) and NAD 83 (CORS96) are not equivalent to NAD 83 (HARN), the High Accuracy Reference Network realizations. This is also known as the High Precision Geodetic (or GPS) Network (HPGN) and has NGS datum tags of 1991 and 1993 in the WMATA Coordinate System design area. No datum transformations relating the 2007 and HARN realizations have been defined by the NGS. The difference between the 2007 and HARN coordinates is within about 2.5 feet (horizontally and vertically) for published NGS control in the WMATA Coordinate System design area, and the average difference is within about 0.1 foot. Because of this, for some applications NAD 83 (2007) can be considered approximately equal to the HARN realization. Nonetheless in all cases the actual realization should be documented in the metadata to ensure spatial consistency, particularly for high-accuracy (survey-grade) data.

2012 Datum realization (datum tag): National Adjustment of 2011 (NA2011) epoch 2010.00.

Map projection: Lambert Conformal Conic (single parallel)

Projection parameters (single parallel definition):

Standard parallel (latitude of grid origin):

38° 50' 00.00000" N (=+38.833 333 333 333 333…°)

Longitude of central meridian:

77° 02' 00.00000" W (= -77.033 333 333 333 333…°)

False northing (at grid origin):

150,000.000 sft (.45, 720.091 440 182 880… m)

False easting (at central meridian):

200,000.000 sft (.60, 960.121 920 243 840… m)

Standard parallel scale factor:

1.000 000 000 (exact)

Projection parameters (alternate generic double parallel definition):

Latitude of north standard parallel:

38° 50' 00.00000" N (= +38.833 333 333 333 333…°)

Latitude of south standard parallel:

38° 50' 00.00000" N (= +38.833 333 333 333 333…°)

Latitude of grid origin:

38° 50' 00.00000" N (= +38.833 333 333 333 333…°)

Longitude of central meridian:

77° 02' 00.00000" W (= -77.033 333 333 333 333…°)

False northing (at grid origin):

150,000.000 sft (= 45,720.091 440 182 880… m)

False easting (at central meridian):

200,000.000 sft (= 60,960.121 920 243 840… m)

Additional scale applied at grid origin:

1.000 000 000 (exact)

Note: The alternate "double parallel" definition is used in some software packages, such as ESRI products, rather than the single parallel definition. Both definitions yield identical results.

11.2.3 Vertical Control

For the original 103 mile system, WMATA established bench marks where tunnel construction was planned. The goal was to establish a minimum of one deep bench per half mile of vertical control to be used for construction. The relationship between U.S.C. & G.S. datum and the various datum planes common to the Washington Metropolitan area are as shown on Figure 11.4.

On all future tunnel and cut and cover projects deep bench marks shall be installed the designer/contractor at a maximum spacing of one half mile.

For the 103 mile system, in the District of Columbia, the vertical control is related to the U.S. Coast and Geodetic Survey Mean Sea Level Datum, 1929 General Adjustment (NGVD29). Refer to Figure 11.4 for the relationship between District of Columbia and WMATA vertical datum.

For the 103 mile system and the Largo extension, Virginia and Maryland benchmarks for the lines in Virginia and Maryland will be based upon the U.S. Coast and Geodetic Survey Mean Sea Level Datum, 1929 General Adjustment (NGVD29) unless otherwise noted.

For beyond the 106 mile system, in all jurisdictions all vertical control shall be based on North American Vertical Datum of 1988 (NAVD88) is the vertical control datum of or thometric height established for vertical control surveying in the United States of America based upon the General Adjustment of the North American Datum of 1988.

11.2.4 Horizontal and Vertical Control Adjustments

All new control shall conform to the latest version of Standards and Specifications for Geodetic Control Networks published by the Federal Geodetic Control Committee.

Horizontal closures for control traverses shall have a relative accuracy ratio of not less than 1:100,000 (distance accuracy standard) if using GPS.

Secondary control traverses used to establish centerline geometry shall have a relative accuracy ratio of not less than 1:50,000.

Computations for all control (horizontal and vertical) are required to be prepared under the direction of a professional land surveyor registered in the appropriate jurisdiction and sealed prior to submission to WMATA. Computations will show results in the U.S. survey foot. All adjustments shall be done using a minimally constrained least square adjustment program.

WMATA vertical control for primary and secondary control traverses are established to FGCC Second-Order, Class I and Class II accuracy standards

11.3 DESIGN PROCEDURES FOR ALIGNMENT

Development of alignment for a rail corridor is a procedure of successive refinements. The location of new alignments is often dependent on the availability of a corridor for the proposed alignment or the need to locate a station at a particular location for access or concentration of population. Planning the location of the centerline in the proposed alignment is the initial step in the design process.

When the general location of the alignment is decided and topography is available for vertical alignment, the tangents representing the track centerline are laid out. Assume a curve avoiding physical restrictions between tangents. Avoid cemeteries, schools, parks, wetlands and other sensitive areas. The first assumptions should be made as follows:

Layout the centerline tangents. Keep the central angle of the curve as small as possible. Assume a design speed of 75 miles per hour.

Calculate the minimum radius for a curve for a design speed of 75 miles per hour. Use spiral lengths of 300 feet for at-grade or aerial structures and 200 feet for tunnels or cut and cover structures as a point of beginning.

Calculate minimum spiral, curve and super elevation. Compare super elevation with comfort levels and re-calculate as necessary.

Reduce design speed if necessary, and recalculate allowable.

Check alignment clearances of tunnel, at grade or aerial cross section.

Reduce R and V to obtain clearances as required.

Redefine the calculations as required.

List and justify criteria deviations.

11.4 HORIZONTAL ALIGNMENT

The main line horizontal alignment will consist of tangents joined to circular curves by spiral transition curves. All curves on the main line tracks will use spirals for entering and exiting the curve.

Curvature and super elevation shall be related to design speed, considering the acceleration and deceleration characteristics of the design vehicle as presented in Section 8 of this Manual. Every attempt shall be made to maintain a minimum design speed of 40 miles per hour. Wherever possible, the geometrics shall accommodate the maximum design speed up to 75 miles per hour, considering the locations of curves, station stop spacings, and the performance characteristics of the design vehicle. The maximum design speed shall not be limited to the available speed settings. Design speeds other than available speed settings may be used to allow for acceleration and deceleration through curves.

Coordination of horizontal and vertical alignment shall avoid a combination of minimum radius and maximum grade.

All routes shall be stationed radially from reference points; 0+00 at Metro Center Station for the Red, Blue, Orange and Silver lines; and 0+00 on 7th Street, N.W., at Gallery Place Station for the Green and Yellow lines. Stationing for routes originating at junction points shall be equated to the base route stationing at the junction points.

Stationing and geometrics shall generally be denoted for the centerline of the outbound track; however, independent track stationing and geometrics shall be required in the following cases:

Where widened track centers are required for clearance requirements,

When tracks are not concentric or parallel, or

When the inbound and outbound tracks are in separate structures.

11.4.1 Drawing Format and Track Designations

The outbound and inbound vertical alignment must be defined on the profile drawings. Where both inbound and outbound alignments are parallel, the Outbound T/R should be drawn.

Label the Top of Rail as "OB T/R ONLY" (Outbound Top of Rail ONLY) or "OB AND IB T/R," (Outbound and Inbound Top of Rail) as applicable. Show vertical curve data (PVI, PVC, PVT, STA., Elev., and LVC) for both IB and OB tracks. The profile grade should be shown for both IB and OB. For example: “4.00% IB AND OB” or “4.00% OB, 3.87% IB.”

The locations of station equations should be in the following format:

Apply a station equation at the point where non-parallel tracks become parallel. Locate station equations at an ST, either IB or OB, opposite a POT on the adjacent track.

The OB stationing should, in general, be continuous. The station equation should be of the form:

STA XXX IB BACK =

STA XXX OB & IB AHD

Under special circumstances, it could be of the form:

STA XXX IB BACK =

STA XXX OB BACK =

STA XXX OB & IB AHD

The maximum horizontal limits of the design vehicle dynamic outline as it moves through the standard WMATA crossovers at the various design track centers is shown on Figures 11.73 through 11.77

11.4.2 Accuracy of Data

Calculate and define horizontal alignment and curve data to the following accuracy:

- Coordinates: 4 decimal places
- Stationing: 2 decimal places
- Curve and Spiral Elements: 4 decimal places
- Angles and Bearings: Nearest second with 2 decimal places

11.4.3 Tangent Lengths

The desirable minimum tangent length shall be 200 feet. In special circumstances the minimum tangent shall be 75 feet. At rapid transit stations the horizontal alignment shall be tangent throughout the 600-foot platform length; the tangent shall extend a minimum distance of 65 feet beyond each end of the station platform for a total tangent of 730'. Deviation from these lengths shall require approval by WMATA.

Within crossover tracks, the minimum tangent length may be less than 75 feet.

Where the tangent distance between curves in the same direction is less than the minimum, the tangent will be replaced with either a transition spiral or a compound curve segment connecting the adjoining curves to eliminate the broken back curve configuration.

11.4.4 Track Survey of Existing Conditions

A Top of Rail Survey for all existing tracks shall include the following information as a minimum:

- Horizontal location of the centerline of track shall be obtained every50 feet along tangent track and 25 feet along curved track.
- The top of rail survey shall be performed at the same stations used to locate the centerline of track.
- The rail survey shall also include the locations of point of switches, point of frogs and all other appurtenances such as switch machines, rail lubricators, restraining rail, emergency guard rail, insulated joints, derails, etc.
- Transition point between Ballasted Construction and Direct Fixation Fastener Construction

11.5 CURVATURE

11.5.1 Circular Curves

Circular curves shall be defined by the arc definition of curvature, and specified by their radii. The length of curve is defined by the equation:

Equation 11.5.1.1 $L = 100 * \Delta / D$

Where: L = Length of curve, feet

Δ = Central angle of curve, degrees

D = Degree of curvature, degrees

For mainline running track the minimum desirable radius of circular curves is 1000 feet. The absolute minimum radius of circular curves in mainline track is 755 feet.

The absolute minimum radius of curvature for yard and secondary track is 300 feet.

The desirable minimum length of circular curve is 100 feet. However, if physical conditions prohibit this minimum curve length and is approved by WMATA , circular curve length may be less than 100 feet but should be kept as long as possible.

Refer to Figure 11.5 for circular curve functions and abbreviations.

11.5.2 Spiral Transition Curves

Spiral transition curves shall be used to connect all circular curves and tangents, except in yard and secondary track. The spiral used shall be the Barnett spiral. Spiral curve functions and abbreviations are shown on Figure 11.6.

The minimum length of spiral shall be the greater of the lengths as determined by the following three formulae:

11.5.2.1 Vertical Frame Twist

Track twist is defined as the allowable rate at which actual super elevation (Ea) is introduced and removed along the given length of spiral to avoid over stressing the vehicle frame thru twisting and also to prevent any excessive rocking forces that may be created. The maximum ratio of super elevation change across 52-ft truck centers is 1:624 as in one inch of twist in 624 inches of track length for ballasted track forms and direct fixation track forms.

The minimum length of spiral is calculated by the following formula:

11.5.2.1.1 $L_s = 50 * E_a$

Where: L_s = Minimum length of spiral, feet

E_a = Actual super elevation of rail, inches

11.5.2.2 Jerk Rate

Jerk rate is defined as the rate of change of lateral acceleration with respect to time that is not balanced by actual super elevation (Ea) through a spiral transition and is expressed in g/second, where g is a measure of apparent gravity caused by acceleration.

The maximum jerk limit is established based on a passenger comfort level in which the change in the rate of acceleration (g/sec) from zero to 0.10 g should not exceed the following:

- Desirable Maximum: 0.03 g/sec
- Acceptable Maximum: 0.04 g/sec
- Absolute Maximum: 0.05 g/sec

The jerk rate should be half the above values in reverse curve situations.

The Acceptable Minimum length of spiral is calculated by the following formula with a lateral acceleration of 0.1g, an acceptable maximum jerk rate of 0.04g/sec and a maximum E_u of 3.0 inches:

11.5.2.2.1 $L_s = 1.22 * E_u * V$

Where L_s = Minimum length of spiral, feet

E_u = Unbalanced super elevation on curve, inches

Unbalanced super elevation is defined as the difference between the equilibrium super elevation, E_{bal}, and the actual super elevation, E_a.

V = Design velocity at the circular curve, mph.

11.5.2.3 Absolute Minimum Spiral Length

11.5.2.3.1 $L_s = 100' minimum$

Where geometric conditions are extremely restricted, the spiral length may be reduced to an Absolute Minimum of 100 feet. In both cases, train speed must be controlled to limit jerk to no greater than the absolute maximum of 0.05g/s. As with all absolute criteria, the reason for using Absolute Minimum lengths must be fully explained and is subject to acceptance by WMATA.

The relationship between super elevation and spiral length is shown on Figure 11.7.

11.5.3 Compound Curves

If adjacent curves in the same direction are in close proximity to one another and cannot be replaced by a single simple curve due to geometric constraints, a series of compound curves shall be the preferred arrangement. Broken back curves (i.e., short tangents between curves in the same direction) shall be avoided.

Where compound circular curves are required, a spiral of sufficient length to satisfy the requirements of Spiral Transition Curves, shall be inserted between the circular curves. The controlling formulae for Spiral Transition Curves shall apply, modified as follows:

11.5.3.1 Vehicle Frame Twist

11.5.3.1.1 $L_s = 50 * (E_{a_2} - E_{a_1})$

Where: L_s = Minimum length of spiral, feet

E_{a1} = Actual super elevation of rail on the first circular curve, inches.

E_{a2} =Actual super elevation of rail on the second circular curve, inches.

11.5.3.2 Jerk Rate

11.5.3.2.1 $L_s = 1.22 * (E_{u2} - E_{u1}) * V$

Where: L_s = Minimum length of spiral, feet

E_{u1} = Unbalanced superelevation on the first circular curve, inches. E_{u2} =Unbalanced superelevation on the second circularcurve,inches. V = Design velocity at the circular curves, mph.

11.5.3.3 Absolute Minimum Spiral Length

11.5.3.3.1 $L_s = 100'$ *minimum*

Where geometric conditions are extremely restricted, the spiral length maybe reduced to an Absolute Minimum of 100 feet. In both cases, train speed must be controlled to limit jerk to no greater than the absolute maximum of 0.05g/s. As with all absolute criteria, the reason for using Absolute Minimum lengths must be fully explained and is subject to acceptance by WMATA.

11.5.4 Point of Reverse Curves

Where corridor constraints restrict the horizontal alignment so that the minimum tangent length between reverse curves cannot be provided, the curves may meet at a point of reverse spiral subject to approval from WMATA.

The point of reverse spiral will be established based on the following relationship:

11.5.4.1 $$L_{s1} * E_{a_2} = L_{s_2} * E_{a_1}$$

Where: L_{s1} = Length of spiral leaving first curve (feet)

L_{s2} = Length of spiral entering second curve (feet)

E_{a1} = Applied super elevation of first curve (inches)

E_{a2} = Applied super elevation of second curve (inches)

A maximum tangent of 3 feet separating the reverse curves is acceptable in lieu of meeting at a point. This allowable gap between spirals is dependent upon the actual dimensions and design characteristics of the vehicle.

Where track twist is doubled at back-to-back spirals, the spiral lengths should be doubled. A Desirable Maximum value of twist should be 1:500 as in one inch of E_a in 500 inches of track length.

Reverse curves with no intervening tangent will only be allowed if the two spirals have the same or nearly the same jerk rate and the jerk rate is 0.03g/sec or less. This condition would be considered the Acceptable Minimum. The Preferred condition would require an intervening tangent. The Absolute Minimum condition for a Point of Reverse Spiral would allow jerk to be 0.04g/sec.

11.5.5 Double Reverse Curves

Double reverse curves shall not be used in the system unless each circular curve segment complies with the 3V criterion for curve length and each spiral limits jerk to 0.04g/sec.

11.6 SUPERELEVATION

11.6.1 Method of Attaining Superelevation

Superelevation will be attained and removed linearly throughout the full length of the spiral transition curve, by raising the rail farthest from the curve center while maintaining the top of the inside rail at the profile grade. The superelevation will be maintained as a constant throughout the circular curve between the two spiral transitions.

11.6.2 Balanced Superelevation

Balanced or equilibrium superelevation is defined as the state of the rail car in motion along a curved track such that the downward force perpendicular to the floor of the car, acts through the car center of gravity and the passengers feel no centrifugal force. When the force through the car center of gravity is not perpendicular to the floor of the rail car then the total superelevation E_{bal} necessary to bring the car into equilibrium and the downward force perpendicular to the car floor is the sum of the actual and the unbalanced superelevation.

Balanced superelevation shall be determined byeither of the following equations:

11.6.2.1 $E_{bal} = 4.011 * V^2/R$

11.6.2.2 $E_{bal} = 0.0007 * V^2 * D$

Where: E_{bal} = Balanced or equilibrium superelevation

V = Design speed through the curve in mph

R = Radius of curve in feet

D = Degree of curve in degrees (arc definition)

11.6.3 Unbalanced Superelevation

Unbalanced superelevation is defined as the deficiency of superelevation when a vehicle operates on a curve above equilibrium speed. It is expressed in inches and is directly related to centrifugal force acting on the vehicle and passengers. The unbalanced superelevation also allows the cars to transit the curve at a higher design speed.

The length of spiral should be such that the introduction of actual superelevation and unbalanced superelevation on the track will not be uncomfortable to passengers. With average roll tendency of rail cars operated on the track, the rate of change of the unbalanced lateral acceleration should not exceed 0.04 g per sec. Therefore, only a portion of the calculated equilibrium superelevation Ebal and the actual superelevation Ea, shall be designed for and installed in the track. The difference between the equilibrium superelevation and the actual superelevation is called the unbalance, and is designated as E_u

11.6.3.1 $E_a = E_{bal} - E_u$ (4.011 - V^2 /R) - E_u

Where: E_u = Unbalanced superelevation, inches.

E_a = Actual superelevation, inches.

E_{bal} = Balanced or equilibrium superelevation

No superelevation unbalance is applied until actual superelevation (E_a) reaches the maximum allowable level. Actual superelevation is thus equal to the equilibrium superelevation for most curves. Under ideal conditions, where all vehicles operate at the same maximum speed and do not stop (or slow down) on curves, this strategy creates the least amount of passenger and vehicle lateral acceleration for a given transition curve length.

Unbalanced superelevation shall vary from 0 inches (desirable) to 4 ½" inches (maximum) in the following manner:

For E_a = 4 inches maximum, the unbalanced superelevation, E_u, shall equal 0 inches until E_a = 4 inches is reached. Actual super elevation, E_a, will then be maintained at 4 inches until the total E_a+ E_u is equal to 8 ½inches. At this point, a limit is placed on design speed of operation.

For E_a = 6 inches maximum, the unbalanced superelevation, E_u, shall equal 0 inches until E_a = 6 inches is reached. Actual superelevation, E_a, will then be maintained at 6 inches until the total E_a+ E_u is equal to 10 ½inches. At this point, a limit is placed on design speed of operation.

Introduction of unbalanced superelevation before E_a maximum is achieved shall require approval of WMATA.

Calculated values of actual superelevation, E_a, shall be rounded to the nearest one-quarter inch. For a calculated superelevation of ½ inch or less, no superelevation need be applied.
Yard and secondary track will be superelevated in accordance with the Yard & Shop Criteria, Section 17.

11.6.4 Maximum Superelevation - E_a

The maximum actual superelevation for curves in the system shall be as follows:

E_a = 4 inches. E_a = 6 inches.

For curves in tunnels or in cut and cover structures, For curves at grade or on elevated structures,

11.6.5 Amount of Superelevation

Superelevation shall be determined by the formula:

11.6.5.1 $E_a = (0.0007 * V^2 * D) - E_u$

Where: E_a = Actual superelevation, inches.

When E_u = 0, then Ea = equilibrium or balanced superelevation.

V = Velocity, mph.

D = Degree of curve, degrees.

E_u = Unbalanced superelevation, inches.

Expressed in terms of radius of curvature, this becomes:

11.6.5.2 $E_a = (4.011 * V^2/R) - E_u$

Where E_a, E_u and V are as above, and

R = Radius of circular curve, feet

The relationship between superelevation, degree of curve and design speed is shown on Figure 11.8.

11.7 VERTICAL ALIGNMENT

Profile grade shall represent the elevation of the top of low rail. When only one track profile is given for curved alignment, the profile of the second track shall be adjusted uniformly to accommodate the difference in length through the curve.

11.7.1 Mainline Grades

The desirable maximum for mainline running track shall be 4.0 percent. In exceptional circumstances, such as split-level junctions and other isolated cases, the maximum grade may be increased to 5.0 percent, on downgrades only. The minimum grade in underground and aerial structures shall be 0.35 percent to accommodate drainage runoff. Except at stations, there is no minimum grade for at-grade construction; in this case drainage ditches shall be sloped as necessary to accommodate runoff. A desirable grade of 0.35 percent shall be held through underground and aerial stations. Any constant grade from 0.35 percent to 0.20 percent is acceptable for at-grade stations. Under exceptional circumstances, grades through stations may be increased with approval of WMATA and the General Consultants.

11.7.2 Yard and Secondary Track Areas

In yard and secondary tracks, the maximum grade shall be 1.0 percent. The minimum desirable grade shall be 0.20 percent to achieve good track drainage at the subballast level. For storage tracks, desirable grade shall be 0.20 percent, except at tracks adjacent to stations, where a 0.35% grade is preferable.

Additional requirements for Yards can be found in Section 17.3.

11.7.3 Miscellaneous

Permanent stub end tracks should be sloped away (down) from the turnout using gravity to insure that the transit vehicle remains at rest in the stub track. For the same reason, through storage tracks or sidings, should have a sag in their profiles, if possible.

11.7.4 Vertical Curvature

All changes in grades shall be connected by parabolic vertical curves. The minimum length of vertical curve shall be determined by the formula:

$$L = (G_1 - G_2) * 100$$

Where: L = Length of vertical curve, feet

$(G_1 - G_2)$ Algebraic difference of grades connected by the vertical curve, percent.

The designer should be liberal when establishing length of vertical curve, allowing up to twice the minimum if possible.

The absolute minimum length of vertical curve shall be 200 feet.

11.7.5 Minimum Length of Grade

The desirable minimum length of constant profile grade between vertical curves shall be 100 feet. Compound vertical curves are preferable to broken-back curves provided all other criteria are met.

11.7.6 Compensation

No compensation of grades is required for horizontal curvature.

11.8 TRACKWORK

Metro track materials and special trackwork shall comply with the Design Drawings, Design Criteria and Standard Drawings of WMATA which are based on the current American Railway Engineering and Maintenance-of-Way Association (AREMA) "Manual for Railway Engineering" and “Portfolio of Trackwork Plans”.

Railroad trackwork shall comply with current plans and specifications.

11.8.1 Direct Fixation Track Fastening

Running track and special trackwork shall be fastened directly to the concrete trackbed of underground and non-ballasted aerial structures. Second-pour plinth concrete (top-down) construction may be used as an alternative where physical clearances permit use of this installation.

Special trackwork throughout the system shall be fabricated and installed on special steel base plates. In the underground and non-ballasted aerial portions of the system, these base plates shall be installed on elastomer pads to reduce the transmission of noise and vibrations. The rail fasteners required beyond the limits of the steel base plates in the special trackwork units shall be the same basic rail fastener used in running track construction.

11.8.2 Gauge

Metrorail track gauge for wood tie track shall comply with Table 11.1:

TABLE 11.1

	Track Gauge	
HORIZONTAL TRACK ALIGNMENT	Main Tracks	Yard and Secondary Tracks
Tangent Track	4'-8 1/4"	4'-8 ½"
Curve of Radius $1425'	4'-8 1/4"	4'-8 ½"
Curve of Radius between 1425' and 350'	4'-8 ½"	4'-8 ½"
Curve of Radius <350'	N/A	4'-9"
Curve of Radius <350' with restraining rail	N/A	4'-9 1/4"

These gauges apply only with standard AAR wheel Gages of 4'-7 11/16" and vehicle axle spacing of 7'-0" and 8'-6" inclusive.

For concrete tie installation, track gauge shall conform to Table 11.1, except that main track tangent alignment and curves above 350' radius shall have 4'-81/2" gauge.

For every 1/4" change in track gauge, the transition in gauge shall be made in a length of track not less than 31" nor more than 62".

Basic track gauge for special trackwork shall conform to WMATA Standard Trackwork Plans.

11.8.3 Rail

Running rail shall be 115 RE section, welded in continuous lengths, with insulated joints at interlocking locations. All main track rail shall conform to the sections below confirming to in-line head hardened running rail,in accordance with AREMA specifications.

11.8.3.1 High Strength (Head Hardened) Rail

Head hardened rails shall conform to AREMA specifications for head hardened (high strength) running rail, in accordance with WMATA Design Drawings and Standard Drawings.

11.8.3.2 Standard Rail

Control cooled rail conforming to AREMA specifications shall be used in yard and storage tracks, except at turnouts where head hardened rail shall be used.

11.8.4 Ballast

Ballastis a selected crushed and graded hard aggregate material placed upon the sub-ballast to provide support for distributing the track load to the subgrade. AREMA states that the depth of ballast (plus sub-ballast) must be sufficient to distribute pressure between the underside of the crosstie and the top of the subgrade without over stressing the latter.

The prime functions of the ballast are to drain the track system, distribute the rail vehicle loads to the subgrade.

11.8.5 Special Trackwork

11.8.5.1 General

The WMATA system contains two types of specific special trackwork: direct fixation and ballasted special trackwork for the mainline and ballasted special trackwork for yard and secondary tracks. Turnout designs shall meet the requirements of the AREMA Portfolio of Standard Plans, where applicable, except as modified herein.

The preferred frog numbers shall be No. 6 and No. 8 in the yard, with No.

10, and No. 15 turnouts along the mainline tracks. The special trackwork shall be developed as single turnouts, single crossovers, and double crossover arrangements.

Solid manganese frogs shall have tangent geometry for No. 6, 8, 10, and 15 turnouts. In the event that other unique special trackwork designs must be developed to address site-specific conditions, the trackwork shall be designed to use standard switch point rails, stock rails, frogs, and guard rails wherever practicable to minimize inventory.

11.8.5.2 Crossovers and Trunouts

Crossovers and turnouts shall be located on horizontal and vertical tangent track. Location of turnouts on horizontal curves without superelevation is possible in special cases with approval of WMATA.

Crossovers are to be located to allow emergency single track operations on either track, in both directions, with a sustained 10-minute headway in each direction, where economically practical. Crossovers shall be located at the first station beyond a diverging route.

Double crossovers shall be used in the underground and non-ballasted aerial portions of the system to reduce the overall length of special structure. Double crossovers shall be located on parallel tracks only. Single crossovers shall be used in the at-grade portion of the system unless space limitations are prohibitive. Special trackwork shall not be located within 200 feet of a transition between direct fixation and ballasted track construction. The desired tangent length between a point of switch and the end of a station platform shall be 80 feet. The location of special trackwork requires coordination with train control equipment requirements and transit system operations criteria.

The minimum horizontal and vertical tangent distance preceding a point of switch shall be 40 feet on ballasted track or 10 feet on direct fixation track.

The placement of special trackwork on non-ballasted aerial structures shall be avoided wherever possible in order to eliminate a costly special design of the structure and track. The special design would be required to prevent misalignment of the special trackwork due to the thermal stresses in the aerial structure and track.

The switch unit is to be located where there is minimum relative movement between rail and structure (see Section 15.5.1.2.10, Rail/Structure Interaction Force). The special steel base plates for frogs and diamonds should be designed to accept relative movement between rail and structure while minimizing the interaction force.

11.8.6 Maximum Speeds

The maximum speeds for the design vehicle through the various turnouts designated for use on Metro are shown on Table 11.2. For design purposes, the normal operating speed shall be used.

TABLE 11.2					
OPERATING SPEEDS THROUGH TURNOUTS					
Turnout Number	Switch Rail Length	Switch Type	Speed Through Turnout-MPH		
			Normal Operating Speed[1]	Maximum Operating Speed (Eu = 4.5")	Critical Speed (Eu = 6")
6 (Old MOW[2]Track Standard)	11'-0"	Straight	15	17.2	19.8
6 Guarded (Yard Storage Tracks)	16'-6"	Curved	15	17.9	20.6
6 Equilateral Guarded (Storage Turnaround Tracks)	16'-6"	Curved	22	25.3	29.2
8 (MOW Tracks)	16'-6"	Straight	22	22.8	26.3

[1]The normal operating speed in Table 11.2 is the nearest Automatic Train Control (ATC) speed command below the maximum operating speed. The maximum operating speed is based upon the value of unbalanced superelevation equal to 4 ½inches and is determined using the lead radius and the switch radius or theoretical switch radius with the most restrictive speed governing. The critical speed is based upon the unbalanced superelevation being equal to six (6") inches and is the safe maximum speed.

[2]MOW stands for Maintenance-of-Way

8 Guarded	26'-0"	Curved	22	23.9	27.6
10	22'-0"	Curved	28	30.2	34.9
15	26'-0"	Curved	40	46.3	53.5

11.8.7 Standard Turnout and Crossovers

Special trackwork shall comply with the criteria and WMATA Standard Drawings:

Center storage (pocket) tracks on underground and non-ballasted aerial structures: No. 6 guarded equilateral turnouts.

Center storage tracks at-grade: No. 8 guarded curved switch.

Yards: No. 8 guarded preferred, No. 6 guarded turnouts where approved by WMATA. Crossovers shall be No. 10 turrnouts.

Main track emergency crossovers and yard and secondary track connections to main track: Guarded No. 8 or No. 10 turnouts.

Permanent turnback crossovers located near the end of a station platform: No.10 turnouts.

Junction of main line routes: No. 15 turnouts.

11.8.8 Special Trackwork Limiting Factors

Limiting factors to be considered in designing the horizontal and vertical alignment adjacent to special trackwork units are:

Table 11.3

Turnout No.	Type of Track Construction	**Minimum Length of Turnouts** Absolute Minimum from Point of Switch to *T.S. or P.C.	Distance from Point of Switch to *P.V.C.	Minimum Distance from Point of Switch to the End of Turnout Unit and TS or Point of Curve
6 Eql. Guarded	Direct Fixation	57'	57'	70'
6 Eql. Guarded	Ballasted	57'	71'	71'
6	Ballasted	57'	71'	71'
6 Guarded	Ballasted	70'	82'	82'
8	Direct Fixation	81'	81'	87'
8	Ballasted	81'	98'	98'
8 Guarded	Direct Fixation	81'	81'	91'
8 Guarded	Ballasted	94'	110'	110'
10	Direct Fixation	97'	97'	102'
10	Ballasted	97'	116'	116'
15	Direct Fixation	140'	140'	147'
15	Ballasted	140'	165'	165'

* These are the absolute minimum values that may be used. The desired minimum values are those listed in the "End of Turnout Units" column. Absolute minimum values shall be used only with prior approval of WMATA.

The limits of any design or construction contract shall not be located within a special trackwork unit.

11.9 CONTACT RAIL

Contact (third) rail shall consist of composite steel rail and aluminum fishplate cladding as shown in the Design Drawings.

The Contact Rail End Approach is defined as the vertical transition at each end of the contact rail to allow for smooth shoe contact of the third rail. End approach rails come in several lengths.

During design the location of the third rail in the relation to the turnout is controlled by the separation distances required between the point of switch of adjacent switches. Various combinations of switches and their directions in relation to each other are shown in Figures 11.22through 11.27. These tables provide the distances between point of switch A and point of switch B.

The contact rail end approaches shall be used as follows: 11'-0" end approaches on mainline track; 5'-6" end approaches on yard and secondary tracks and storage tracks; 3'-0" end approaches on kicker rail on No. 8 double crossovers at 14'-0" track centers. See Design Drawings for typical details of the composite rail end approaches.

The location of the third rail shall be opposite the safety walk, opposite station platforms including access to service rooms off the platform, and opposite personnel access points.

11.10 ADDITIONAL TRACKWORK - Ties, Derails, Bumping Posts

11.10.1 Derails

Derails shall be installed on yard and secondary track normally used for the storage of unattended vehicles if this track is directly connected to the main track and its prevailing grade is descending to the main track.

Derails shall be located as follows:

At the downgrade end of the yard and secondary track, to derail equipment

away from the main track, if possible, and To derail equipment away from

the contact rail.

The location of derails in relation to turnouts shall be as shown on Figure 11.18 to Figure 11.20 and shall be coordinated with WMATA.

11.10.2 Tie Spacing

Concrete ties will be used for new construction in ballasted track. Either wood or concrete ties will be used in ballasted track for replacement ties to match existing tie conditions. Wood ties shall be spaced 27 inches center-to-centerin main track and 30 inches center-to-center in yard and secondary track. Concrete ties shall be spaced 30 inches center-to-centerin main track and 33 inches center-to-center in yard and secondary track. Yard and secondary tracks which are used at speeds greater than 15 mph shall use mainline tie spacing. Yard and secondary tracks with radii less than 350 feet shall use 24 inch tie spacing. Only wood ties shall be used in ballasted special trackwork units and they shall be spaced in accordance with the trackwork Standard Drawings. Except in special trackwork units, every fourth tie shall be a contact rail tie.

11.10.3 Direct Fixation Rail Fastener Spacing

Concrete trackbed reinforcing steel shall be designed to provide the anchorage clearance envelopes shown on the Design Drawings and in such manner as to permit the following direct fixation rail fastener spacing:

30 inches in main track

33 inches in yard and secondary track

11.10.4 Bumping Posts

A bumping post shall be installed at the end of each stub end track. The minimum distance between the face of bumping post when un-compressed and the end of track shall be 14'-6".

11.10.5 Approach Slabs

An approach slab shall be provided at all transitions between direct fixation and ballasted track construction.

At the mainline track transitions, where the track types change, matching the vertical fastener stiffness of direct fixation track to the track modulus and rail deflection behavior of at-grade ballasted track must be considered.

11.10.6 Emergency Guard Rail

Emergency guard rail shall be installed on all main track ballasted bridges and direct fixation aerial structures. The designer must investigate the need for emergency guard rail along retained fill and steep embankment sections. On all single track structures, two emergency guard rails shall be installed, one inside of each running rail.

Emergency guard rail shall be fabricated from 6 inch x 6 inch x ¾ inch structural angle and installed with the outside face of the vertical leg 15 inches from the gauge line of the running rail. The horizontal leg shall extend toward the center of the track. The 16 foot long end approaches shall be fabricated from the same size structural angle. The end approach shall be installed with the one end at the center of the track and the other at a point 15 inches from the gauge line of the running rail and shall be welded to the emergency guard rail. Emergency guard rail shall be continuously welded except for expansion gaps where required. A minimum of two gaps per guard rail are required. Expansion Gaps in ballasted track shall be not more than 100 feet apart.

On multiple track structures where tracks are supported on the same deck or on separate decks having less than 4½ inches opening between decks, each exterior track shall have one guard rail installed to the inside of the running rail farthest from the edge of the structure. On multiple track structures where tracks are supported on separate decks having 4½ inches or more opening between decks, each track shall have two guard rails, one rail to the inside of each running rail.

No emergency guard rail shall be installed within the limits of special trackwork.

Emergency guard rail must remain continuous where required. No portion of the emergency guard rail shall be cut or removed to accommodate equipment requirements unless WMATA has approved the proposed alternative measures to maintain an equivalent continuous configuration. Complete coordination with all affected disciplines is required.

Emergency guard rails shall extend 60 feet ahead of the abutment face on the approach end and 26 feet beyond the abutment face on the departure end of each structure. The above lengths do not include the emergency guard rail end approach sections which shall be 16 feet long at each end of every emergency guard rail installation.

Emergency guard rail shall be fastened to every second tie in ballasted track. In direct fixation track the guard rail anchorages shall be not more than 5 feet on centers.

11.10.7 Restraining Rail

Restraining rail shall be installed on all main track with curves of radius less than 800 feet, and on yard and storage tracks with curves of radius less than 500 feet. It shall consistof132 RE jointed rail mounted vertically with spacer blocks with the top of the restraining rail no more than 3/4 inch above the top of the plane of running rails. The base of the restraining rail shall be planed and the fasteners and joints designed so that no portion of the installation extends more than 8-7/16 inches above the base of the running rail. The flange way between the restraining rail and the running rail shall be 1- 7/8 inches wide and not less than 1-7/8 inches deep. The restraining rail separator block assemblies shall be adjustable laterally to compensate for rail wear. Restraining rail separator blocks shall be spaced not more than 5 feet on centers.

Mainline curves with restraining rail, outside of special trackwork zones, will require restraining rail lubrication including applicators and sensors.

11.10.8 Constructibility and Maintainability of Trackwork

All trackwork design shall be performed with the objective of obtaining an optimum degree of constructibility and maintainability. Alternative analyses of major cost items of trackwork shall be made using life cycle and other analytic procedures which address the following principles:

Selection of materials, configurations, and tolerances (manufacturing and construction) shall be based on lowest life cycle cost which meets the level of quality established by Metro standards, good engineering practice, and the level of service intended, with consideration of constructability and maintainability. Key components shall be standardized to provide interchangeability and reduce maintenance stockpiles.

Constructibility shall be considered from initial design development to final detailing. Packaging and scheduling of trackwork procurement and installation contracts shall seek to minimize brokering, periods of inactivity, excessive storage time, re-handling of materials, and interference with other contractors. Installation contracts shall be staged to maximize trackbed availability, access, and continuity of work. Special consideration should be given to handling of continuous welded rail. Contractors should be provided with convenient, adequate staging and storage sites. Selection of materials and configuration of materials should give consideration to the site conditions, and contractor's skill levels and plant capacity for their affect on the ease of handling and installing materials and the tolerances to be met.

Maintainability encompasses the selection of materials and configurations that result in highly durable, easily accessible and easily repaired or replaced components and systems. Durability is achieved by materials which resist wear, fatigue and deterioration due to environmental conditions. Accessibility is achieved by configuring materials, particularly fasteners, and clearances to permit inspection, adjustment, repair and replacement with minimum disturbance to other components. Maximum accessibility should be provided to these components requiring most frequent maintenance. Repair ability is achieved by providing materials and configurations which require minimum quality control effort in the field to inspect, adjust, repair or replace by avoiding complex sequences of steps to mix, place, cure, tighten, finish, or adjust and which require minimum tolerance to be acceptable.

Where a conflict between constructibility and maintainability occurs, preference shall be given to maintainability. Within maintainability, preference shall be given to durability over accessibility and repair ability.

11.11 CLEARANCES

Clearances between obstructions and the rail car are determined from the clearance envelope of the rail car. The clearance envelope is shown on Design Drawing DD-C-1 "WMATA Rapid Transit Car Clearance Envelope." The clearance envelope is developed from the rail car dynamic outline, and is a composite of the WMATA Design Vehicle, the Rohr Car and the Breda Car. Each of the extreme dimensions of each car have been taken into account in the development of the Clearance Envelope. All future rail car dynamic and static clearances must not exceed the clearances given in DD-C-1. The Clearance Envelope is equal to the Dynamic Outline plus 2" (inches). The design of tunnel structures, surface sections and aerial structures must accommodate the dynamic outline of the rail car for safe operations.

11.11.1 Clearance Definitions

11.11.1.1 **DW** Dynamic Width - Maximum horizontal width of dynamic outline or superelevated track, exclusive of M.O. and E.O. and equal to $DW_A + DW_T$

11.11.1.2 **DW_A** Dynamic Width Away - Maximum horizontal distance from the centerline of track to the dynamic outline, exclusive of M.O., on the side of the rail car away from the curve center.

11.11.1.3 **DW_T** Dynamic Width Toward - Maximum horizontal distance from the centerline of track to the dynamic outline, exclusive of M.O., on the side of the rail car toward the curve center.

11.11.1.4 **M.O.** Mid Ordinate - Distance from the centerline of a curved track to the centerline of the rail car at a point midway between the trucks.

11.11.1.5 **E.O**. End Overhang - Distance from the centerline of a curved track to centerline of car at each end of the car measured normal to the centerline of the track.

11.11.1.6 **A_C** Allowance Corded Construction - Measured horizontally.

11.11.1.7 **C.T.** Construction Tolerance Allowance.

11.11.1.8 **SW** Safety Walk

11.11.1.9 **X_A** Structure Centerline Offset - Away from Curve Center

11.11.1.10 **X_T** Structure Centerline Offset - Toward the Curve Center

11.11.1.11 **Offset** Offset is measured from centerline of track in all cases except in double track rock tunnel where it is measured from the centerline of the safety walk.

11.11.1.12 **Y** **Difference** in elevation from top of low rail to working point of tunnel.

11.11.1.13 **P.G.** Profile Grade Elevation at top of low rail.

11.11.1.14 **M_A & M_T** In arched roof section, the distance from the centerline of track to the vertical wall with provision from a minimum of 6" clearance at the arch and a minimum of 8 inch clearance at the vertical wall between the dynamic outline and the structure. This distance is the equivalent to 4 inches clearance at the arch and 6 inches clearance at the vertical wall between the clearance envelope and the structure.

11.11.1.15 **Structure Size** Factors used in sizing the structure but not included in the clearance envelope are allowances for corded construction, construction tolerances and clearances to walls specified by type of cross-section.

11.11.2 Safety Walks

For existing facilities the center safety walk widths are defined as a 3'-0" minimum distance between vertical lines through the edges (widest point) of the dynamic outlines and a 2'-0" minimum, measured as above. In tunnels and at grade sections the outside safety walk is 2'-0" minimum, measured as above. The dynamic outline shall not intrude into the safety walk area. Figures 11.10 through 11.60provide minimum clearance details for various types of construction.

For new facilities the safety walk shall be in accordance with the latest edition of NFPA 130, Chapter 6, Trainways, Section 6.2.1.9

11.11.3 Construction Tolerance

All walls and roof slabs shall have a horizontal and vertical construction tolerance allowance of 1”. Fences, piers, columns, light standards and miscellaneous structures shall have a horizontal construction tolerance of ±1".

11.11.4 Middle Ordinate Displacement

Is the horizontal displacement of the center of the side of the design vehicle toward the center of the curve, as it transits a curve of a specific radius. The Middle Ordinate can be calculated for any radius from the formula M.O.= R - $(R^2\ 676)^n$where R = radius in feet and n = ½. For design purposes, the end overhang and middle ordinate of the vehicle are considered equal. The formula is based on a 75'-0" long vehicle with 52'-0" truck centers. Rounding at car corners has not been considered. The centerline radius of the curve should be reduced by half of the width of the car plus the dynamic outline.

11.11.5 Chorded Construction

Walls for Cut and Cover Rectangular Sections shall be constructed in chords whose length shall be measured along the inside face of the wall nearest the curve center. Single Track Rock

Tunnel Sections and Single Circular Tunnel Sections maybe constructed in chords whose length shall be measured along the inside face of the wall nearest the curve center Maximum lengths of chord for certain radii are:

Radii 2500 feet or greater Radii less than 2500 feet

50 feet 25 feet

Values to be used for the allowance for chorded construction in clearance calculations on the inside face of the wall shall be calculated in accordance with the formula for Middle Ordinate Displacement.

11.11.6 Effect of Superelevation

The effect of superelevation is considered independently in determining the clearance envelope and has been taken into account in establishing the dimensional clearances for the various construction sections. The width of the design vehicle dynamic outline on superelevated track, exclusive of values for mid-ordinate and end overhang, is called the dynamic width. This width includes the dynamic width toward the curve center, (DW_T) shown on Fig 11.30, and the dynamic width away from the curve center, (DW_A) shown on Fig.11. 31. These values are measured horizontally from the centerline of track to the widest point on the design vehicle dynamic outline.

Each such restriction is to be considered independently and submitted for approval.

11.11.7 Minimum Clearances from the Dynamic Outline

The design vehicle dynamic outline shall be located to satisfy the following criteria:

Table 11.4	
Minimum Clearances from the Dynamic Outline Description of Location (*)	**Clearance Distance**
Between the face of wall and the clearance envelope outline	6"
Between the roof surface and the clearance envelope outline	4"
Between any fixed installation (e.g., pipes, pipe hangers, pipe supports, signals, luminaries , air conditioning units, etc.) and the design vehicle dynamic outline.	2"
Between light standards and the design vehicle dynamic outline.	4"
Between existing adjacent intermittent columns and existing point restrictions, and the clearance envelope	6"
Between new adjacent intermittent columns and new point restrictions, and the clearance envelope	2'-0"
Between top of low rail to the under-clearance point of overhead structure.	13'-0"
Between track centers.	14'-0"
Between top of rail and bottom of new bridges spanning the right-of-way	15'-0"
The design vehicle dynamic outline shall not encroach into the safety walk space.	0"
Additional allowance for finish on exterior walls at stations	0'-6"
(*) These clearances are defined by the clearance envelope. However, installations shall be so dimensioned and located that maximal distances are obtained between these and the clearance envelope along tangent and curved alignments.	

11.11.8 Clearances Diagrams

The clearance requirements for surface track sections are indicated in Figure 11.54. Figures 11.34 and 11.35 indicate the clearance requirements for cut and cover sections. The walls of all structures shall be designed to clear design vehicle dynamic outline and to satisfy the following additional clearance criteria:

11.11.9 Structure Width

The structure width is determined by the factors shown on the various Figures that relate to the applicable design type of tunnel structure. In chorded construction, the horizontal dimensions from centerline of track to inside face of wall and the dimension from the top of low rail to the inside face of roof slab shall be measured at the breakpoint location of the chorded elements.

11.11.10 Tunnel Turnout Clearances

The horizontal offsets from centerline of track to the design vehicle dynamic outline as shown on Figures 11.63 to 11.66 have been determined graphically from a plan drawn at a scale of 1" = 1'-0". In developing these offsets it has been assumed that the design vehicle is on a tangent track as it approaches the turnout and as it leaves the turnout. It is also assumed that the vehicle is operating on track that is not superelevated. If the turnout is from a curved or superelevated track, the values shown on Figures 11.63 to 11.66 must be adjusted to compensate for additional clearance required for curvature and superelevation.

11.11.11 Design Tables

The tabulated values for the horizontal dimensions A, T, A_s, and T_s, measured from centerline of track to inside face of wall, are shown in the Figures for each typical section. These values shall be used for sizing sections. Linear interpolation is to be used for values of radii and superelevation intermediate to those shown in the tables

11.11.12 Widening Track Centers on Curves

Track centers on circular curves must be widened geometrically to accommodate the clearance requirements. The total clearance required and the changes in the curves to accommodate the clearance must be checked by the Designer when producing structural details.

Values shown in the tables for width of structure on a circular curve shall be applied and removed linearly over a length equal to the spiral length, beginning at a point on the tangent25 feet prior to the T.S. and ending at a point 25 feet after the S.T. Full width required on the circular curve shall be reached at a point on the spiral 25 feet before the S.C. and maintained 25 feet after the C.S.

11.11.13 Design Tables

Tabulated values for track center spacing are shown in Figure 11.56. These values allow for installation of a 10 inch" light standard or similar pole structure between the tracks.

11.11.14 Continuous Fence Clearance

The horizontal clearance distance from centerline of track to continuous fence shall be:

1. For track between railroad mains and alongside railroad mains:

   10'-6" minimum (13'-0" desirable) and 11'-0" minimum (13'-0" desirable) on outside of curve when track superelevation exceeds 3 3/4";

2. For tangent track in highway median:

   10'-9" minimum (13'-0" desirable)

3. For superelevated track in highway median:

   10'-9" minimum for superelevation less than 3 3/4", 11'-0" minimum for superelevation greater than 3 3/4" (13'-0" desirable) on the high side and;

   10-9" minimum (13'-0" desirable) on the low side.

For absolute minimum clearances to fences use A_s and T_s values in Figures 11.56 to 11.59 These absolute minimum dimensions are to be used only in special circumstances when approved by WMATA.

The tabulated values for the horizontal dimensions A and T, measured from centerline of track to face of columns or point restrictions and for A_s and T_s, measured from centerline of track to face of parallel bridge abutments and piers, are shown in Figures 11.56 to 11.59.

Widening on Curves

Track centers on circular curves in surface sections must be widened geometrically to maintain the 1'-8" minimum space reserved for installation of light standards and similar structures. Values shown in the tables for distance from centerline of track to intermittent columns and point restrictions shall be interpolated linearly for points which fall on the spiral.

11.12 AERIAL TRACK STRUCTURES

11.12.1 General

Double track aerial structures shall have an independent girder for each track with the safety walks located between, and outside of each track on opposite side of contact rail. On curved track, each girder shall be superelevated as required by the track geometry. If not constructed concentric with the centerline of track, the proper corrections for chorded construction must be made. Where light standards are required, they shall be located between the tracks.

Figure 11.67 indicates the clearance requirements for double track aerial structures. The design vehicle dynamic outline shall be located to satisfy the following criteria:

Allowance is to be made for installation of a 10 inch wide light standard or similar pole structure between tracks.

11.12.2 Design Tables

Tabulated values for track center spacing are shown in Figure 11.68. The horizontal dimensions A and T measured from centerline of track to adjacent columns and point restrictions are shown in design tables for Surface Track Section, Figure 11.56 to Figure 11.59.

Linear interpolation is to be used for values of radii and superelevation intermediate to those shown in the tables.

11.12.3 Horizontal Track Clearances:

Minimum horizontal clearances measured from centerline of track on tangent alignment shall be as follows:

Converging Tracks: Clearance distances for two converging tracks are determined from the transit clearance envelope and, where appropriate, include the allowances for middle ordinate and end overhang of the transit car.

Two converging tracks, the absolute minimum clearances between track centers with respect to vehicles only are shown on Figure 11.18 to Figure 11.20. The dimensions shown must be increased for structures, structural clearances, safety walks, and other installations as noted in Section 8 of this criteria. Track capacity will be determined from the location of the insulated joint farthest from the clearance point as shown on Figure 11.18 to Figure 11.20. Insulated joint locations will be coordinated WMATA.

11.12.4 Fixed Structure in Open

Intermittent columns and point restrictions: **7' – 6 5/8"** preferred. Refer to Figure 11.54.

Continuous restrictions: **8' – 6"**

Fences parallel with track: **10' – 6"** Varies with situation.

For clearance in tunnels and in cut-and-cover structures on tangent tracks, see Figures 11.10 to 11.17. For clearances on curved alignment, see Section 11.11.

11.12.5 Station Clearances

The following are platform minimum widths. Additional width shall be added to accommodate projected platform passenger load.

Center platform width: **30' – 0 1/2"** minimum,

Side platform width: **13' – 6"** minimum,

Edge of platform to centerline of track: **5' – 2 3/4" (+1/4",-0")**

11.13 RAILROAD CLEARANCES

Railroad clearances for each jurisdiction shall satisfy the requirements for that jurisdiction in the latest edition of the following publications:

The Designer shall establish minimum requirements acceptable to the railroad in each instance, and will report thereon to WMATA. In the course of consultation with the railroad existing clearances and conditions shall be considered in order to achieve a Metro alignment at minimum construction and acquisition costs. The study and report to WMATA shall contain cost comparisons and plans illustrating alignment, construction types and acquisition alternatives to enable WMATA to comprehensively review the alternatives prior to negotiating agreement with the railroad. Railroad requirements are subject to approval by WMATA.

11.13.1 In the District of Columbia

"Safety Standards, Rules and Regulations for Railroad Clearances," published by the Minimum Wage and Industrial Safety Board of the District of Columbia.

11.13.2 In Maryland

Orders of the Public Service Commission

11.13.3 In Virginia

Regulations of the State Corporation Commission

11.14 HIGHWAY AND OTHER CLEARANCES

Vertical clearance, rapid transit structure over highway

The above vertical clearances, in addition to horizontal clearance requirements, shall be verified by the Designer with the appropriate authorities at the time of final design. For structures under the jurisdiction of agencies other than those listed above, the Designer shall coordinate his design with the appropriate owner.

11.14.1 District of Columbia

Each overpass will be evaluated individually by the Department of Public Works of Washington, D.C.

Minimum vertical clearance: **14' – 6"**

11.14.2 Maryland

On roadways under Maryland State Highway Administration jurisdiction

Minimum vertical clearance: **16' – 19"**

On roadways under Montgomery County Department of Public Works and Transportation jurisdiction

Minimum vertical clearance: **16' – 9"**

On roadways under Prince George's County Department of Public Works and Transportation jurisdiction

Minimum vertical clearance: **15' – 0"**

Desirable vertical clearance: **16' – 9"**

11.14.3 Virginia

On roadway under Virginia Department of Transportation jurisdiction

Minimum vertical clearance: **16' – 6"**

On roadways under Arlington County Department of Transportation jurisdiction

Minimum vertical clearance: **16' – 0"**

Desirable vertical clearance: **16' – 6"**

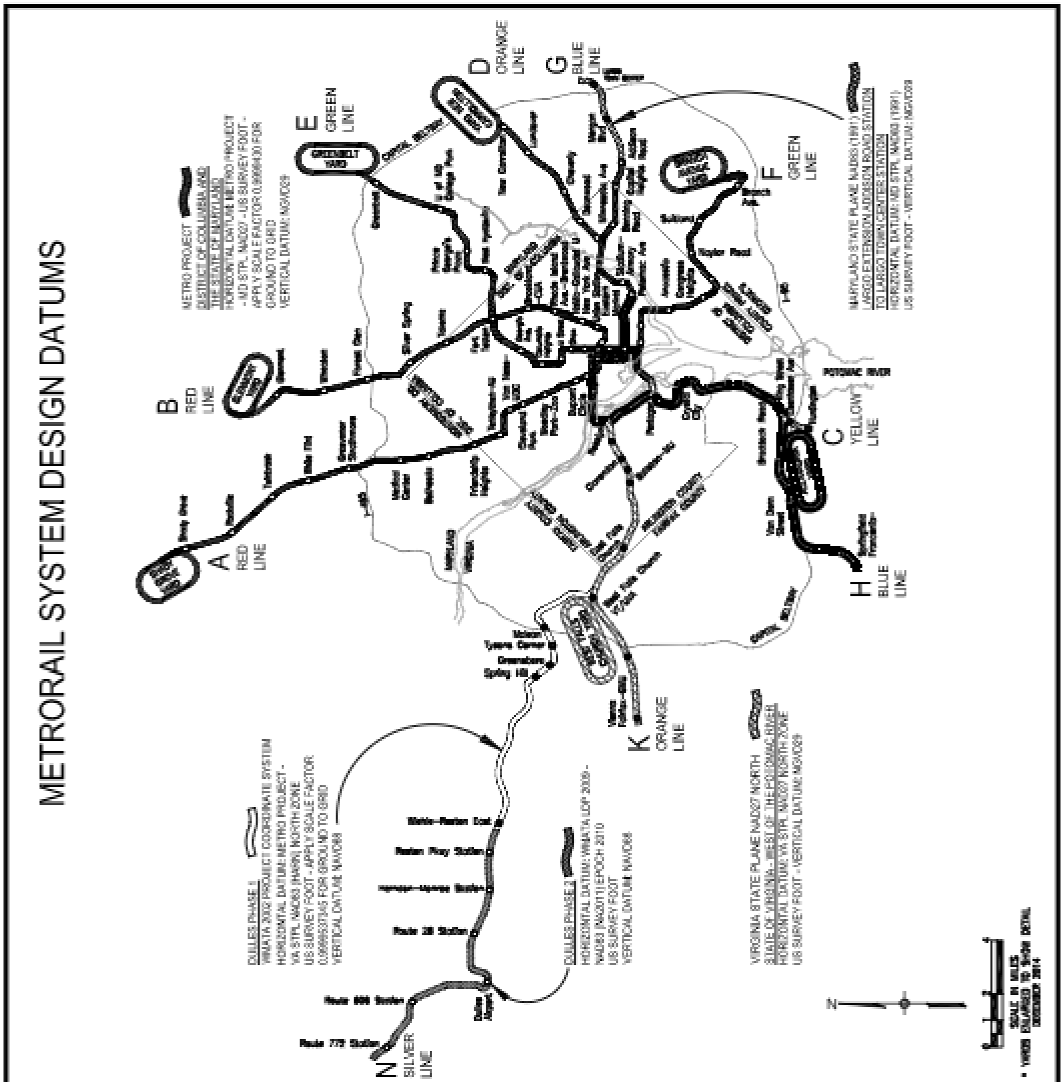
On roadways under Alexandria City jurisdiction

Minimum vertical clearance: **14' – 6"**

Desirable vertical clearance: **16' – 6"**

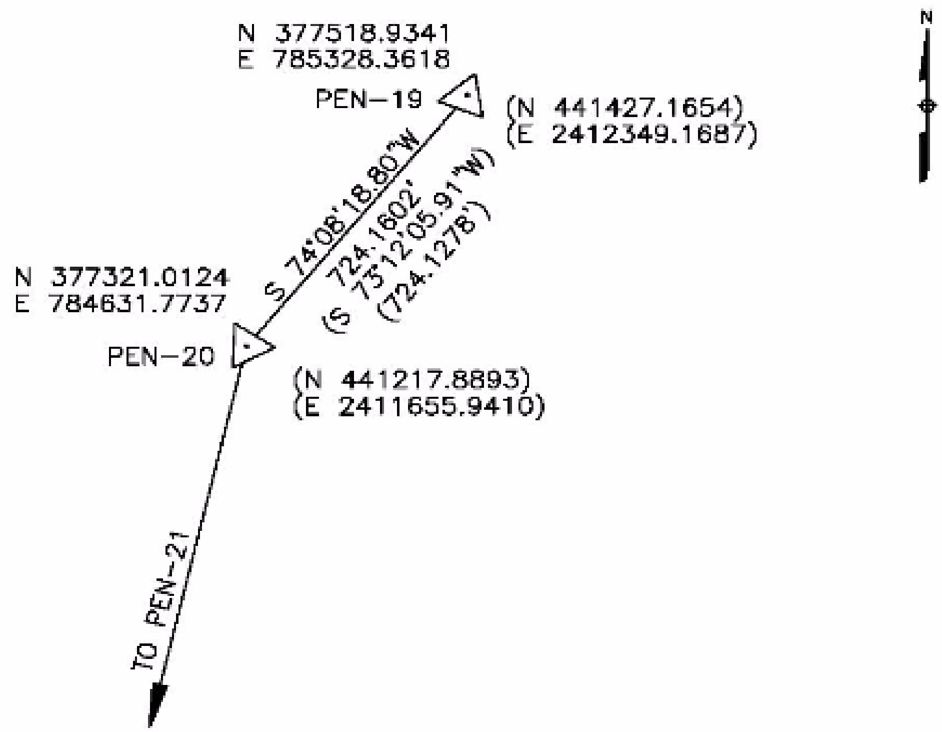
On roadway under Fairfax County Department of Transportation Planning jurisdiction

Minimum vertical clearance: **16' – 6"**



metro — DESIGNATION OF COORDINATE SYSTEMS	DRAWING NO. FIGURE 11.1	
	SCALE NONE	SHEET NO. 1 of 1
DEPARTMENT OF TRANSIT INFRASTRUCTURE AND ENGINEERING SERVICES		CONTRACT NO. N/A

FIGURE 11.1

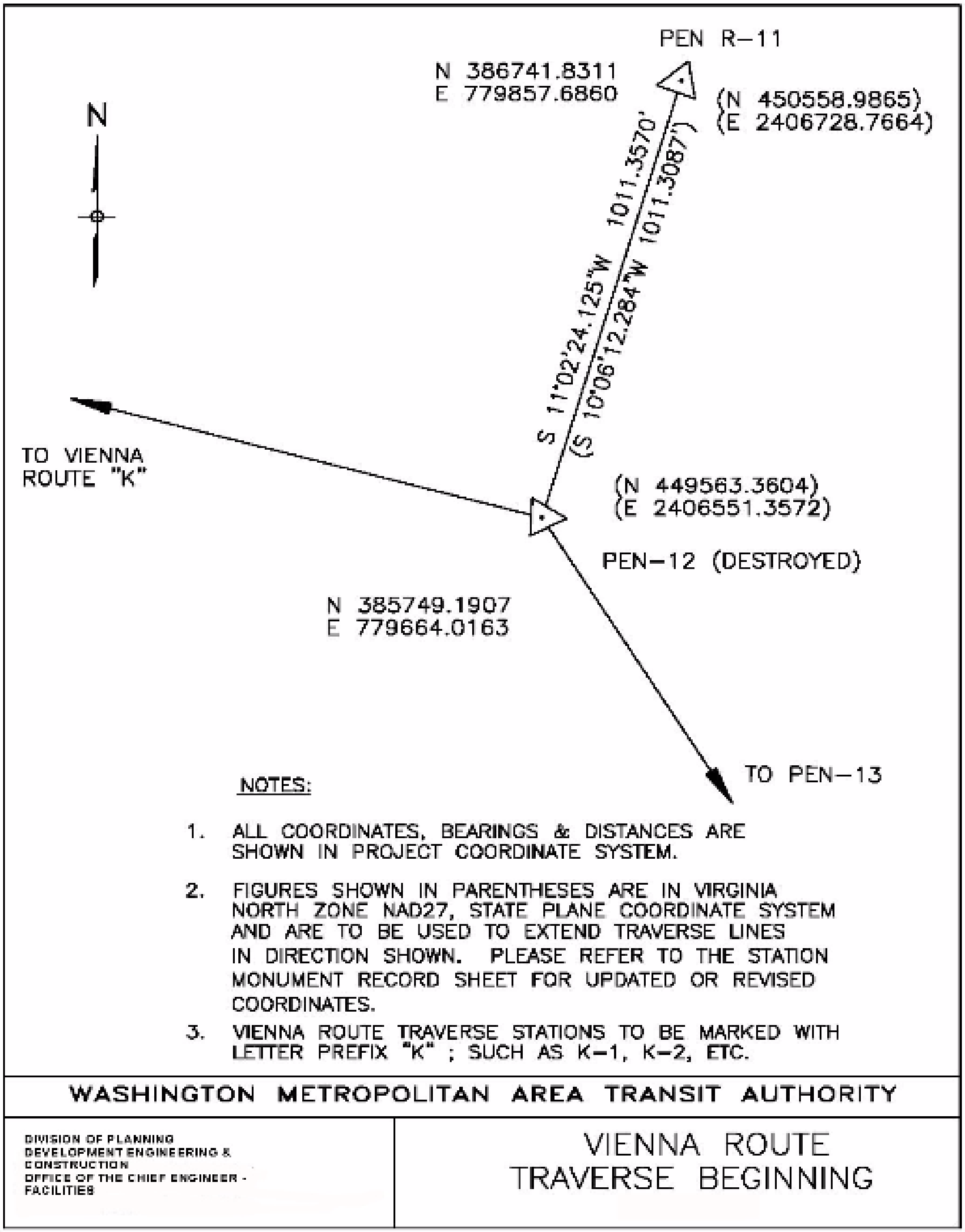


NOTES:

1. ALL COORDINATES, BEARINGS & DISTANCES ARE SHOWN IN PROJECT COORDINATE SYSTEM.
2. FIGURES SHOWN IN PARENTHESES ARE IN VIRGINIA NORTH ZONE NAD27, STATE PLANE COORDINATE SYSTEM AND ARE TO BE USED TO EXTEND TRAVERSE LINES IN DIRECTION SHOWN. PLEASE REFER TO THE STATION MONUMENT RECORD SHEET FOR UPDATED OR REVISED COORDINATES.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES	HUNTINGTON ROUTE TRAVERSE BEGINNING

FIGURE 11.2



PEN R–11
N 386741.8311
E 779857.6860
(N 450558.9865)
(E 2406728.7664)
N
S 11°02'24.125"W 1011.3570'
(S 10°06'12.284"W 1011.3087')
TO VIENNA
ROUTE "K"
(N 449563.3604)
(E 2406551.3572)
PEN–12 (DESTROYED)
N 385749.1907
E 779664.0163
TO PEN–13
NOTES:
1. ALL COORDINATES, BEARINGS & DISTANCES ARE SHOWN IN PROJECT COORDINATE SYSTEM.
2. FIGURES SHOWN IN PARENTHESES ARE IN VIRGINIA NORTH ZONE NAD27, STATE PLANE COORDINATE SYSTEM AND ARE TO BE USED TO EXTEND TRAVERSE LINES IN DIRECTION SHOWN. PLEASE REFER TO THE STATION MONUMENT RECORD SHEET FOR UPDATED OR REVISED COORDINATES.
3. VIENNA ROUTE TRAVERSE STATIONS TO BE MARKED WITH LETTER PREFIX "K" ; SUCH AS K–1, K–2, ETC.
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING
DEVELOPMENT ENGINEERING &
CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER -
FACILITIES
VIENNA ROUTE
TRAVERSE BEGINNING

FIGURE 11.3

DATUM PLANES - WASHINGTON METROPOLITAN AREA

	ELEVATION RELATIVE TO PROJECT DATUM (FEET)	DATUM
ABOVE PROJECT DATUM	0.94	WASHINGTON AQUEDUCT AND FILTRATION PLANTS (W.A.D.)
	0.70	DISTRICT OF COLUMBIA ENGINEERING DEPARTMENT POTOMAC ELECTRIC POWER COMPANY WASHINGTON GAS COMPANY C. & P. TELEPHONE COMPANY D. C. ENGINEERING DEPARTMENTS
	0.57	PENNSYLVANIA RAILROAD
	0.00	PROJECT DATUM = SEA LEVEL DATUM (NGVD 1929 GENERAL ADJUSTMENT) U.S. COAST & GEODETIC SURVEY U.S. GEOLOGICAL SURVEY NAVAL RESEARCH LABORATORY (BELLEVUE) R. F. & P. RAILROAD B. & O. RAILROAD (ALEXANDRIA BRANCH) ARLINGTON COUNTY
BELOW PROJECT DATUM	0.15	SEA LEVEL DATUM (1912 GENERAL ADJUSTMENT) *WASHINGTON SUBURBAN SANITARY COMMISSION *MONTGOMERY COUNTY
	1.41	LOW WATER DATUM – WASHINGTON HARBOR (L.W.D.) BALTIMORE DISTRICT, CORPS OF ENGINEERS (EXCEPT WASHINGTON AQUEDUCT) NATIONAL PARK SERVICE PUBLIC ROADS ADMINISTRATION WASHINGTON NATIONAL AIRPORT
	1.63	BOLLING AIR FORCE BASE
	4.50	NAVAL GUN FACTORY
	4.70	ANACOSTIA NAVAL AIR STATION

*NOTE: THE WASHINGTON SUBURBAN SANITARY COMMISSION AND MONTGOMERY COUNTY ALSO USE SEA LEVEL DATUM (1929 GENERAL ADJUSTMENT) IN SOME AREAS.

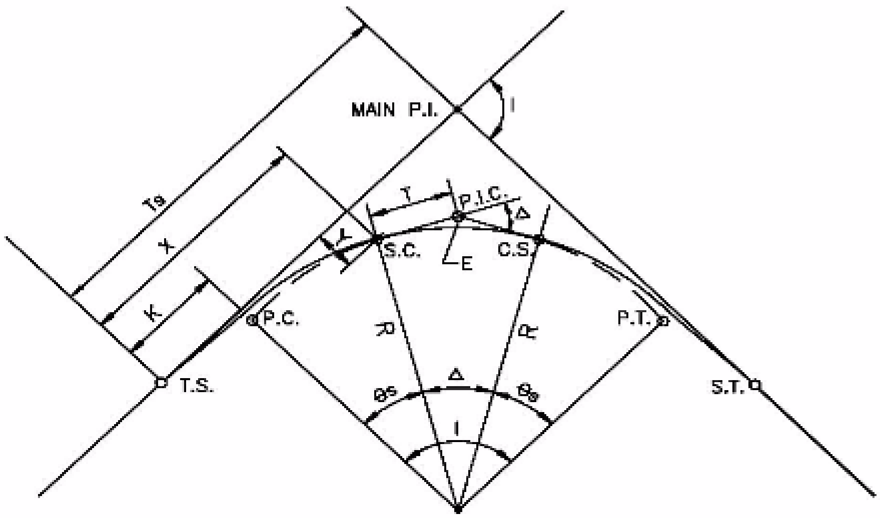
EXAMPLE:

CAPITOL BENCH MARK – APEX OF BRONZE BOLT SET IN EAST WINDOW SILL OF THE SOUTH SIDE OF THE SENATE WING OF THE U.S. CAPITOL. IT WAS PLACED IN POSITION IN JUNE 1894 AND IS INSCRIBED "CAPITOL B.M."

DISTRICT OF COLUMBIA ENGINEERING DEPARTMENT	89.840
PENNSYLVANIA RAILROAD	89.970
PROJECT DATUM = SEA LEVEL DATUM (1929 GEN. ADJ.)	90.540
NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88)	89.760

metro DATUM PLANES WASHINGTON METROPOLITAN AREA	DRAWING NO. FIGURE 11.4	
	SCALE N.T.S.	SHEET NO. 1 of 1
DEPARTMENT OF TRANSIT INFRASTRUCTURE AND ENGINEERING SERVICES		CONTRACT NO. N/A

FIGURE 11.4



I = TOTAL INTERSECTION ANGLE

Θs = SPIRAL ANGLE = $\frac{LsDc}{200}$

Δ = CENTRAL ANGLE OF CIRCULAR CURVE = $I-2\ \Theta s$

R = RADIUS OF CIRCULAR CURVE

T = TANGENT LENGTH OF CIRCULAR CURVE = R TAN $\Delta/2$

L = LENGTH OF CIRCULAR CURVE = $\frac{\Delta \pi R}{180}$

E = EXTERNAL DISTANCE = R EXSEC $\Delta/2$

Ts = TANGENT LENGTH FROM T.S. TO MAIN P.I. = (R+P) TAN I/2 +K

P.C. = POINT OF CURVATURE

P.T. = POINT OF TANGENCY

T.S. = TANGENT TO SPIRAL

S.C. = SPIRAL TO CURVE

C.S. = CURVE TO SPIRAL

S.T. = SPIRAL TO TANGENT

P.I. = POINT OF INTERSECTION

NOTE:
SEE FIG. III.6 FOR SPIRAL CURVE FUNCTIONS & ABBREVIATIONS.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES	CIRCULAR CURVES FUNCTIONS & ABBREVIATIONS

FIGURE 11.5

Ls = LENGTH OF SPIRAL (BARNETT SPIRAL)

$\Theta s = \frac{LsDc}{200}$

$$X = Ls\left(1 - \frac{\delta s^2}{10} + \frac{\delta s^4}{216} - \frac{\delta s^6}{9360} + \frac{\delta s^8}{685440} - \frac{\delta s^{10}}{76204800} + \frac{\delta s^{12}}{11975040000}\right)$$

$$Y = Ls\left(\frac{\delta s}{3} - \frac{\delta s^3}{42} + \frac{\delta s^5}{1320} - \frac{\delta s^7}{75600} + \frac{\delta s^9}{6894720} - \frac{\delta s^{11}}{91808640} + \frac{\delta s^{13}}{168129561600}\right)$$

Ts = TANGENT LENGTH FROM T.S. TO MAIN P.I. = (R+P) TAN I/2 + K

P = Y−R (1−COS Θs)

K = X−R SIN Θs

ST = Y/SIN Θs

LT = X−Y/TAN Θs

LC = $\sqrt{X^2+Y^2}$

Dc = DEGREE OF CURVE (ARC DEFINITION)

R = RADIUS OF CIRCULAR CURVE

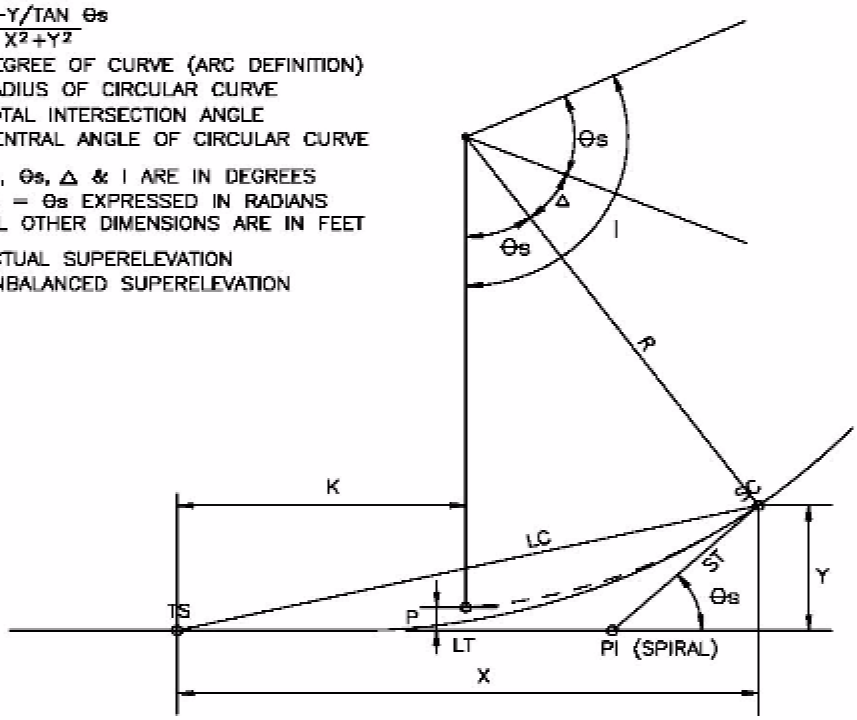
I = TOTAL INTERSECTION ANGLE

Δ = CENTRAL ANGLE OF CIRCULAR CURVE

Dc, Θs, Δ & I ARE IN DEGREES
δs = Θs EXPRESSED IN RADIANS
ALL OTHER DIMENSIONS ARE IN FEET

Ea = ACTUAL SUPERELEVATION

Eu = UNBALANCED SUPERELEVATION



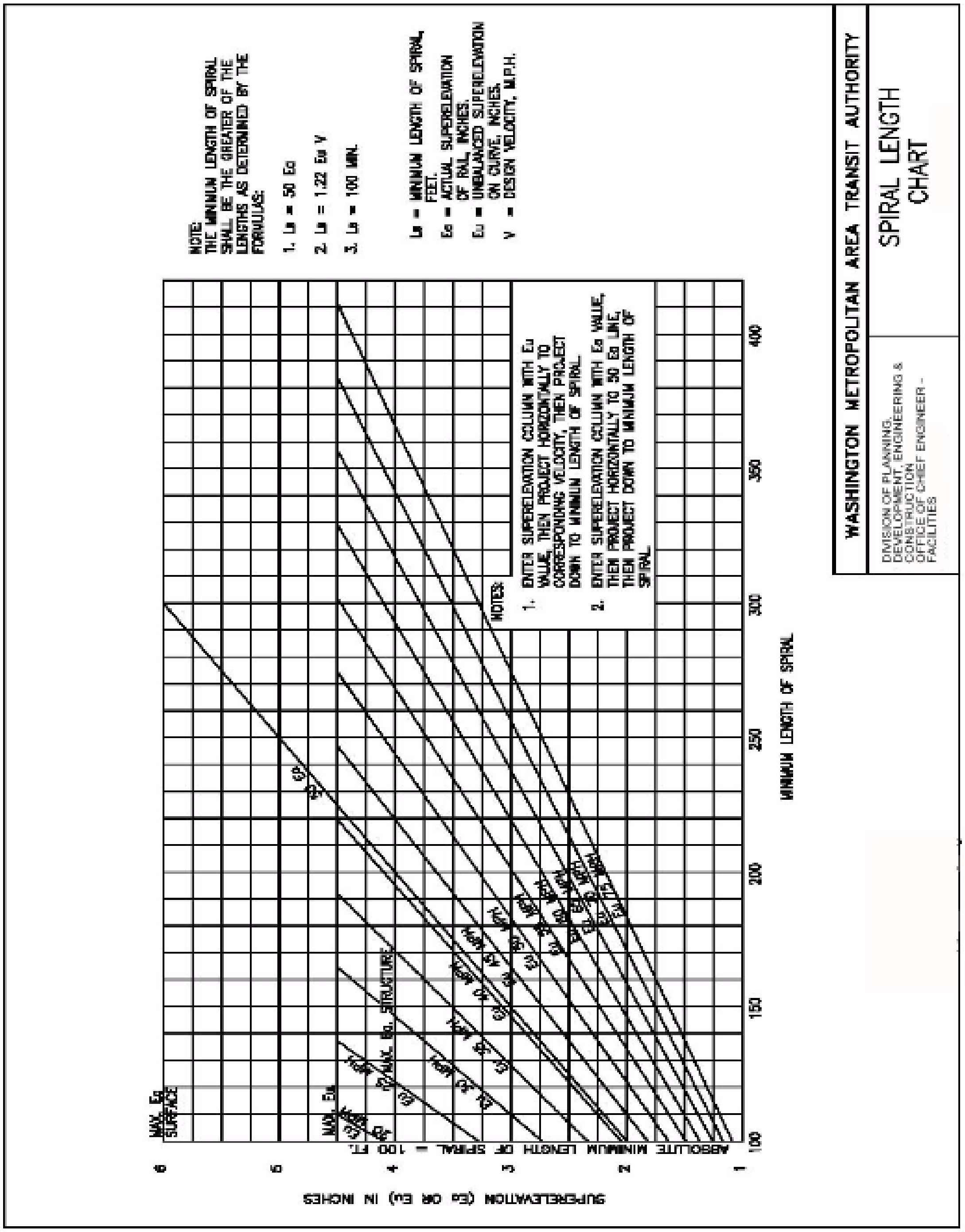
NOTES:

1. ACTUAL SUPERELEVATION (Ea) WILL START AT THE TS AND BE PRORATED LINEARLY THROUGHOUT THE FULL LENGTH OF THE SPIRAL TRANSITION CURVE TO FULL SUPERELEVATION AT THE SC.
2. SEE FIG. III.5 FOR CIRCULAR CURVE FUNCTIONS & ABBREVIATIONS.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES	SPIRAL CURVES FUNCTIONS & ABBREVIATIONS

FIGURE 11.6



NOTE:
THE MINIMUM LENGTH OF SPIRAL SHALL BE THE GREATER OF THE LENGTHS AS DETERMINED BY THE FORMULAS:
1. Ls = 50 Ea
2. Ls = 1.22 Eu V
3. Ls = 100 MIN.
Ls = MINIMUM LENGTH OF SPIRAL, FEET.
Ea = ACTUAL SUPERELEVATION OF RAIL, INCHES.
Eu = UNBALANCED SUPERELEVATION ON CURVE, INCHES.
V = DESIGN VELOCITY, M.P.H.
NOTES:
1. ENTER SUPERELEVATION COLUMN WITH Eu VALUE, THEN PROJECT HORIZONTALLY TO CORRESPONDING VELOCITY, THEN PROJECT DOWN TO MINIMUM LENGTH OF SPIRAL.
2. ENTER SUPERELEVATION COLUMN WITH Ea VALUE, THEN PROJECT HORIZONTALLY TO 50 Ea LINE, THEN PROJECT DOWN TO MINIMUM LENGTH OF SPIRAL.
MAX. Ea SURFACE
MAX. Eu
MAX. Ea, STRUCTURE
ABSOLUTE MINIMUM LENGTH OF SPIRAL = 100 FT.
SUPERELEVATION (Ea OR Eu) IN INCHES
MINIMUM LENGTH OF SPIRAL
100
150
200
250
300
350
400
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING & CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
SPIRAL LENGTH CHART

FIGURE 11.7

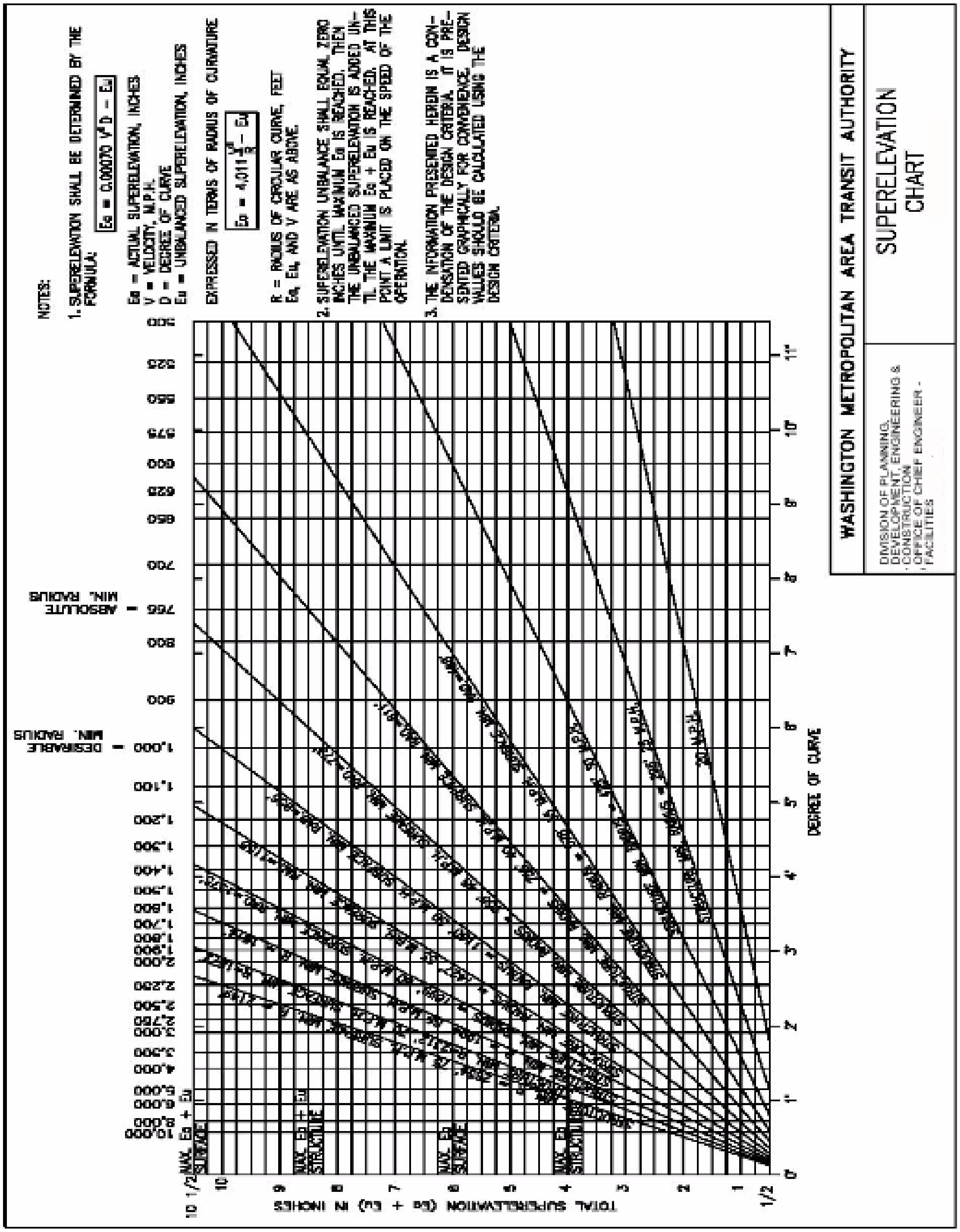

NOTES:
1. SUPERELEVATION SHALL BE DETERMINED BY THE FORMULA:
Ea = 0.00070 V²D − Eu
Ea = ACTUAL SUPERELEVATION, INCHES
V = VELOCITY, M.P.H.
D = DEGREE OF CURVE
Eu = UNBALANCED SUPERELEVATION, INCHES
EXPRESSED IN TERMS OF RADIUS OF CURVATURE
Ea = 4.011 V²/R − Eu
R = RADIUS OF CIRCULAR CURVE, FEET
Ea, Eu, AND V ARE AS ABOVE.
2. SUPERELEVATION UNBALANCE SHALL EQUAL ZERO INCHES UNTIL MAXIMUM Ea IS REACHED. THEN THE UNBALANCED SUPERELEVATION IS ADDED UNTIL THE MAXIMUM Ea + Eu IS REACHED. AT THIS POINT A LIMIT IS PLACED ON THE SPEED OF THE OPERATION.
3. THE INFORMATION PRESENTED HEREIN IS A CONDENSATION OF THE DESIGN CRITERIA. IT IS PRESENTED GRAPHICALLY FOR CONVENIENCE. DESIGN VALUES SHOULD BE CALCULATED USING THE DESIGN CRITERIA.
1,000 − DESIRABLE MIN. RADIUS
755 − ABSOLUTE MIN. RADIUS
TOTAL SUPERELEVATION (Ea + Eu) IN INCHES
DEGREE OF CURVE
MAX. Ea + Eu SURFACE
MAX. Ea + Eu STRUCTURE
MAX. Ea SURFACE
MAX. Ea STRUCTURE
20 M.P.H.
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING & CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
SUPERELEVATION CHART

FIGURE 11.8

HORIZONTAL TRACK ALIGNMENT	TRACK GAUGE	
	MAIN	YARD AND SECONDARY
TANGENT TRACK	4'–8 1/4"	4'–8 1/2"
CURVE OF RADIUS ≥ 1425'	4'–8 1/4"	4'–8 1/2"
CURVE OF 1425' > RADIUS ≥ 755'	4'–8 3/4"	4'–8 3/4"
CURVE OF 755' > RADIUS ≥ 500'	4'–8 3/4"	4'–8 3/4"
CURVE OF 500' > RADIUS ≥ 400'	N/A	4'–9"
CURVE OF 400' > RADIUS ≥ 300' *	N/A	4'–9 1/4"

* MINIMUM RADUIS IN YARDS & SECONDARY TRACKS.

NOTES:

1 THESE GAUGES APPLY ONLY WITH STANDARD AAR WHEEL GAUGES OF 4'–7 11/16" AND VEHICLE AXLE SPACING 7'–0" AND 8'–6" INCLUSIVE.

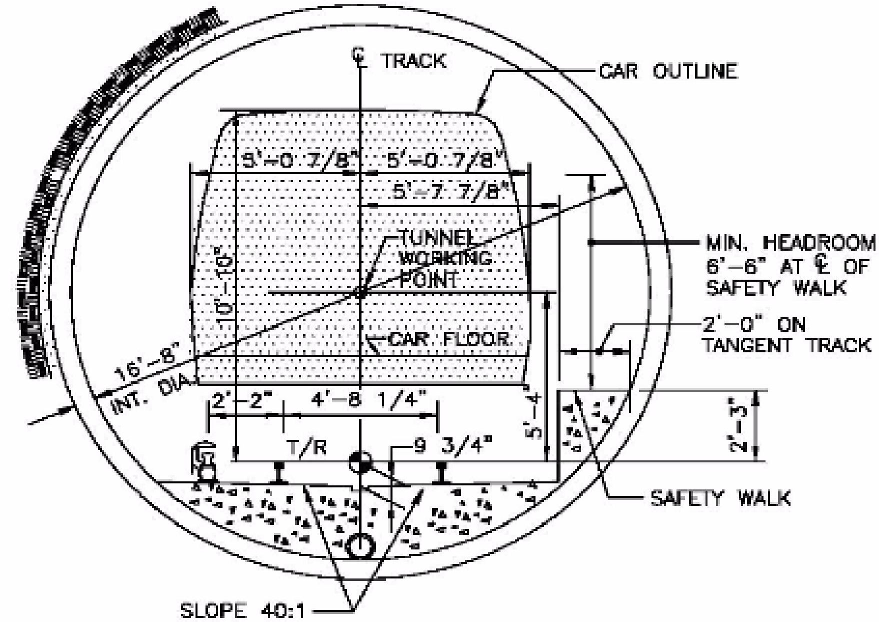
2 FOR EVERY 1/4" CHANGE IN TRACK GAUGE, THE TRANSITION SHALL BE MADE IN A LENGTH OF NOT LESS THAN 31' NOR MORE THAN 62'.

3 BASIC TRACK GAUGE FOR SPECIAL TRACKWORK SHALL CONFORM TO AREA PORTFOLIO OF TRACKWORK PLANS AND SPECIFICATIONS.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES	METRO TRACK GAUGE

FIGURE 11.9



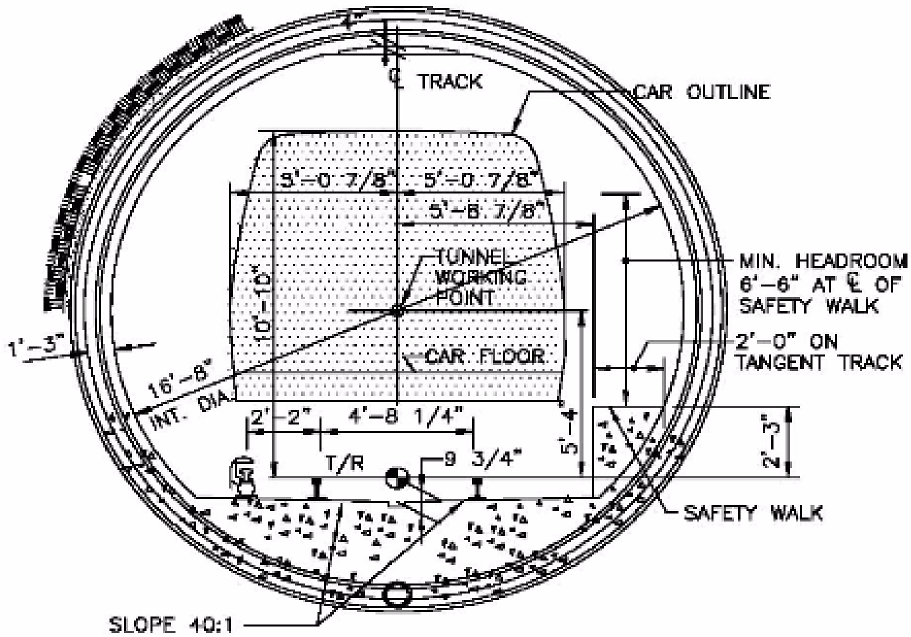
NOTES:

1. THIS SECTION APPLIES TO TUNNELS IN EARTH.
2. THE STANDARD 16'–8" DIAMETER TUNNEL CAN BE USED FOR RADII EQUAL TO OR GREATER THAN 700'. THE LOCATION OF THE TUNNEL WORKING POINT VARIES WITH THE HORIZONTAL CURVATURE. SEE FIGURES II.22 AND II.23.
3. CAR OUTLINE IS INDICATED, DYNAMIC OUTLINE IS NOT SHOWN.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES	CIRCULAR SEGMENTAL TUNNEL SECTION TANGENT TRACK

FIGURE 11.10



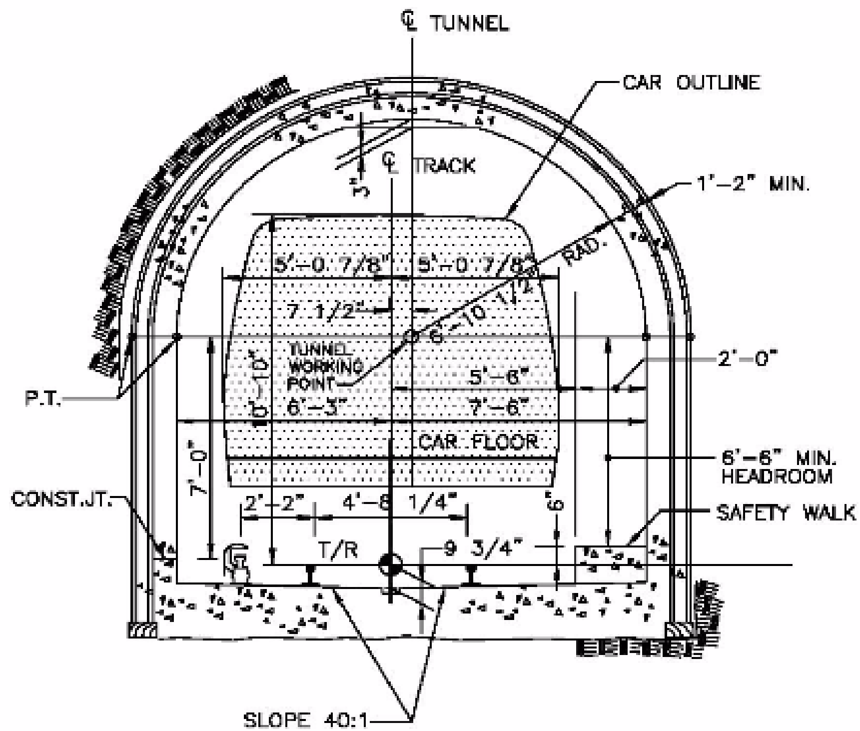
NOTES:

1. THIS SECTION APPLIES TO TUNNELS IN EARTH.
2. THE STANDARD 16'-8" DIAMETER TUNNEL CAN BE USED FOR RADII EQUAL TO OR GREATER THAN 700'. THE LOCATION OF THE TUNNEL WORKING POINT VARIES WITH THE HORIZONTAL CURVATURE. SEE FIGURES III.50 AND III.51.
3. CAR OUTLINE IS INDICATED, DYNAMIC OUTLINE IS NOT SHOWN.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES	CIRCULAR CAST–IN–PLACE TUNNEL SECTION TANGENT TRACK

FIGURE 11.11



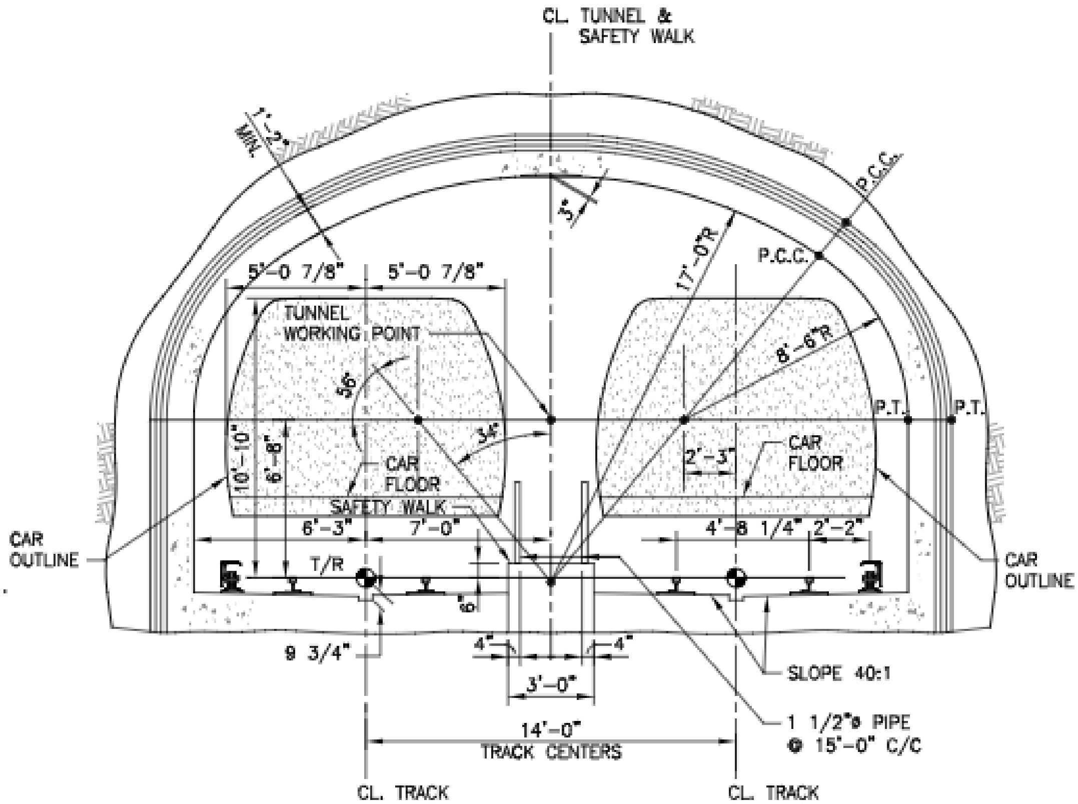
NOTES:

1. THIS SECTION APPLIES ONLY TO TANGENT TUNNEL IN ROCK.
2. THE OUTSIDE DIMENSIONS ARE SUBJECT TO LOCAL CONDITIONS.
3. CAR OUTLINE IS INDICATED, DYNAMIC OUTLINE IS NOT SHOWN.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES	SINGLE TRACK ROCK TUNNEL SECTION TANGENT TRACK

FIGURE 11.12



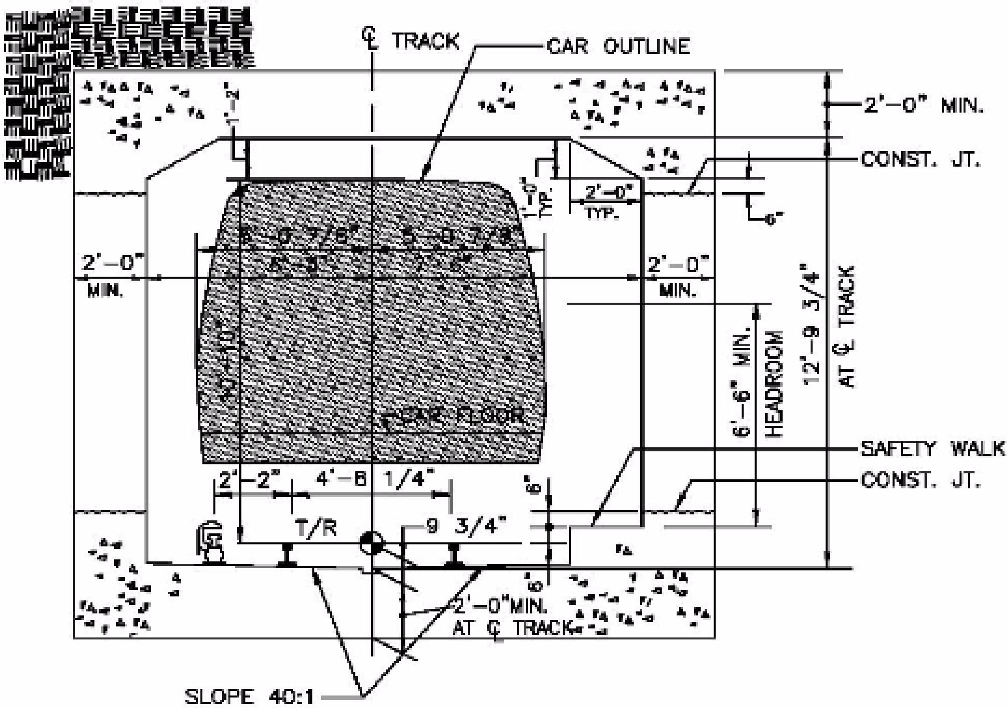
NOTES:

1. THIS SECTION APPLIES ONLY TO TANGENT TUNNEL IN ROCK.
2. THE OUTSIDE DIMENSIONS ARE SUBJECT TO LOCAL CONDITIONS.
3. CAR OUTLINES ARE INDICATED, DYNAMIC OUTLINES ARE NOT SHOWN.

metro — DOUBLE TRACK ROCK TUNNEL SECTION TANGENT TRACK	DRAWING NO. FIGURE 11.13	
	SCALE N.T.S.	SHEET NO. 1 of 1
DEPARTMENT OF TRANSIT INFRASTRUCTURE AND ENGINEERING SERVICES		CONTRACT NO. N/A

DEC. 2015

FIGURE 11.13

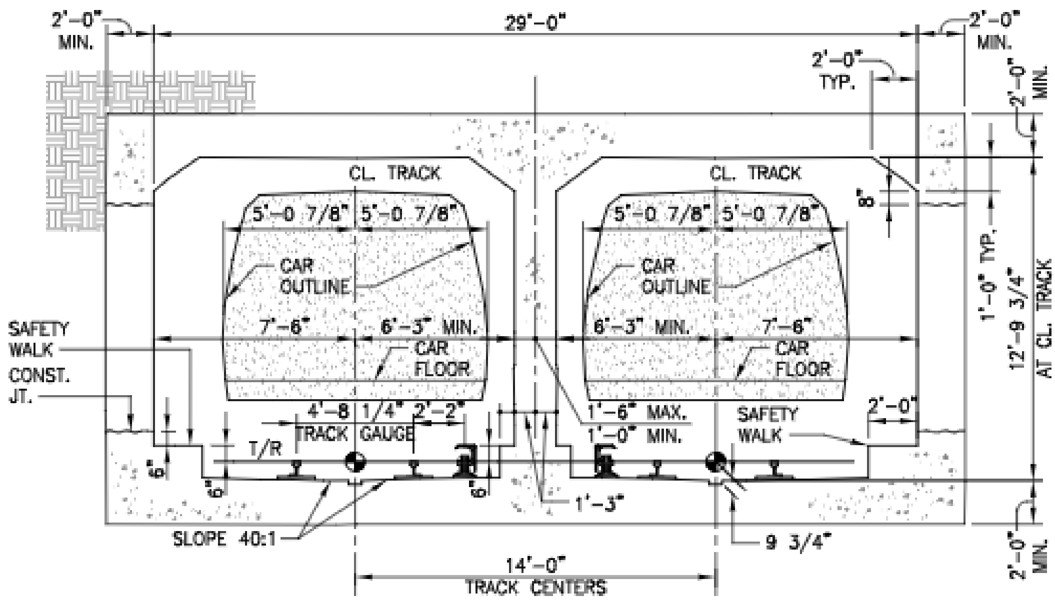


NOTES:

1. THIS SECTION APPLIES TO CUT AND COVER CONSTRUCTION.
2. THE INTERIOR DIMENSIONS OF THE BOX SECTION VARY WITH THE HORIZONTAL CURVATURE. SEE FIGURES III.34 & III.35.
3. CAR OUTLINE IS INDICATED, DYNAMIC OUTLINE IS NOT SHOWN.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES	SINGLE BOX SECTION TANGENT TRACK

FIGURE 11.14

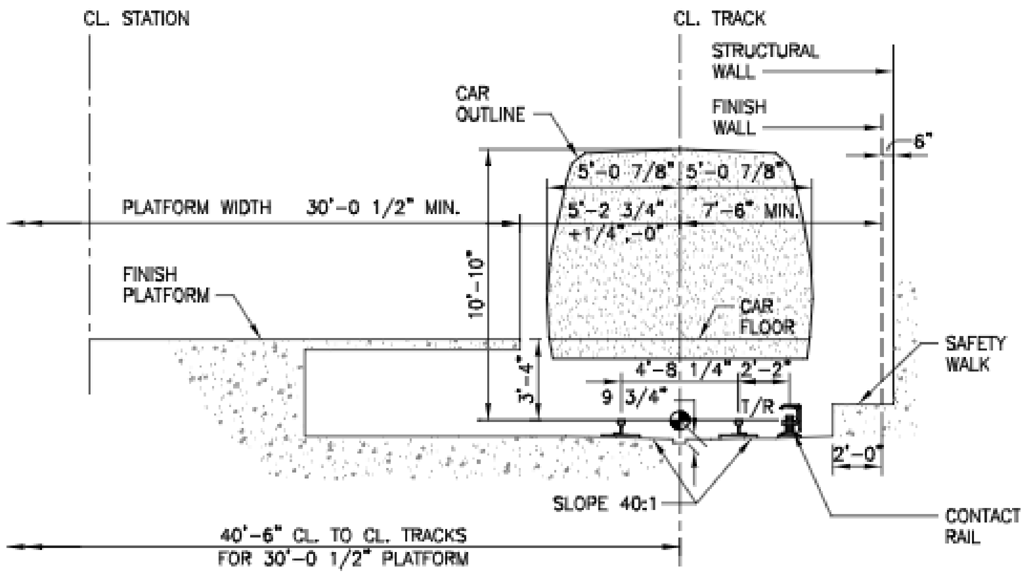


NOTES:

1. THIS SECTION APPLIES TO CUT AND COVER CONSTRUCTION.
2. THE INTERIOR DIMENSIONS OF THE BOX SECTION VARY WITH THE HORIZONTAL CURVATURE. SEE FIGURES 111.34 & 111.35.
3. CAR OUTLINES ARE INDICATED, DYNAMIC OUTLINES ARE NOT SHOWN.

metro — DOUBLE BOX SECTION TANGENT TRACK	DRAWING NO. FIGURE 11.15	
	SCALE N.T.S.	SHEET NO. 1 of 1
DEPARTMENT OF TRANSIT INFRASTRUCTURE AND ENGINEERING SERVICES		CONTRACT NO. N/A

FIGURE 11.15

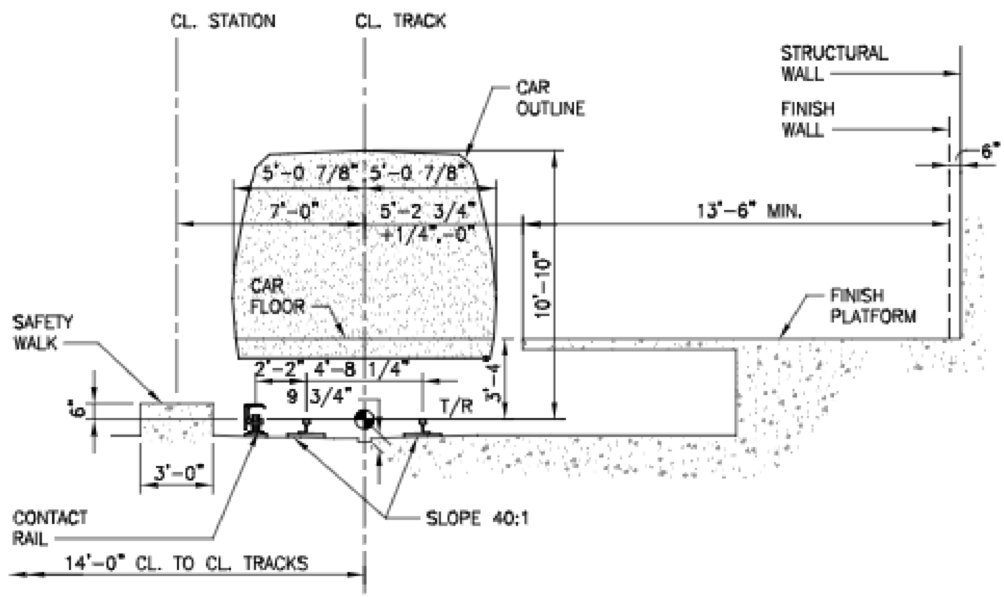


NOTES:

1. PLATFORM WIDTH: 30'-0 1/2" MINIMUM OR AS NECESSARY TO ACCOMMODATE PROJECTED PLATFORM PASSENGER LOADS.
2. CAR OUTLINE IS INDICATED, DYNAMIC OUTLINE IS NOT SHOWN.
3. ELECTRICAL CONTACT RAIL TO BE LOCATED ON SIDE OF TRACK OPPOSITE THE PLATFORM.

metro — STATION CLEARANCES CENTER PLATFORM STATION	DRAWING NO. FIGURE 11.16	
	SCALE N.T.S.	SHEET NO. 1 of 1
DEPARTMENT OF TRANSIT INFRASTRUCTURE AND ENGINEERING SERVICES		CONTRACT NO. N/A

FIGURE 11.16



NOTES:

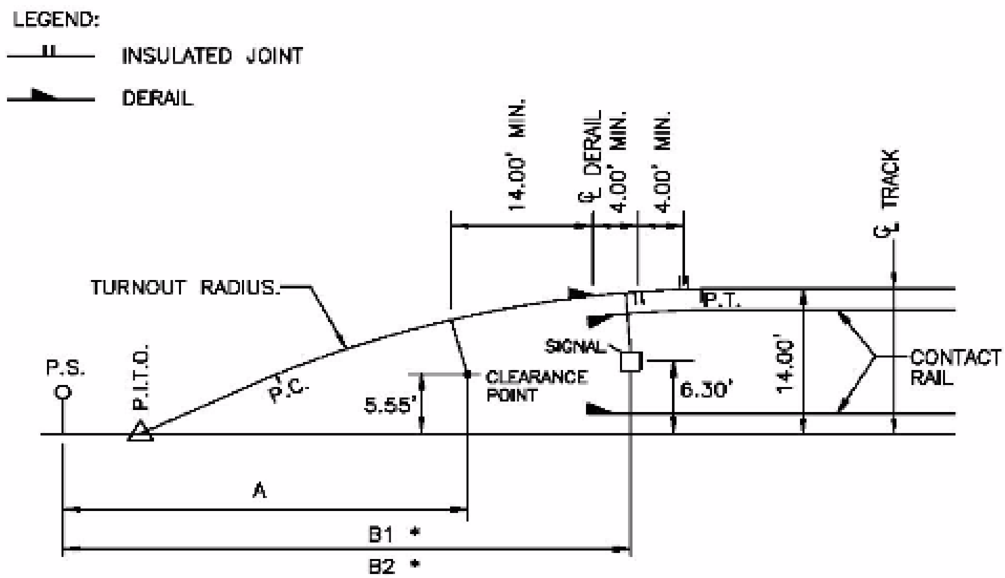
1. PLATFORM WIDTH: 13'-6" MINIMUM OR AS NECESSARY TO ACCOMMODATE PROJECTED PLATFORM PASSENGER LOADS.

2. CAR OUTLINE IS INDICATED. DYNAMIC OUTLINE IS NOT SHOWN.

3. ELECTRICAL CONTACT RAIL TO BE LOCATED ON SIDE OF TRACK OPPOSITE THE PLATFORM.

metro — STATION CLEARANCES SIDE PLATFORM STATION	DRAWING NO. FIGURE 11.17	
	SCALE N.T.S.	SHEET NO. 1 of 1
DEPARTMENT OF TRANSIT INFRASTRUCTURE AND ENGINEERING SERVICES		CONTRACT NO. N/A

FIGURE 11.17



SIGNAL IS LOCATED WITH MINIMUM CLEARANCE AND A 1 FOOT WIDE SIGNAL HEAD.

T.O. NO.	A	B1 (Min.)	B2 (Min.)
6	102'	111'	111'
8	137'	150'	150'
10	158'	175'	175'
15	221'	247'	250'

* IF EITHER CONTACT RAIL IS TO THE INSIDE (AS SHOWN) THEN B2 APPLIES.

NOTE:

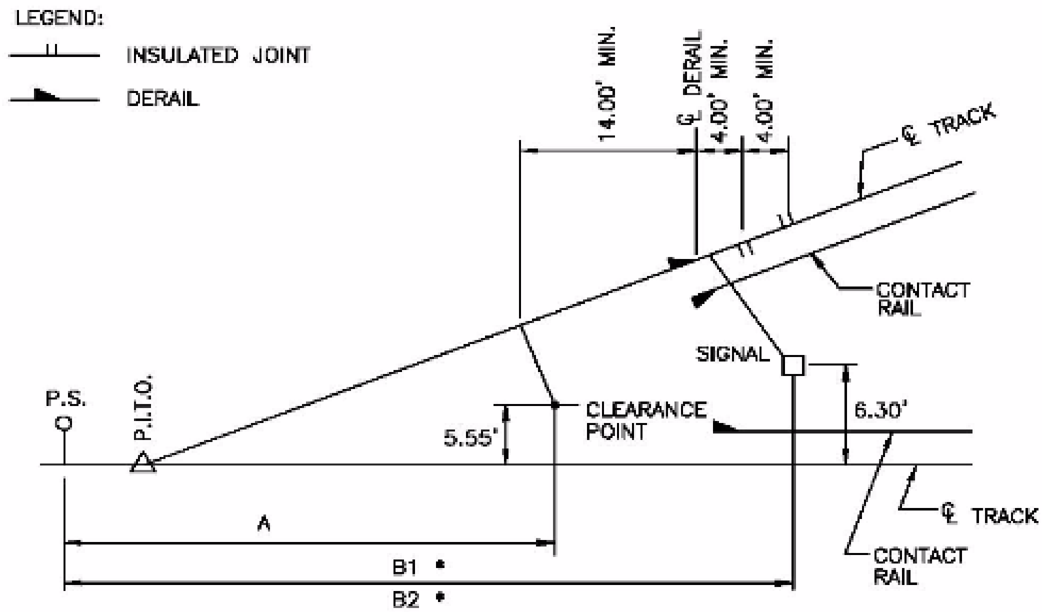
IF DERAIL IS NOT REQUIRED, THE INSULATED JOINT NEAREST THE P.S. SHALL BE LOCATED NOT LESS THAN 14.00' BEHIND THE CLEARANCE POINT. THE SECOND INSULATED JOINT, IF REQUIRED, SHALL BE LOCATED IN THE OPPOSITE RAIL 4.00' BEHIND THE FIRST INSULATED JOINT.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING
DEVELOPMENT ENGINEERING & CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES

CLEARANCE FOR TURNOUTS TO PARALLEL SIDINGS ON 14 FOOT TRACK CENTERS

FIGURE 11.18



SIGNAL IS LOCATED WITH MINIMUM CLEARANCE AND A 1 FOOT WIDE SIGNAL HEAD.

T.O. NO.	A	B1 (Min.)	B2 (Min.)
6	85'	94'	110'
8	118'	130'	140' YARD 150' M/L
10	141'	155'	175'
15	204'	224'	250'

* IF EITHER CONTACT RAIL IS TO THE INSIDE (AS SHOWN) THEN B2 APPLIES.

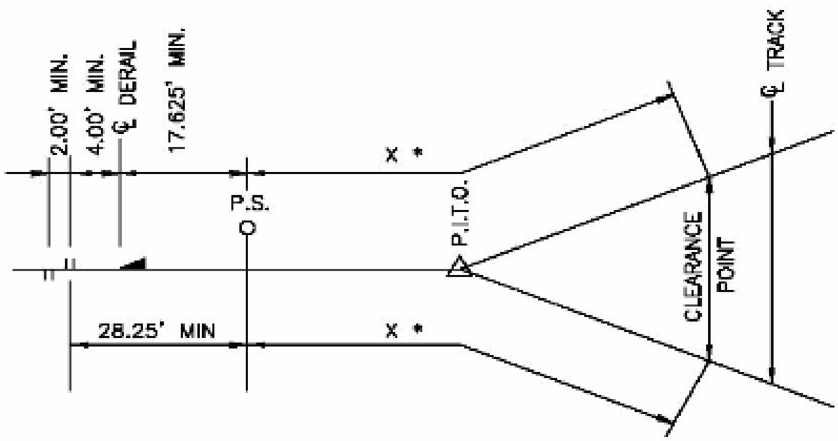
NOTE:

IF DERAIL IS NOT REQUIRED, THE INSULATED JOINT NEAREST THE P.S. SHALL BE LOCATED NOT LESS THAN 14.00' BEHIND THE CLEARANCE POINT. THE SECOND INSULATED JOINT, IF REQUIRED, SHALL BE LOCATED IN THE OPPOSITE RAIL 4.00' BEHIND THE FIRST INSULATED JOINT.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES	CLEARANCE FOR TURNOUTS WITH TANGENT TRACKS BEYOND THE FROG

FIGURE 11.19



LEGEND:

INSULATED JOINT

DERAIL

T.O. NO.	X
4-Y	75'
6-Y	99'

X * IS MEASURED ALONG THE CENTERLINE OF TRACK FROM P.S. TO P.I.T.O. AND THENCE TO THE CLEARANCE POINT.

NOTE:

IF THE DERAIL IS NOT REQUIRED, THE FIRST INSULATED JOINT SHALL BE 5.75' FROM THE P.S. AND THE SECOND INSULATED JOINT SHALL BE LOCATED IN THE OPPOSITE RAIL 2.00' BEHIND THE FIRST INSULATED JOINT.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING
DEVELOPMENT ENGINEERING & CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES

CLEARANCE FOR EQUILATERAL TURNOUTS WITH TANGENT TRACKS BEYOND THE FROG

FIGURE 11.20

NO. OF TURNOUT	SWITCH RAIL LENGTH	TYPE OF SWITCH	SPEED THROUGH TURNOUT		
			NORMAL OPERATING SPEED	MAXIMUM OPERATING SPEED	CRITICAL SPEED
NO. 4–Y	11'–0"	EQUILATERAL	15	16	18.5
NO. 6	11'–0"	STRAIGHT	15	16.5	19.0
NO. 6–Y	13'–0"	EQUILATERAL	22	25.6	29.6
NO. 8	16'–6"	STRAIGHT	22	22.7	26.3
NO. 10	19'–6"	CURVED	28	30.0	34.7
NO. 15	26'–0"	CURVED	40	45.8	52.9

NOTES:

1. NORMAL OPERATING SPEED IS THE NEAREST ATC SPEED COMMAND BELOW MAXIMUM OPERATING SPEED.
2. MAXIMUM OPERATING SPEED IS BASED ON Eu= 4 1/2" AND IS DETERMINED USING THE LEAD RADIUS AND THE SWITCH RADIUS (FOR CURVED SWITCHES) OR THEORETICAL SWITCH RADIUS (FOR STRAIGHT SWITCHES) WITH THE MOST RESTRICTIVE SPEED GOVERNING.
3. CRITICAL SPEED IS BASED ON Eu= 6" AND IS THE MAXIMUM SAFE SPEED.

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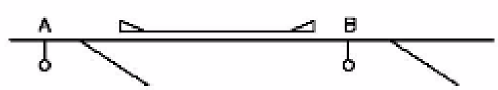
SPEED THROUGH TURNOUTS

FIGURE 11.21

BACK–TO–POINT TURNOUTS OF SAME HAND

TURNOUT & HAND		11'–0" END APPROACH	5'–6" END APPROACH
A	B		
6R	6R	N.A.	84.58'
6L	6L	"	"
6R	8R	"	"
6L	8L	"	"
6R	10R	"	"
6L	10L	"	"
6R	15R	"	"
6L	15L	"	"
8R	8R	112.44'	112.44'
8L	8L	"	"
8R	10R	"	"
8L	10L	"	"
8R	15R	"	"
8L	15L	"	"
10R	10R	140.35'	140.35'
10L	10L	"	"
10R	15R	"	"
10L	15L	"	"
15R	15R	210.23'	210.35'
15L	15L	"	"



NOTE: CONTACT RAIL IS REQUIRED IN ALL THE ABOVE CASES.

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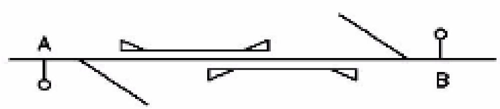
DIVISION OF PLANNING
DEVELOPMENT ENGINEERING & CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES

REQUIRED DISTANCES BETWEEN SWITCH POINTS–I

FIGURE 11.22

BACK–TO–POINT TURNOUTS OF SAME HAND

TURNOUT & HAND		11'–0" END APPROACH	5'–6" END APPROACH
A	B		
6R	6R	N.A.	168.0'
6L	6L	"	"
6R	8R	"	194.0'
6L	8L	"	"
6R	10R	"	224.0'
6L	10L	"	"
6R	15R	"	284.0'
6L	15L	"	"
8R	8R	220.0'	220.0'
8L	8L	"	"
8R	10R	250.0'	250.0'
8L	10L	"	"
8R	15R	310.0'	310.0'
8L	15L	"	"
10R	10R	280.0'	280.0'
10L	10L	"	"
10R	15R	340.0'	340.0'
10L	15L	"	"
15R	15R	400.0'	400.0'
15L	15L	"	"



NOTE: CONTACT RAIL IS REQUIRED IN ALL THE ABOVE CASES.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

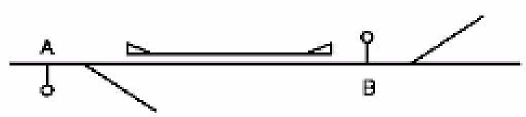
DIVISION OF PLANNING
DEVELOPMENT ENGINEERING & CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES

REQUIRED DISTANCES BETWEEN SWITCH POINTS–II

FIGURE 11.23

BACK–TO–POINT TURNOUTS OF OPPOSITE HAND
(LARGER FROG ANGLE LEADING)

TURNOUT & HAND		11'–0" END APPROACH		5'–6" END APPROACH	
A	B	MINIMUM	DESIRED	MINIMUM	DESIRED
6R	6L	N.A.	N.A.	81.71'	82.00'
6L	6R	"	"	"	"
6R	8L	"	"	85.00'*	85.00'*
6L	8R	"	"	"	"
6R	10L	"	"	81.58'	81.88'
6L	10R	"	"	"	"
6R	15L	"	"	"	91.33'
6L	15R	"	"	"	"
8R	8L	104.08'	109.00'	104.08'	109.00'
8L	8R	"	"	"	"
8R	10L	"	"	"	"
8L	10R	"	"	"	"
8R	15L	"	118.46'	"	118.46'
8L	15R	"	"	"	"
10R	10L	116.92'	127.44'	116.92'	127.44'
10L	10R	"	"	"	"
10R	15L	"	136.90'	"	136.90'
10L	15R	"	"	"	"
15R	15L	154.23'	183.13'	154.23'	183.13'
15L	15R	"	"	"	"



NOTE: CONTACT RAIL IS REQUIRED IN ALL THE ABOVE CASES.
* CONTACT RAIL REQUIREMENTS GOVERN.

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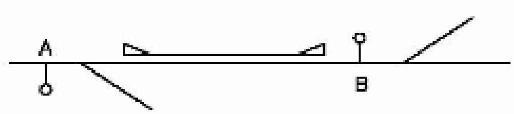
DIVISION OF PLANNING
DEVELOPMENT ENGINEERING & CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES

REQUIRED DISTANCES BETWEEN SWITCH POINTS–III

FIGURE 11.24

BACK–TO–POINT TURNOUTS OF OPPOSITE HAND
(SMALLER FROG ANGLE LEADING)

TURNOUT & HAND		11'–0" END APPROACH		5'–6" END APPROACH	
A	B	MINIMUM	DESIRED	MINIMUM	DESIRED
6R	6L	N.A.	N.A.	81.71'	82.00'
6L	6R	"	"	"	"
8R	6L	"	"	104.21'	109.13'
8L	6R	"	"	"	"
8R	8L	104.08'	109.00'	104.08'	109.00'
8L	8R	"	"	"	"
10R	6L	N.A.	N.A.	117.04'	127.56'
10L	6R	"	"	"	"
10R	8L	116.92'	127.44'	116.92'	127.44'
10L	8R	"	"	"	"
10R	10L	"	"	"	"
10L	10R	"	"	"	"
15R	6L	N.A.	N.A.	154.35'	173.79'
15L	6R	"	"	"	"
15R	8L	154.23'	173.67'	154.23'	173.67'
15L	8R	"	"	"	"
15R	10L	"	"	"	"
15L	10R	"	"	"	"
15R	15L	"	183.13'	"	183.13'
15L	15R	"	"	"	"



NOTE: CONTACT RAIL IS REQUIRED IN ALL THE ABOVE CASES.

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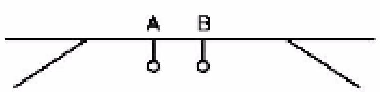
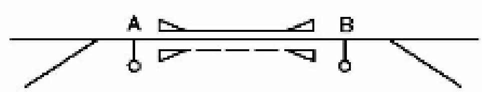
REQUIRED DISTANCES
BETWEEN SWITCH POINTS–IV

FIGURE 11.25

POINT–TO–POINT TURNOUTS OF OPPOSITE HAND

TURNOUT		REQ'D DIST. W/O SPACER RAIL OR CONTACT RAIL	MINIMUM DISTANCES WITH SPACER RAIL AND CONTACT RAIL	
A	B		11'–0" APPROACH	5'–6" APPROACH
4Y	4Y	N.A.	N.A.	76.0'
4Y	6R	"	"	"
4Y	8R	"	"	"
4Y	10R	"	"	83.0'
4Y	15R	"	"	111.0'
6 R/L	6 L/R	11.53'	"	61.0'
6 R/L	8 L/R	11.41'	"	71.0'
6 R/L	10 L/R	"	"	62.0'
6 R/L	15 L/R	N.A.	"	"
8 R/L	8 L/R	11.28'	95.0'	81.0'
8 R/L	10 L/R	"	86.0'	72.0'
8 R/L	15 L/R	N.A.	"	"
10 R/L	10 L/R	"	77.0'	63.0'
10 R/L	15 L/R	"	"	"
15 R/L	15 L/R	"	"	"





NOTE: SPACER RAIL IS A 19' LENGTH OF RAIL PLACED BETWEEN THE STOCK RAILS OF THE POINT–TO–POINT TURNOUTS.

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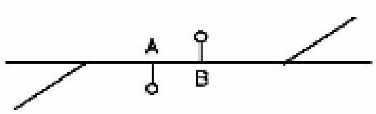
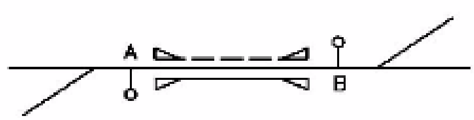
REQUIRED DISTANCES BETWEEN SWITCH POINTS–V

FIGURE 11.26

POINT–TO–POINT TURNOUTS OF SAME HAND

TURNOUT		REQ'D DIST. W/O SPACER RAIL OR CONTACT RAIL	MINIMUM DISTANCES WITH SPACER RAIL AND CONTACT RAIL	
A	B		11'–0" APPROACH	5'–6" APPROACH
4Y	4Y	N.A.	N.A.	76.0'
4Y	6L	"	"	62.0'
4Y	8L	"	"	72.0'
4Y	10L	"	"	63.0'
4Y	15L	"	"	"
6 L/R	6 L/R	13.53'	"	61.0'
6 L/R	8 L/R	13.41'	"	71.0'
6 L/R	10 L/R	"	"	62.0'
6 L/R	15 L/R	N.A.	"	"
8 L/R	8 L/R	13.28'	95.0'	81.0'
8 L/R	10 L/R	"	86.0'	72.0'
8 L/R	15 L/R	N.A.	"	"
10 L/R	10 L/R	"	77.0'	63.0'
10 L/R	15 L/R	"	"	"
15 L/R	15 L/R	"	"	"





NOTE: SPACER RAIL IS A 19' LENGTH OF RAIL PLACED BETWEEN THE STOCK RAILS OF THE POINT–TO–POINT TURNOUTS.

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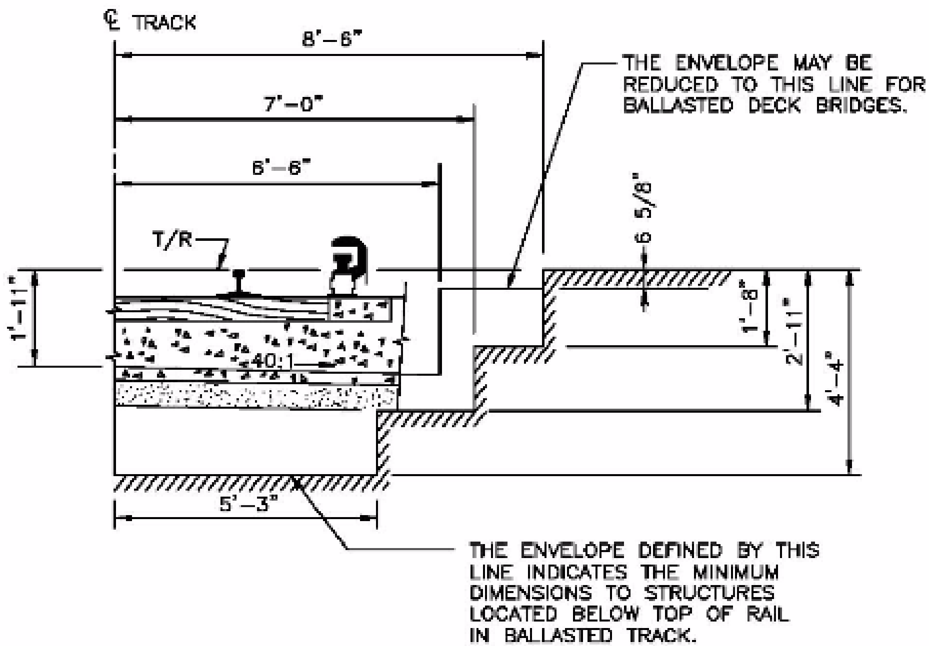
REQUIRED DISTANCES BETWEEN SWITCH POINTS–VI

FIGURE 11.27



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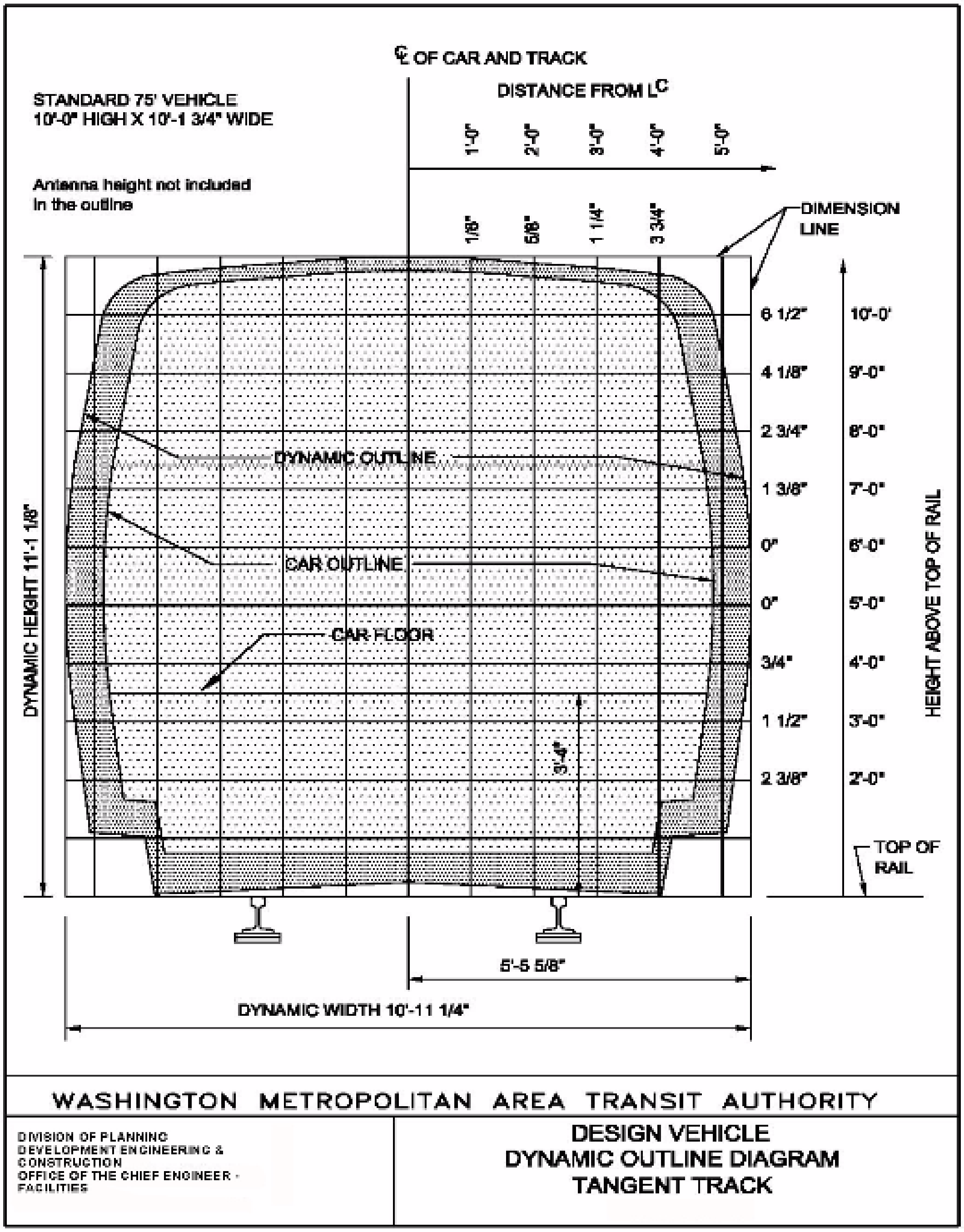
DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES	CLEARANCE ENVELOPE FOR STRUCTURES BELOW T/R IN BALLASTED TRACK

FIGURE 11.28



℄ OF CAR AND TRACK
STANDARD 75' VEHICLE
10'-0" HIGH X 10'-1 3/4" WIDE
DISTANCE FROM ℄
1'-0"
2'-0"
3'-0"
4'-0"
5'-0"
Antenna height not included
in the outline
1/8"
5/8"
1 1/4"
3 3/4"
DIMENSION
LINE
6 1/2"
4 1/8"
2 3/4"
1 3/8"
0"
0"
3/4"
1 1/2"
2 3/8"
10'-0'
9'-0"
8'-0"
7'-0"
6'-0"
5'-0"
4'-0"
3'-0"
2'-0"
HEIGHT ABOVE TOP OF RAIL
DYNAMIC OUTLINE
CAR OUTLINE
CAR FLOOR
DYNAMIC HEIGHT 11'-1 1/8"
3'-4"
TOP OF
RAIL
5'-5 5/8"
DYNAMIC WIDTH 10'-11 1/4"
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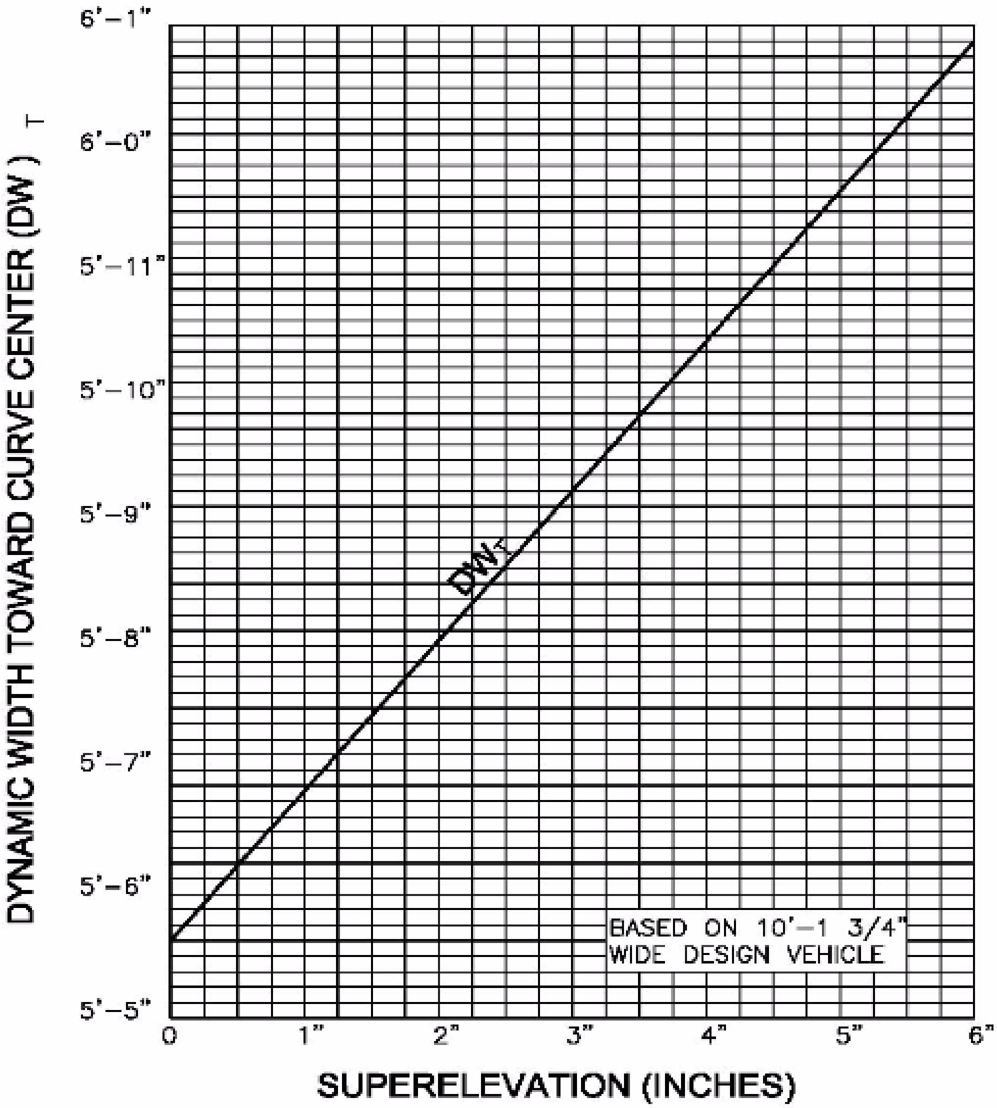
OFFICE OF THE CHIEF ENGINEER -
FACILITIES
DESIGN VEHICLE
DYNAMIC OUTLINE DIAGRAM
TANGENT TRACK

FIGURE 11.29



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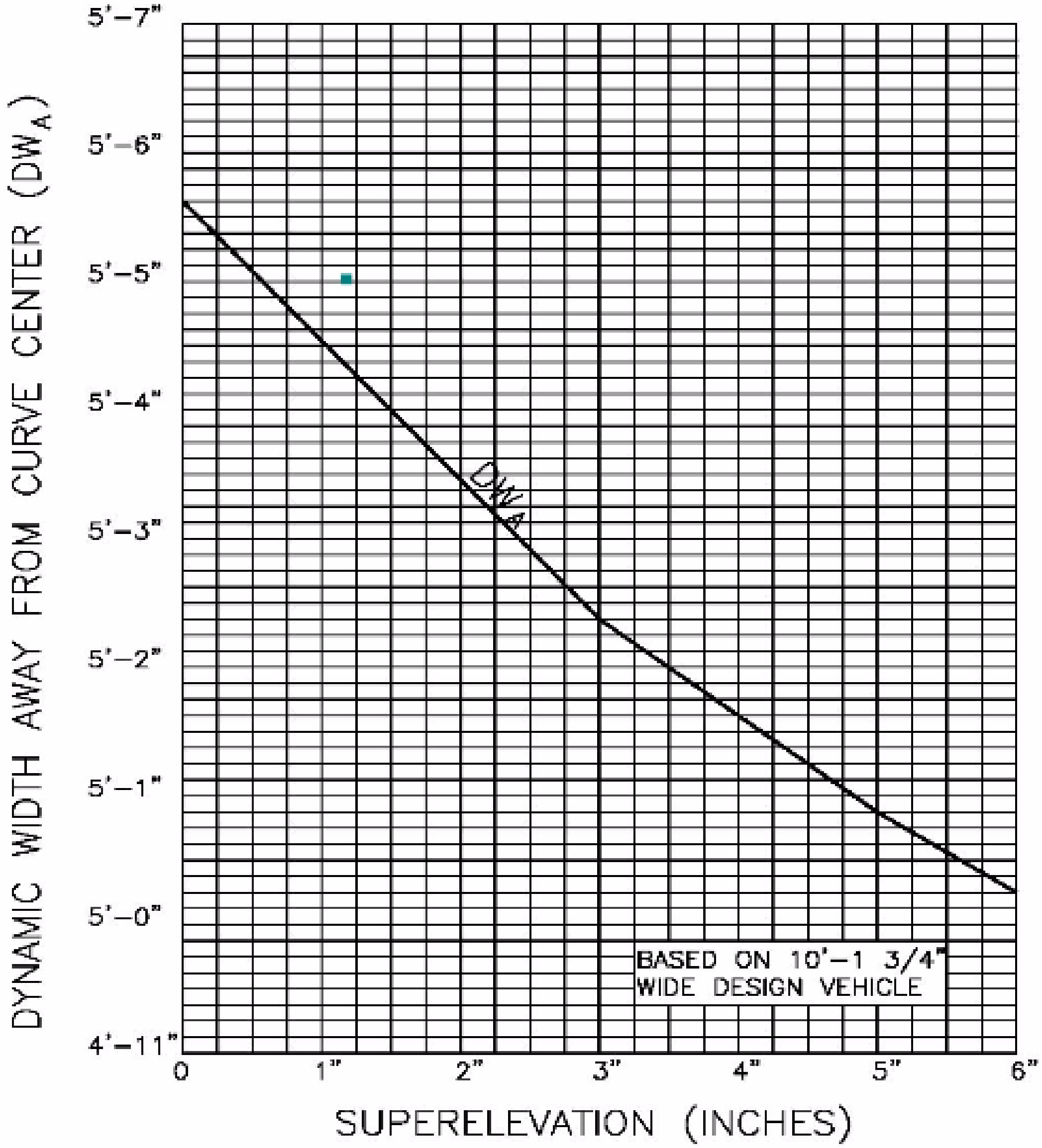
DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES	DYNAMIC WIDTH TOWARD CURVE CENTER

FIGURE 11.30



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DIVISION OF PLANNING
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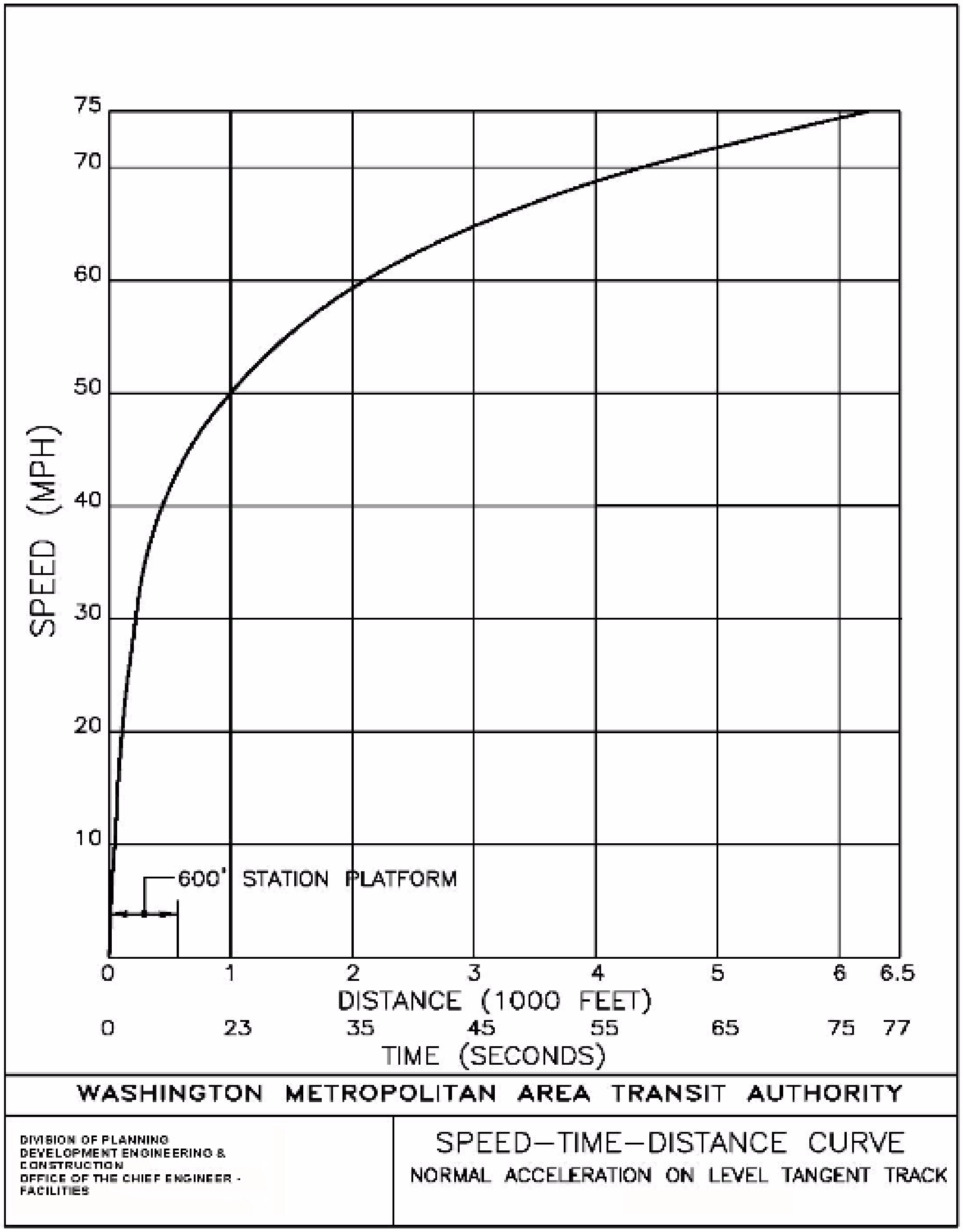
OFFICE OF THE CHIEF ENGINEER - FACILITIES

DYNAMIC WIDTH
AWAY FROM CURVE CENTER

FIGURE 11.31



75
70
60
50
40
30
20
10
SPEED (MPH)
600' STATION PLATFORM
0 1 2 3 4 5 6 6.5
DISTANCE (1000 FEET)
0 23 35 45 55 65 75 77
TIME (SECONDS)
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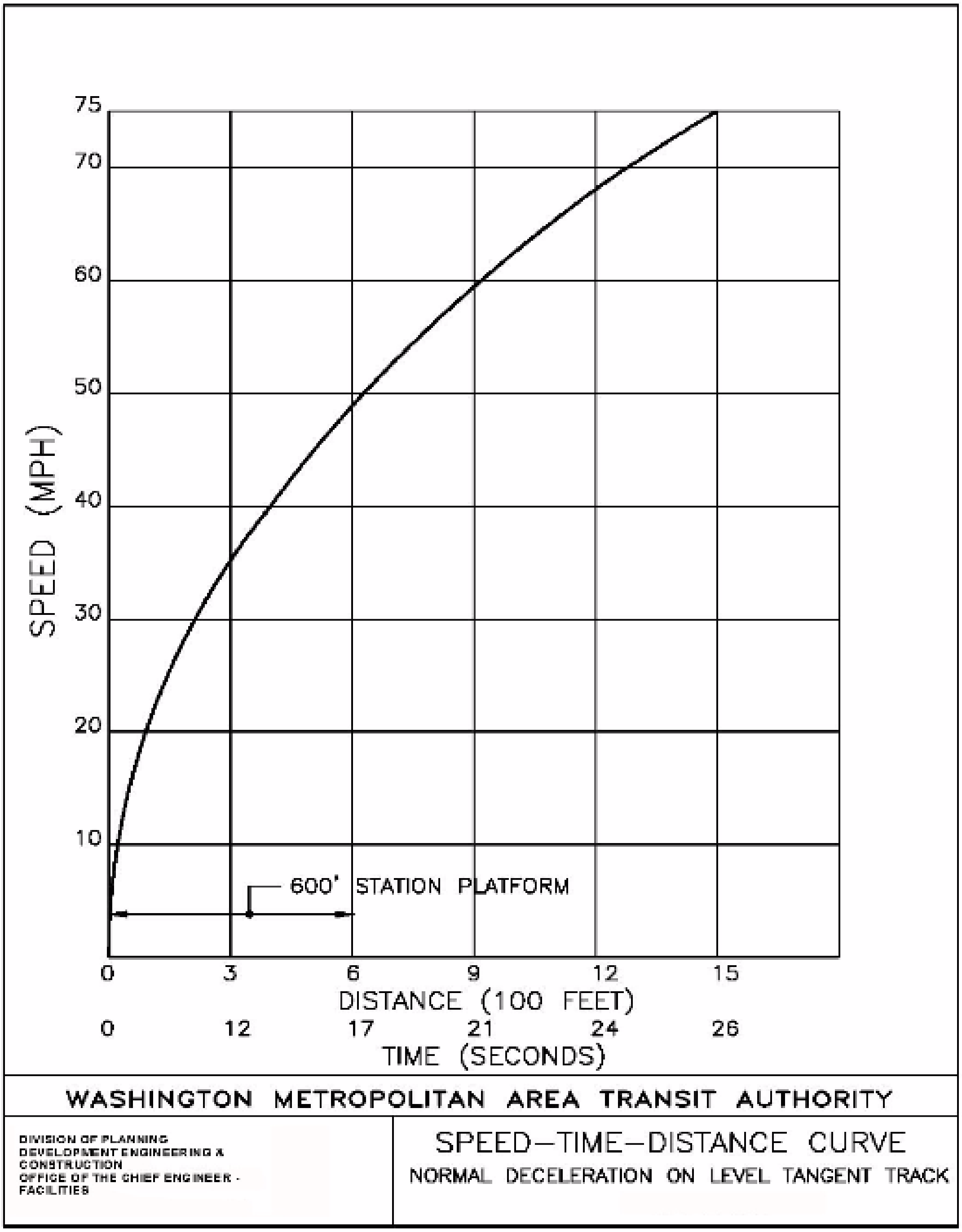
FACILITIES
SPEED—TIME—DISTANCE CURVE
NORMAL ACCELERATION ON LEVEL TANGENT TRACK

FIGURE 11.32


SPEED (MPH)
75
70
60
50
40
30
20
10
600' STATION PLATFORM
0 3 6 9 12 15
DISTANCE (100 FEET)
0 12 17 21 24 26
TIME (SECONDS)
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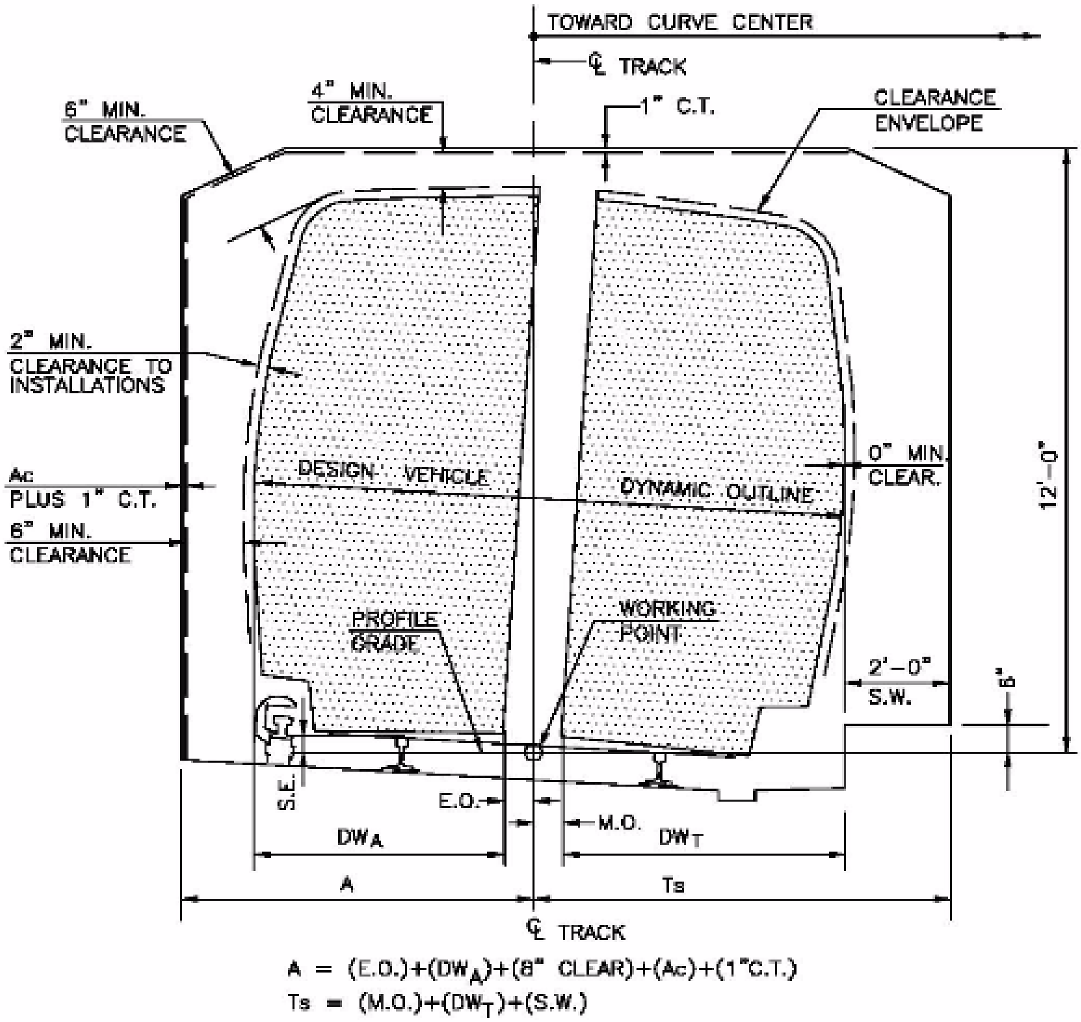
CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER -
FACILITIES
SPEED—TIME—DISTANCE CURVE
NORMAL DECELERATION ON LEVEL TANGENT TRACK

FIGURE 11.33



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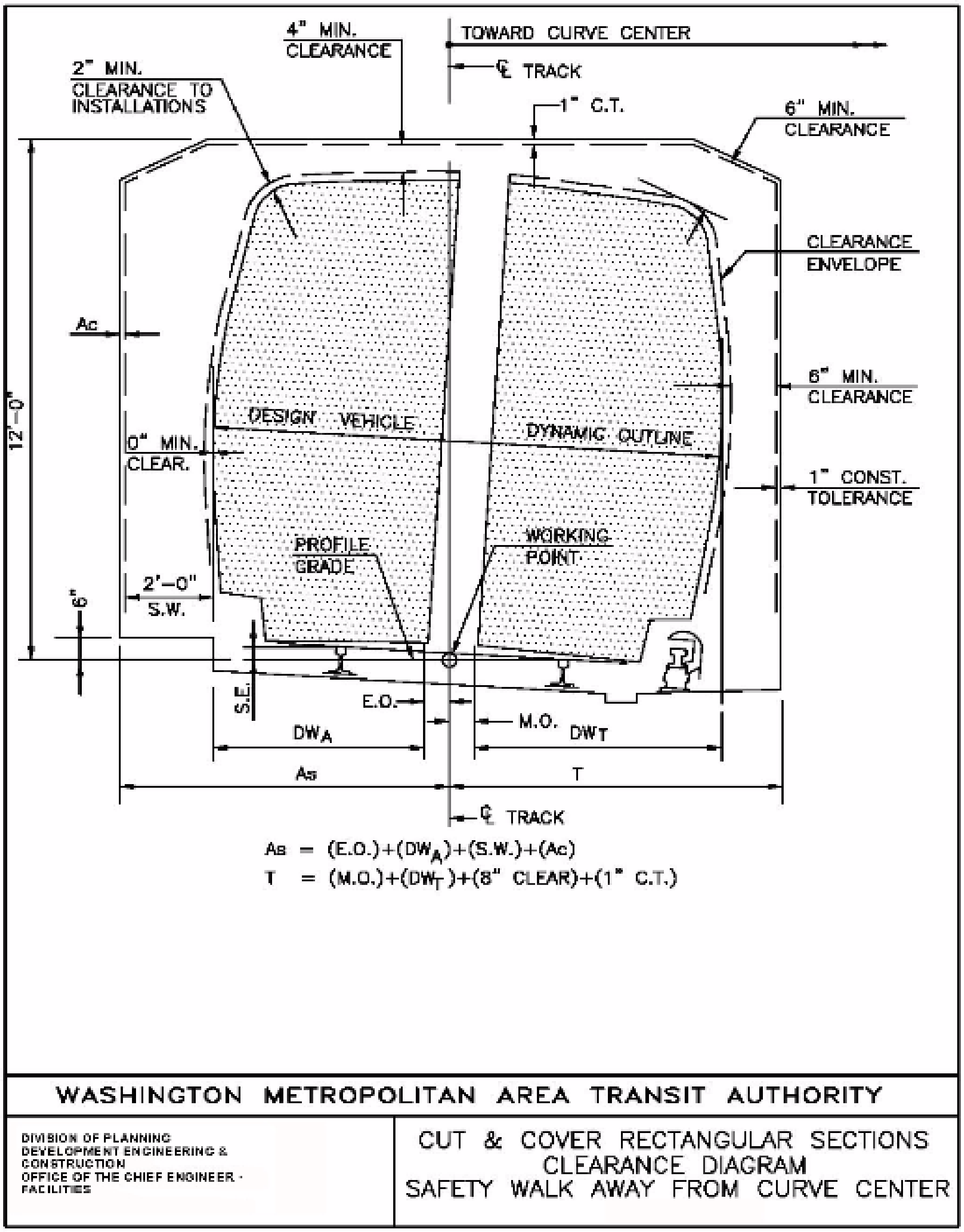
DIVISION OF PLANNING
DEVELOPMENT ENGINEERING X
CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES

CUT & COVER RECTANGULAR SECTIONS
CLEARANCE DIAGRAM
SAFETY WALK TOWARD CURVE CENTER

FIGURE 11.34


4" MIN.
CLEARANCE
TOWARD CURVE CENTER
2" MIN.
CLEARANCE TO
INSTALLATIONS
℄ TRACK
1" C.T.
6" MIN.
CLEARANCE
CLEARANCE
ENVELOPE
Ac
6" MIN.
CLEARANCE
12'-0"
DESIGN VEHICLE
DYNAMIC OUTLINE
0" MIN.
CLEAR.
1" CONST.
TOLERANCE
PROFILE
GRADE
WORKING
POINT
2'-0"
S.W.
6"
S.E.
E.O.
M.O.
DWA
DWT
As
T
℄ TRACK
As = (E.O.)+(DWA)+(S.W.)+(Ac)
T = (M.O.)+(DWT)+(8" CLEAR)+(1" C.T.)
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CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER -
FACILITIES
CUT & COVER RECTANGULAR SECTIONS
CLEARANCE DIAGRAM
SAFETY WALK AWAY FROM CURVE CENTER

FIGURE 11.35

RADIUS	SUPERELEVATION=0"				SUPERELEVATION=1"			
	A	Ts	As	T	A	Ts	As	T
200'	8'-4 1/4"	9'-2"	9'-7 1/4"	7'-11"	8'-3 1/4"	9'-3 1/4"	9'-6 1/4"	8'-0 1/4"
300'	7'-7 1/2"	8'-7 1/8"	8'-10 1/2"	7'-4 1/8"	7'-6 1/2	8'-8 3/8"	8'-9 1/2"	7'-5 3/8"
400'	7'-3 1/4"	8'-3 3/4"	8'-6 1/4"	7'-0 3/4"	7'-2 1/4"	8'-5"	8'-5 1/4"	7'-2"
500'	7'-0 3/4"	8'-1 3/4"	8'-3 3/4"	6'-10 3/4"	6'-11 3/4"	8'-3"	8'-2 3/4"	7'-0"
600'	6'-11"	8'-0 3/8"	8'-2"	6'-9 3/8"	6'-10"	8'-1 5/8"	8'-1"	6'-10 5/8"
700'	6'-9 3/4"	7'-11 3/8"	8'-0 3/4"	6'-8 3/8"	6'-8 3/4"	8'-0 5/8"	7'-11 3/4"	6'-9 5/8"
800'	6'-9"	7'-10 3/4"	8'-0"	6'-7 3/4"	6'-8"	8'-0"	7'-11"	6'-9"
1000'	6'-7 3/4"	7'-9 3/4"	7'-10 3/4"	6'-6 3/4"	6'-6 3/4"	7'-11"	7'-9 3/4"	6'-8"
1200'	6'-6 7/8"	7'-9"	7'-9 7/8"	6'-6"	6'-5 7/8"	7'-10 1/4"	7'-8 7/8"	6'-7 1/4"
1400'	6'-6 1/4"	7'-8 1/2"	7'-9 1/4"	6'-5 1/2"	6'-5 1/4"	7'-9 3/4"	7'-8 1/4"	6'-6 3/4"
1600'	6'-5 3/4"	7'-8 1/8"	7'-8 3/4"	6'-5 1/8"	6'-4 3/4"	7'-9 3/8"	7'-7 3/4"	6'-6 3/8"
1800'	6'-5 3/8"	7'-7 7/8"	7'-8 3/8"	6'-4 7/8"	6'-4 3/8"	7'-9 1/8"	7'-7 3/8"	6'-6 1/8"
2000'	6'-5 1/8"	7'-7 5/8"	7'-8 1/8"	6'-4 5/8"	6'-4 1/8"	7'-8 7/8"	7'-7 1/8"	6'-5 7/8"
2500'	6'-5 3/4"	7'-7 1/4"	7'-8 3/4"	6'-4 1/4"	6'-4 3/4"	7'-8 1/2"	7'-7 3/4"	6'-5 1/2"
3000'	6'-5 1/4"	7'-7"	7'-8 1/4"	6'-4"	6'-4 1/4"	7'-8 1/4"	7'-7 1/4"	6'-5 1/4"
4000'	6'-4 5/8"	7'-6 5/8"	7'-7 5/8"	6'-3 5/8"	6'-3 5/8"	7'-7 7/8"	7'-6 5/8"	6'-4 7/8"
5000'	6'-4 1/4"	7'-6 3/8"	7'-7 1/4"	6'-3 3/8"	6'-3 1/4"	7'-7 3/4"	7'-6 1/4"	6'-4 3/4"
6000'	6'-3 7/8"	7'-6 1/4"	7'-6 7/8"	6'-3 1/4"	6'-2 7/8"	7'-7 1/2"	7'-5 7/8"	6'-4 1/2"
7000'	6'-3 3/4"	7'-6 1/4"	7'-6 3/4"	6'-3 1/4"	6'-2 3/4"	7'-7 1/2"	7'-5 3/4"	6'-4 1/2"
8000'	6'-3 5/8"	7'-6 1/8"	7'-6 5/8"	6'-3 1/8"	6'-2 5/8"	7'-7 3/8"	7'-5 5/8"	6'-4 3/8"
9000'	6'-3 1/2"	7'-6 1/8"	7'-6 1/2"	6'-3 1/8"	6'-2 1/2"	7'-7 3/8"	7'-5 1/2"	6'-4 3/8"
10,000'	6'-3 1/2"	7'-6 1/8"	7'-6 1/2"	6'-3 1/8"	6'-2 3/8"	7'-7 1/4"	7'-5 3/8"	6'-4 1/4"
15,000'	6'-3 1/4"	7'-6"	7'-6 1/4"	6'-3"	6'-2 1/8"	7'-7 1/8"	7'-5 1/8"	6'-4 1/8"
25,000'	6'-3"	7'-6"	7'-6"	6'-3"	6'-1 7/8"	7'-7"	7'-4 7/8"	6'-4"
TANGENT	6'-3"	7'-6"	7'-6"	6'-3"				

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FIGURE 11.36

RADIUS	SUPERELEVATION=2"				SUPERELEVATION=3"			
	A	Ts	As	T	A	Ts	As	T
200'	8'-2 1/8"	9'-4 3/8"	9'-5 1/8"	8'-1 3/8"	8'-1"	9'-5 5/8"	9'-4"	8'-2 5/8"
300'	7'-5 3/8"	8'-9 1/2"	8'-8 3/8"	7'-6 1/2"	7'-4 1/4"	8'-10 3/4"	8'-7 1/4"	7'-7 3/4"
400'	7'-1 1/8"	8'-5 1/8"	8'-4 1/8"	7'-3 1/8"	7'-0"	8'-7 3/8"	8'-3"	7'-4 3/8"
500'	6'-10 5/8"	8'-4 1/8"	8'-1 5/8"	7'-1 1/8"	6'-9 1/2"	8'-5 3/8"	8'-0 1/2"	7'-2 3/8"
600'	6'-8 7/8"	8'-2 3/4"	7'-11 7/8"	6'-11 3/4"	6'-7 3/4"	8'-4"	7'-10 3/4"	7'-1"
700'	6'-7 5/8"	8'-1 3/4"	7'-10 5/8"	6'-10 3/4"	6'-6 1/2"	8'-3"	7'-9 1/2"	7'-0"
800'	6'-6 7/8"	8'-1 1/8"	7'-9 7/8"	6'-10 1/8"	6'-5 3/4"	8'-2 3/8"	7'-8 3/4"	6'-11 3/8"
1000'	6'-5 5/8"	8'-0 1/8"	7'-8 5/8"	6'-9 1/8"	6'-4 1/2"	8'-1 3/8"	7'-7 1/2"	6'-10 3/8"
1200'	6'-4 3/4"	7'-11 3/8"	7'-7 3/4"	6'-8 3/8"	6'-3 5/8"	8'-0 5/8"	7'-6 5/8"	6'-9 5/8"
1400'	6'-4 1/8"	7'-10 7/8"	7'-7 1/8"	6'-7 7/8"	6'-3"	8'-0 1/8"	7'-6"	6'-9 1/8"
1600'	6'-3 5/8"	7'-10 1/2"	7'-6 5/8"	6'-7 1/2"	6'-2 1/2"	7'-11 3/4"	7'-5 1/2"	6'-8 3/4"
1800'	6'-3 1/4"	7'-10 1/4"	7'-6 1/4"	6'-7 1/4"	6'-2 1/8"	7'-11 1/2"	7'-5 1/8"	6'-8 1/2"
2000'	6'-3"	7'-10"	7'-6"	6'-7"	6'-1 7/8"	7'-11 1/4"	7'-4 7/8"	6'-8 1/4"
2500'	6'-3 5/8"	7'-9 5/8"	7'-6 5/8"	6'-6 5/8"	6'-2 1/2"	7'-10 7/8"	7'-5 1/2"	6'-7 7/8"
3000'	6'-3 1/8"	7'-9 3/8"	7'-6 1/8"	6'-6 3/8"	6'-2"	7'-10 5/8"	7'-5"	6'-7 5/8"
4000'	6'-2 1/2"	7'-9"	7'-5 1/2"	6'-6"	6'-1 3/8"	7'-10 1/4"	7'-4 3/8"	6'-7 1/4"
5000'	6'-2 1/8"	7'-8 7/8"	7'-5 1/8"	6'-5 7/8"	6'-1"	7'-10 1/8"	7'-4"	6'-7 1/8"
6000'	6'-1 3/4"	7'-8 5/8"	7'-4 3/4"	6'-5 5/8"	6'-0 5/8"	7'-9 7/8"	7'-3 5/8"	6'-6 7/8"
7000'	6'-1 5/8"	7'-8 5/8"	7'-4 5/8"	6'-5 5/8"	6'-0 1/2"	7'-9 7/8"	7'-3 1/2"	6'-6 7/8"
8000'	6'-1 1/2"	7'-8 1/2"	7'-4 1/2"	6'-5 1/2"	6'-0 3/8"	7'-9 3/4"	7'-3 3/8"	6'-6 3/4"
9000'	6'-1 3/8"	7'-8 1/2"	7'-4 3/8"	6'-5 1/2"				
10,000'	6'-1 1/4"	7'-8 3/8"	7'-4 1/4"	6'-5 3/8"				
15,000'	6'-1"	7'-8 1/4"	7'-4"	6'-5 1/4"				

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FIGURE 11.37

RADIUS	SUPERELEVATION=4"							
	A	Ts	As	T				
200'	8'-0 1/4"	9'-6 7/8"	9'-3 1/4"	8'-3 7/8"				
300'	7'-3 1/2"	9'-0"	8'-6 1/2"	7'-9"				
400'	6'-11 1/4"	8'-8 5/8"	8'-2 1/4"	7'-5 5/8"				
500'	6'-8 3/4"	8'-6 5/8"	7'-11 3/4"	7'-3 5/8"				
600'	6'-7"	8'-5 1/4"	7'-10"	7'-2 1/4"				
700'	6'-5 3/4"	8'-4 1/4"	7'-8 3/4"	7'-1 1/4"				
800'	6'-5"	8'-3 5/8"	7'-8"	7'-0 5/8"				
1000'	6'-3 3/4"	8'-2 5/8"	7'-6 3/4"	6'-11 5/8"				
1200'	6'-2 7/8"	8'-1 7/8"	7'-5 7/8"	6'-10 7/8"				
1400'	6'-2 1/4"	8'-1 3/8"	7'-5 1/4"	6'-10 3/8"				
1600'	6'-1 3/4"	8'-1"	7'-4 3/4"	6'-10"				
1800'	6'-1 3/8"	8'-0 3/4"	7'-4 3/8"	6'-9 3/4"				
2000'	6'-1 1/8"	8'-0 1/2"	7'-4 1/8"	6'-9 1/2"				
2500'	6'-1 3/4"	8'-0 1/8"	7'-4 3/4"	6'-9 1/8"				
3000'	6'-1 1/4"	7'-11 7/8"	7'-4 1/4"	6'-8 7/8"				
4000'	6'-0 5/8"	7'-11 1/2"	7'-3 5/8"	6'-8 1/2"				
5000'	6'-0 1/4"	7'-11 3/8"	7'-3 1/4"	6'-8 3/8"				
6000'	5'-11 7/8"	7'-11 1/8"	7'-2 7/8"	6'-8 1/8"				

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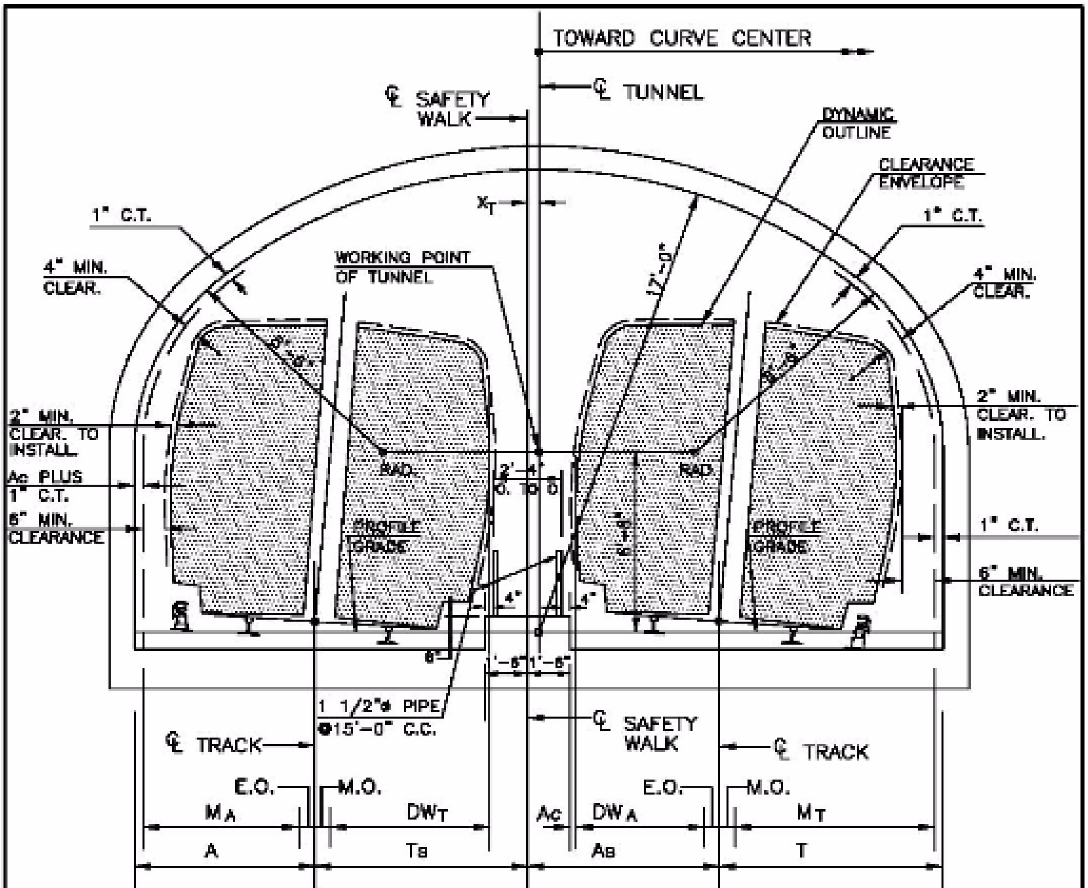
FIGURE 11.38



A = (E.O.)+(M_A)+(Ac)+(1" C.T.)
Ts = (M.O.)+(DW_T)+(1'-6" S.W.)

As = (1'-6" S.W.)+(Ac)+(DW_A)+(E.O.)
T = (M.O.)+(M_T)+(1"C.T.)

NOTES:
FOR A, Ts, As & T VALUES SEE FIGURE III.40 TO III.42.
FOR DW_T & DW_A VALUES SEE FIGURES III.30 & III.31.
FOR X_T VALUES SEE FIGURES III.40 & III.42
FOR M_A & M_T VALUES SEE FIGURES III.40 & III.42.

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DOUBLE TRACK – ROCK TUNNEL
CLEARANCE DIAGRAM
SAFETY WALK BETWEEN TRACKS

FIGURE 11.39

RADIUS	SUPERELEVATION=0"				SUPERELEVATION=1"			
	As	T	A	Ts	As	T	A	Ts
200'	9'-1 1/4"	8'-0"	8'-5 1/8"	8'-8"	9'-0 1/4"	8'-1 7/8"	8'-3 7/8"	8'-9 1/4"
300'	8'-4 1/2"	7'-5 1/8"	7'-8 3/8"	8'-1 1/8"	8'-3 1/2"	7'-7"	7'-7 1/8"	8'-2 3/8"
400'	8'-0 1/4"	7'-1 3/4"	7'-4 1/8"	7'-9 3/4"	7'-11 1/4"	7'-3 5/8"	7'-2 7/8"	7'-11"
500'	7'-9 3/4"	6'-11 3/4"	7'-1 5/8"	7'-7 3/4"	7'-8 3/4"	7'-1 5/8"	7'-0 3/8"	7'-9"
600'	7'-8"	6'-10 3/8"	6'-11 7/8"	7'-6 3/8"	7'-7"	7'-0 1/4"	6'-10 5/8"	7'-7 5/8"
700'	7'-6 3/4"	6'-9 3/8"	6'-10 5/8"	7'-5 3/8"	7'-5 3/4"	6'-11 1/4"	6'-9 3/8"	7'-6 5/8"
800'	7'-6"	6'-8 3/4"	6'-9 7/8"	7'-4 3/4"	7'-5"	6'-10 5/8"	6'-8 5/8"	7'-6"
1000'	7'-4 3/4"	6'-7 3/4"	6'-8 5/8"	7'-3 3/4"	7'-3 3/4"	6'-9 5/8"	6'-7 3/8"	7'-5"
1200'	7'-3 7/8"	6'-7"	6'-7 3/4"	7'-3"	7'-2 7/8"	6'-8 7/8"	6'-6 1/2"	7'-4 1/4"
1400'	7'-3 1/4"	6'-6 1/2"	6'-7 1/8"	7'-2 1/2"	7'-2 1/4"	6'-8 3/8"	6'-5 7/8"	7'-3 3/4"
1600'	7'-2 3/4"	6'-6 1/8"	6'-6 5/8"	7'-2 1/8"	7'-1 3/4"	6'-8"	6'-5 3/8"	7'-3 3/8"
1800'	7'-2 3/8"	6'-5 7/8"	6'-6 1/4"	7'-1 7/8"	7'-1 3/8"	6'-7 3/4"	6'-5"	7'-3 1/8"
2000'	7'-2 1/8"	6'-5 5/8"	6'-6"	7'-1 5/8"	7'-1 1/8"	6'-7 1/2"	6'-4 3/4"	7'-2 7/8"
2500'	7'-2 3/4"	6'-5 1/4"	6'-6 5/8"	7'-1 1/4"	7'-1 3/4"	6'-7 1/8"	6'-5 3/8"	7'-2 1/2"
3000'	7'-2 1/4"	6'-5"	6'-6 1/8"	7'-1"	7'-1 1/4"	6'-6 7/8"	6'-4 7/8"	7'-2 1/4"
4000'	7'-1 5/8"	6'-4 5/8"	6'-5 1/2"	7'-0 5/8"	7'-0 5/8"	6'-6 1/2"	6'-4 1/4"	7'-1 7/8"
5000'	7'-1 1/4"	6'-4 1/2"	6'-5 1/8"	7'-0 1/2"	7'-0 1/4"	6'-6 3/8"	6'-3 7/8"	7'-1 3/4"
6000'	7'-0 7/8"	6'-4 1/4"	6'-4 3/4"	7'-0 1/4"	6'-11 7/8"	6'-6 1/8"	6'-3 1/2"	7'-1 1/2"
7000'	7'-0 3/4"	6'-4 1/4"	6'-4 5/8"	7'-0 1/4"	6'-11 3/4"	6'-6 1/8"	6'-3 3/8"	7'-1 1/2"
8000'	7'-0 5/8"	6'-4 1/8"	6'-4 1/2"	7'-0 1/8"	6'-11 5/8"	6'-6"	6'-3 1/4"	7'-1 3/8"
9000'	7'-0 1/2"	6'-4 1/8"	6'-4 3/8"	7'-0 1/8"	6'-11 1/2"	6'-6"	6'-3 1/8"	7'-1 3/8"
10,000'	7'-0 3/8"	6'-4"	6'-4 1/4"	7'-0"	6'-11 3/8"	6'-5 7/8"	6'-3"	7'-1 1/4"
15,000'	7'-0 1/8"	6'-3 7/8"	6'-4"	6'-11 7/8"	6'-11 1/8"	6'-5 3/4"	6'-2 3/4"	7'-1 1/8"
20,000'	7'-0 1/8"	6'-3 7/8"	6'-4"	6'-11 7/8"	6'-11 1/8"	6'-5 3/4"	6'-2 3/4"	7'-1 1/8"
25,000'	6'-11 7/8"	6'-3 3/4"	6'-3 3/4"	6'-11 3/4"	6'-10 7/8"	6'-5 5/8"	6'-2 1/2"	7'-1"
TANGENT	6'-11 5/8"	6'-3 5/8"	6'-3 5/8"	6'-11 5/8"				

S.E.	X_T	M_A	M_T
0"	0"	6'-2 5/8"	6'-2 5/8"
1"	1/2"	6'-1 1/4"	6'-4 1/2"

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FIGURE 11.40

RADIUS	SUPERELEVATION=2"				SUPERELEVATION=3"			
	As	T	A	Ts	As	T	A	Ts
200'	8'-11 1/8"	8'-3 5/8"	8'-2 5/8"	8'-10 3/8"	8'-10"	8'-5 1/4"	8'-1 1/8"	8'-11 5/8"
300'	8'-2 3/8"	7'-8 3/4"	7'-5 7/8"	8'-3 1/2"	8'-1 1/4"	7'-10 3/8"	7'-4 3/8"	8'-4 3/4"
400'	7'-10 1/8"	7'-5 3/8"	7'-1 5/8"	8'-0 1/8"	7'-9"	7'-7"	7'-0 1/8"	8'-1 3/8"
500'	7'-7 5/8"	7'-3 3/8"	6'-11 1/8"	7'-10 1/8"	7'-6 1/2"	7'-5"	6'-9 5/8"	7'-11 3/8"
600'	7'-5 7/8"	7'-2"	6'-9 3/8"	7'-8 3/4"	7'-4 3/4"	7'-3 5/8"	6'-7 7/8"	7'-10"
700'	7'-4 5/8"	7'-1"	6'-8 1/8"	7'-7 3/4"	7'-3 1/2"	7'-2 5/8"	6'-6 5/8"	7'-9"
800'	7'-3 7/8"	7'-0 3/8"	6'-7 3/8"	7'-7 1/8"	7'-2 3/4"	7'-2"	6'-5 7/8"	7'-8 3/8"
1000'	7'-2 5/8"	6'-11 3/8"	6'-6 1/8"	7'-6 1/8"	7'-1 1/2"	7'-1"	6'-4 5/8"	7'-7 3/8"
1200'	7'-1 3/4"	6'-10 5/8"	6'-5 1/4"	7'-5 3/8"	7'-0 5/8"	7'-0 1/4"	6'-3 3/4"	7'-6 5/8"
1400'	7'-1 1/8"	6'-10 1/8"	6'-4 5/8"	7'-4 7/8"	7'-0"	6'-11 3/4"	6'-3 1/8"	7'-6 1/8"
1600'	7'-0 5/8"	6'-9 3/4"	6'-4 1/8"	7'-4 1/2"	6'-11 1/2"	6'-11 3/8"	6'-2 5/8"	7'-5 3/4"
1800'	7'-0 1/4"	6'-9 1/2"	6'-3 3/4"	7'-4 1/4"	6'-11 1/8"	6'-11 1/8"	6'-2 1/4"	7'-5 1/2"
2000'	7'-0"	6'-9 1/4"	6'-3 1/2"	7'-4"	6'-10 7/8"	6'-10 7/8"	6'-2"	7'-5 1/4"
2500'	7'-0 5/8"	6'-8 7/8"	6'-4 1/8"	7'-3 5/8"	6'-11 1/2"	6'-10 1/2"	6'-2 5/8"	7'-4 7/8"
3000'	7'-0 1/8"	6'-8 5/8"	6'-3 5/8"	7'-3 3/8"	6'-11"	6'-10 1/4"	6'-2 1/8"	7'-4 5/8"
4000'	6'-11 1/2"	6'-8 1/4"	6'-3"	7'-3"	6'-10 3/8"	6'-9 7/8"	6'-1 1/2"	7'-4 1/4"
5000'	6'-11 1/8"	6'-8 1/8"	6'-2 5/8"	7'-2 7/8"	6'-10"	6'-9 3/4"	6'-1 1/8"	7'-4 1/8"
6000'	6'-10 3/4"	6'-7 7/8"	6'-2 1/4"	7'-2 5/8"	6'-9 5/8"	6'-9 1/2"	6'-0 3/4"	7'-3 7/8"
7000'	6'-10 5/8"	6'-7 7/8"	6'-2 1/8"	7'-2 5/8"	6'-9 1/2"	6'-9 1/2"	6'-0 5/8"	7'-3 7/8"
8000'	6'-10 1/2"	6'-7 3/4"	6'-2"	7'-2 1/2"	6'-9 3/8"	6'-9 3/8"	6'-0 1/2"	7'-3 3/4"
9000'	6'-10 3/8"	6'-7 3/4"	6'-1 7/8"	7'-2 1/2"				
10,000'	6'-10 1/4"	6'-7 5/8"	6'-1 3/4"	7'-2 3/8"				
15,000'	6'-10"	6'-7 1/2"	6'-1 1/2"	7'-2 1/4"				

S.E.	X_T	M_A	M_T
2"	7/8"	6'-0"	6'-8 1/4"
3"	1 1/4"	5'-10 1/2"	6'-7 7/8"

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FIGURE 11.41

RADIUS	SUPERELEVATION=4"							
	As	T	A	Ts				
200'	8'-9 1/4"	8'-7 5/8"	8'-0 1/8"	9'-0 7/8"				
300'	8'-0 1/2"	8'-0 3/4"	7'-3 3/8"	8'-6"				
400'	7'-8 1/4"	7'-9 3/8"	6'-11 1/8"	8'-2 5/8"				
500'	7'-5 3/4"	7'-7 3/8"	6'-8 5/8"	8'-0 5/8"				
600'	7'-4"	7'-6"	6'-6 7/8"	7'-11 1/4"				
700'	7'-2 3/4"	7'-5"	6'-5 5/8"	7'-10 1/4"				
800'	7'-2"	7'-4 3/8"	6'-4 7/8"	7'-9 5/8"				
1000'	7'-0 3/4"	7'-3 3/8"	6'-3 5/8"	7'-8 5/8"				
1200'	6'-11 7/8"	7'-2 5/8"	6'-2 3/4"	7'-7 7/8"				
1400'	6'-11 1/4"	7'-2 1/8"	6'-2 1/8"	7'-7 3/8"				
1600'	6'-10 3/4"	7'-1 3/4"	6'-1 5/8"	7'-7"				
1800'	6'-10 3/8"	7'-1 1/2"	6'-1 1/4"	7'-6 3/4"				
2000'	6'-10 1/8"	7'-1 1/4"	6'-1"	7'-6 1/2"				
2500'	6'-10 3/4"	7'-0 7/8"	6'-1 5/8"	7'-6 1/8"				
3000'	6'-10 1/4"	7'-0 5/8"	6'-1 1/8"	7'-5 7/8"				
4000'	6'-9 5/8"	7'-0 1/4"	6'-0 1/2"	7'-5 1/2"				
5000'	6'-9 1/4"	7'-0 1/8"	6'-0 1/8"	7'-5 3/8"				
6000'	6'-8 7/8"	6'-11 7/8"	5'-11 3/4"	7'-5 1/8"				

S.E.	X_T	M_A	M_T
4"	1 7/8"	5'-9 1/2"	6'-10 1/4"

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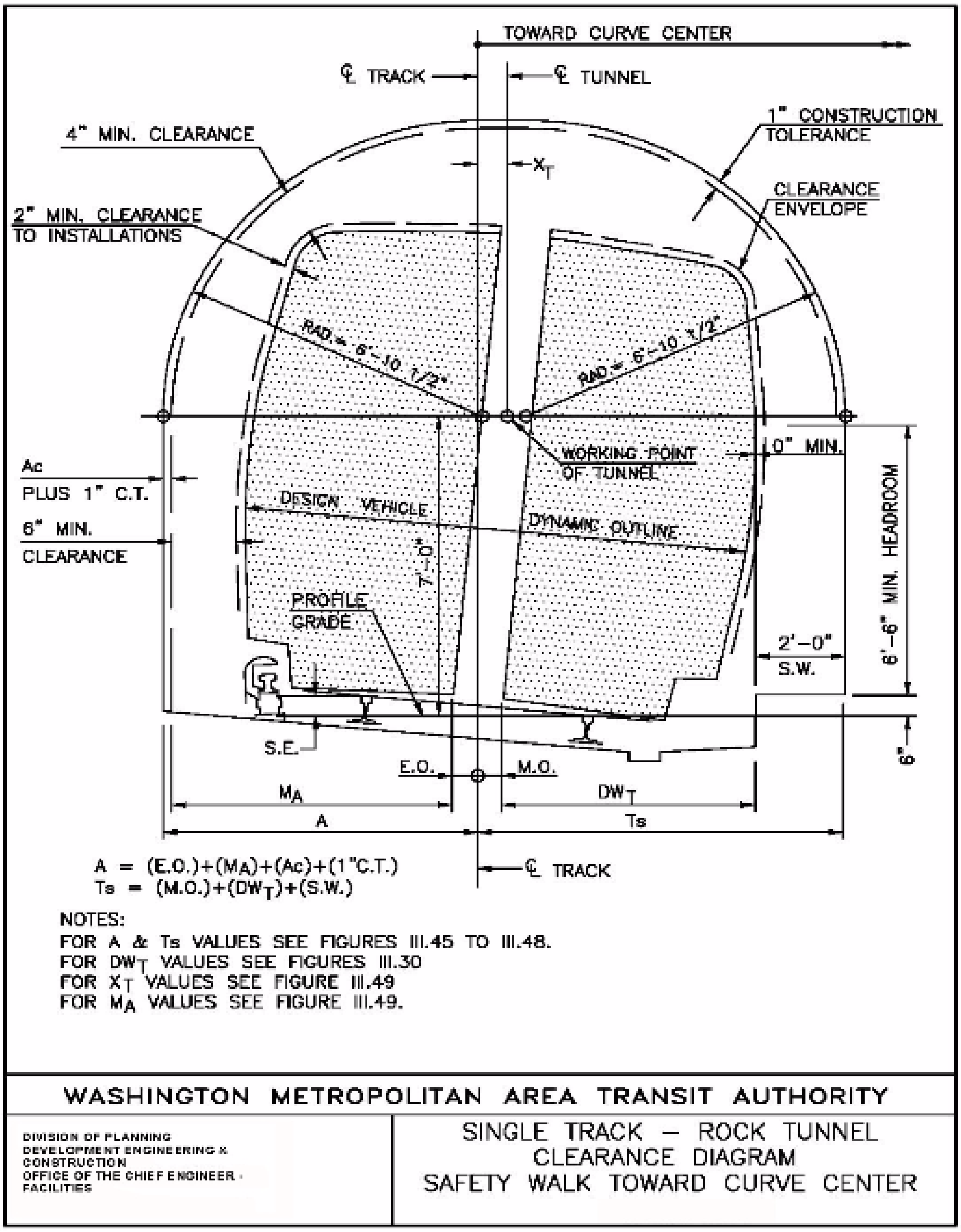
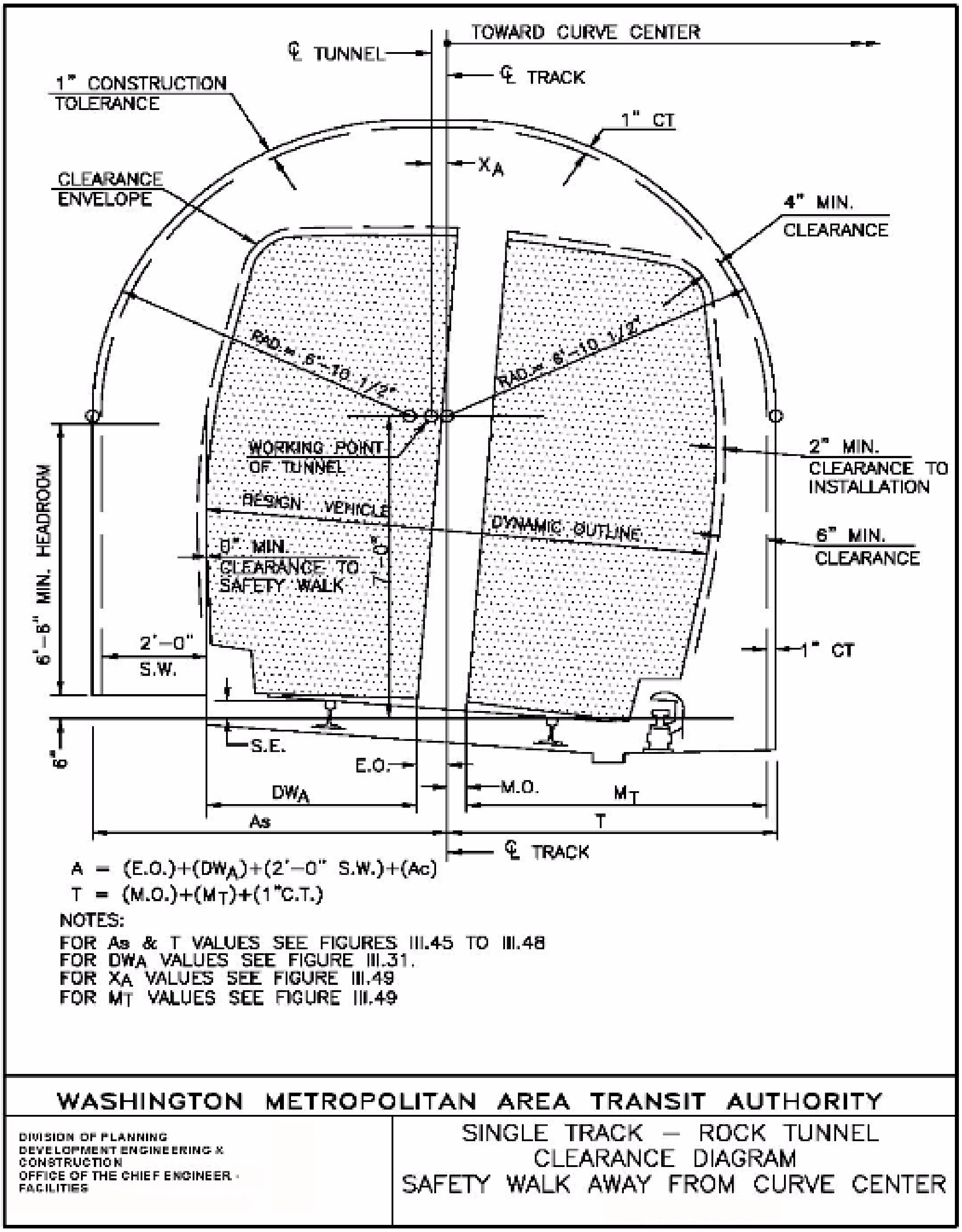
FIGURE 11.42



TOWARD CURVE CENTER
℄ TRACK
℄ TUNNEL
1" CONSTRUCTION TOLERANCE
4" MIN. CLEARANCE
X_T
CLEARANCE ENVELOPE
2" MIN. CLEARANCE TO INSTALLATIONS
RAD = 6'-10 1/2"
RAD = 6'-10 1/2"
WORKING POINT OF TUNNEL
0" MIN.
Ac PLUS 1" C.T.
6" MIN. CLEARANCE
DESIGN VEHICLE
DYNAMIC OUTLINE
6'-6" MIN. HEADROOM
7'-0"
PROFILE GRADE
2'-0" S.W.
S.E.
6"
E.O.
M.O.
M_A
DW_T
A
Ts
A = (E.O.)+(M_A)+(Ac)+(1"C.T.)
Ts = (M.O.)+(DW_T)+(S.W.)
℄ TRACK
NOTES:
FOR A & Ts VALUES SEE FIGURES III.45 TO III.48.
FOR DW_T VALUES SEE FIGURES III.30
FOR X_T VALUES SEE FIGURE III.49
FOR M_A VALUES SEE FIGURE III.49.
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES
SINGLE TRACK – ROCK TUNNEL CLEARANCE DIAGRAM SAFETY WALK TOWARD CURVE CENTER

FIGURE 11.43


TOWARD CURVE CENTER
℄ TUNNEL
℄ TRACK
1" CONSTRUCTION TOLERANCE
1" CT
X_A
CLEARANCE ENVELOPE
4" MIN. CLEARANCE
RAD.= 6'-10 1/2"
RAD.= 6'-10 1/2"
WORKING POINT OF TUNNEL
2" MIN. CLEARANCE TO INSTALLATION
DESIGN VEHICLE
DYNAMIC OUTLINE
6" MIN. CLEARANCE
6" MIN. CLEARANCE TO SAFETY WALK
6'-6" MIN. HEADROOM
2'-0" S.W.
1" CT
6"
S.E.
E.O.
M.O.
DW_A
M_T
As
T
℄ TRACK
A = (E.O.)+(DW_A)+(2'-0" S.W.)+(Ac)
T = (M.O.)+(M_T)+(1"C.T.)
NOTES:
FOR As & T VALUES SEE FIGURES III.45 TO III.48
FOR DW_A VALUES SEE FIGURE III.31.
FOR X_A VALUES SEE FIGURE III.49
FOR M_T VALUES SEE FIGURE III.49
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SINGLE TRACK – ROCK TUNNEL
CLEARANCE DIAGRAM
SAFETY WALK AWAY FROM CURVE CENTER

FIGURE 11.44

RADIUS	SUPERELEVATION=0"				SUPERELEVATION=1"			
	As	T	A	Ts	As	T	A	Ts
500'	8'-3 3/4"	7'-0 3/8"	7'-1 5/8"	8'-1 3/4"	8'-2 3/4"	7'-2 1/8"	7'-0 7/8"	8'-3"
600'	8'-2"	6'-11"	6'-11 7/8"	8'-0 3/8"	8'-1"	7'-0 3/4"	6'-11 1/8"	8'-1 5/8"
700'	8'-0 3/4"	6'-10"	6'-10 5/8"	7'-11 3/8"	7'-11 3/4"	6'-11 3/4"	6'-9 7/8"	8'-0 5/8"
800'	8'-0"	6'-9 3/8"	6'-9 7/8"	7'-10 3/4"	7'-11"	6'-11 1/8"	6'-9 1/8"	8'-0"
1000'	7'-10 3/4"	6'-8 3/8"	6'-8 5/8"	7'-9 3/4"	7'-9 3/4"	6'-10 1/8"	6'-7 7/8"	7'-11"
1200'	7'-9 7/8"	6'-7 5/8"	6'-7 3/4"	7'-9"	7'-8 7/8"	6'-9 3/8"	6'-7"	7'-10 1/4"
1400'	7'-9 1/4"	6'-7 1/8"	6'-7 1/8"	7'-8 1/2"	7'-8 1/4"	6'-8 7/8"	6'-6 3/8"	7'-9 3/4"
1600'	7'-8 3/4"	6'-6 3/4"	6'-6 5/8"	7'-8 1/8"	7'-7 3/4"	6'-8 1/2"	6'-5 7/8"	7'-9 3/8"
1800'	7'-8 3/8"	6'-6 1/2"	6'-6 1/4"	7'-7 7/8"	7'-7 3/8"	6'-8 1/4"	6'-5 1/2"	7'-9 1/8"
2000'	7'-8 1/8"	6'-6 1/4"	6'-6"	7'-7 5/8"	7'-7 1/8"	6'-8"	6'-5 1/4"	7'-8 7/8"
2500'	7'-8 3/4"	6'-5 7/8"	6'-6 5/8"	7'-7 1/4"	7'-7 3/4"	6'-7 5/8"	6'-5 7/8"	7'-8 1/2"
3000'	7'-8 1/4"	6'-5 5/8"	6'-6 1/8"	7'-7"	7'-7 1/4"	6'-7 3/8"	6'-5 3/8"	7'-8 1/4"
4000'	7'-7 5/8"	6'-5 1/4"	6'-5 1/2"	7'-6 5/8"	7'-6 5/8"	6'-7"	6'-4 3/4"	7'-7 7/8"
5000'	7'-7 1/4"	6'-5 1/8"	6'-5 1/8"	7'-6 1/2"	7'-6 1/4"	6'-6 7/8"	6'-4 3/8"	7'-7 3/4"
6000'	7'-6 7/8"	6'-4 7/8"	6'-4 1/2"	7'-6 1/4"	7'-5 7/8"	6'-6 5/8"	6'-4"	7'-7 1/2"
7000'	7'-6 3/4"	6'-4 7/8"	6'-4 3/8"	7'-6 1/4"	7'-5 3/4"	6'-6 5/8"	6'-3 7/8"	7'-7 1/2"
8000'	7'-6 5/8"	6'-4 3/4"	6'-4 1/8"	7'-6 1/8"	7'-5 5/8"	6'-6 1/2"	6'-3 3/4"	7'-7 3/8"
9000'	7'-6 1/2"	6'-4 3/4"	6'-4"	7'-6 1/8"	7'-5 1/2"	6'-6 1/2"	6'-3 5/8"	7'-7 3/8"
10,000'	7'-6 1/2"	6'-4 1/2"	6'-3 3/4"	7'-6 1/8"	7'-5 3/8"	6'-6 3/8"	6'-3 1/2"	7'-7 1/4"
15,000'	7'-6 1/4"	6'-4 1/8"	6'-3 1/2"	7'-6 "	7'-5 1/8"	6'-6 1/4"	6'-3 1/4"	7'-7 1/8"
20,000'	7'-6 1/8"	6'-4 1/8"	6'-3 1/2"	7'-6"	7'-5 1/8"	6'-6 1/4"	6'-3 1/4"	7'-7 1/8"
25,000'	7'-6"	6'-3 3/4"	6'-3 1/2"	7'-6"	7'-4 7/8"	6'-6 1/8"	6'-3"	7'-7"
TANGENT	7'-6"	6'-3 1/2"	6'-3 1/2"	7'-6"				

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DESIGN TABLES

FIGURE 11.45

RADIUS	SUPERELEVATION=2"				SUPERELEVATION=3"			
	As	T	A	Ts	As	T	A	Ts
500'	8'-1 5/8"	7'-3 7/8"	6'-11 5/8"	8'-4 1/8"	8'-0 1/2"	7'-5 7/8"	6'-10 1/8"	8'-5 3/8"
600'	7'-11 7/8"	7'-2 1/2"	6'-9 7/8"	8'-2 3/4"	7'-10 3/4"	7'-4 1/2"	6'-8 3/8"	8'-4"
700'	7'-10 5/8"	7'-1 1/2"	6'-8 5/8"	8'-1 3/4"	7'-9 1/2"	7'-3 1/2"	6'-7 1/8"	8'-3"
800'	7'-9 7/8"	7'-0 7/8"	6'-7 7/8"	8'-1 1/8"	7'-8 3/4"	7'-2 7/8"	6'-6 3/8"	8'-2 3/8"
1000'	7'-8 5/8"	6'-11 7/8"	6'-6 5/8"	8'-0 1/8"	7'-7 1/2"	7'-1 7/8"	6'-5 1/8"	8'-1 3/8"
1200'	7'-7 3/4"	6'-11 1/8"	6'-5 3/4"	7'-11 3/8"	7'-6 5/8"	7'-1 1/8"	6'-4 1/4"	8'-0 5/8"
1400'	7'-7 1/8"	6'-10 5/8"	6'-5 1/8"	7'-10 7/8"	7'-6"	7'-0 5/8"	6'-3 5/8"	8'-0 1/8"
1600'	7'-6 5/8"	6'-10 1/4"	6'-4 5/8"	7'-10 1/2"	7'-5 1/2"	7'-0 1/4"	6'-3 1/8"	7'-11 3/4"
1800'	7'-6 1/4"	6'-10"	6'-4 1/4"	7'-10 1/4"	7'-5 1/8"	7'-0"	6'-2 3/4"	7'-11 1/2"
2000'	7'-6"	6'-9 3/4"	6'-4"	7'-10"	7'-4 7/8"	6'-11 3/4"	6'-2 1/2"	7'-11 1/4"
2500'	7'-6 5/8"	6'-9 3/8"	6'-4 5/8"	7'-9 5/8"	7'-5 1/2"	6'-11 3/8"	6'-3 1/8"	7'-10 7/8"
3000'	7'-6 1/8"	6'-9 1/8"	6'-4 1/8"	7'-9 3/8"	7'-5"	6'-11 1/8"	6'-2 5/8"	7'-10 5/8"
4000'	7'-5 1/2"	6'-8 3/4"	6'-3 1/2"	7'-9"	7'-4 3/8"	6'-10 3/4"	6'-2"	7'-10 1/4"
5000'	7'-5 1/8"	6'-8 5/8"	6'-3 1/8"	7'-8 7/8"	7'-4"	6'-10 5/8"	6'-1 5/8"	7'-10 1/8"
6000'	7'-4 3/4"	6'-8 3/8"	6'-2 3/4"	7'-8 5/8"	7'-3 5/8"	6'-10 3/8"	6'-1 1/4"	7'-9 7/8"
7000'	7'-4 5/8"	6'-8 3/8"	6'-2 5/8"	7'-8 5/8"	7'-3 1/2"	6'-10 3/8"	6'-1 1/8"	7'-9 7/8"
8000'	7'-4 1/2"	6'-8 1/4"	6'-2 1/2"	7'-8 1/2"	7'-3 3/8"	6'-10 1/4"	6'-1"	7'-9 3/4"
9000'	7'-4 3/8"	6'-8 1/4"	6'-2 3/8"	7'-8 1/2"				
10,000'	7'-4 1/4"	6'-8 1/8"	6'-2 1/4"	7'-8 3/8"				
15,000'	7'-4"	6'-8"	6'-2"	7'-8 1/4"				

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SINGLE TRACK–ROCK TUNNEL
DESIGN TABLES

FIGURE 11.46

RADIUS	SUPERELEVATION=4"							
	As	T	A	Ts				
500'	7'-11 3/4"	7'-7 5/8"	6'-8 7/8"	8'-6 5/8"				
600'	7'-10"	7'-6 1/4"	6'-7 1/8"	8'-5 1/4"				
700'	7'-8 3/4"	7'-6 1/4"	6'-6 7/8"	8'-4 1/4"				
800'	7'-6"	7'-4 5/8"	6'-5 1/8"	8'-3 5/8"				
1000'	7'-8 3/4"	7'-3 5/8"	6'-3 7/8"	8'-2 5/8"				
1200'	7'-5 7/8"	7'-2 7/8"	6'-3"	8'-1 7/8"				
1400'	7'-5 1/4"	7'-2 3/8"	6'-2 3/8"	8'-1 3/8"				
1600'	7'-4 3/4"	7'-2"	6'-1 7/8"	8'-1"				
1800'	7'-4 3/8"	7'-1 3/4"	6'-1 1/2"	8'-0 3/4"				
2000'	7'-4 1/8"	7'-1 1/2"	6'-1 1/4"	8'-0 1/2"				
2500'	7'-4 3/4"	7'-1 1/8"	6'-1 7/8"	8'-0 1/8"				
3000'	7'-4 1/4"	7'-0 7/8"	6'-1 3/8"	7'-11 7/8"				
4000'	7'-3 5/8"	7'-0 1/2"	6'-0 3/4"	7'-11 1/2"				
5000'	7'-3 1/4"	7'-0 3/8"	6'-0 3/8"	7'-11 3/8"				
6000'	7'-2 7/8"	7'-0 1/8"	6'-0"	7'-11 1/8"				

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FIGURE 11.47

RADIUS	X_T VALUES SAFETY WALK TOWARD CURVE CENTER				
	0"	1"	2"	3"	4"
500'	6 1/8"	7 1/8"	8 1/4"	9 5/8"	10 7/8"
600'	6 1/4"	7 1/4"	8 1/2"	9 7/8"	11 1/8"
700'	6 3/8"	7 3/8"	8 5/8"	10"	11 1/4"
800'	6 1/2"	7 1/2"	8 5/8"	10"	11 1/4"
1000'	6 5/8"	7 5/8"	8 3/4"	10 1/8"	11 3/8"
1200'	6 5/8"	7 5/8"	8 7/8"	10 1/4"	11 1/2"
1400'	6 3/4"	7 3/4"	8 7/8"	10 1/4"	11 1/2"
1600'	6 3/4"	7 3/4"	9"	10 3/8"	11 5/8"
1800'	6 7/8"	7 7/8"	9"	10 3/8"	11 5/8"
2000'	6 7/8"	7 7/8"	9"	10 3/8"	11 5/8"
2500'	6 3/8"	7 3/8"	8 1/2"	9 7/8"	11 1/8"
3000'	6 1/2"	7 1/2"	8 5/8"	10"	11 1/4"
4000'	6 5/8"	7 5/8"	8 3/4"	10 1/8"	11 3/8"
5000'	6 3/4"	7 3/4"	8 7/8"	10 1/4"	11 1/2"
6000'	7"	7 3/4"	9"	10 3/8"	11 1/2"
7000'	7 1/8"	7 7/8"	9"	10 3/8"	
8000'	7 1/4"	7 7/8"	9"	10 3/8"	
9000'	7 1/4"	7 7/8"	9 1/8"		
10000'	7 3/8"	7 7/8"	9 1/8"		
15,000'	7 1/2"	8"	9 1/8"		
20,000'	7 1/2"	8"			
25,000'	7 1/2"	8"			
TANGENT	7 1/2"				

S.E.	0"	1"	2"	3"	4"
M_A	6'-2 1/2"	6'-1 3/4"	6'-0 1/2"	5'-11"	5'-9 3/4"

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SINGLE TRACK—ROCK TUNNEL
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FIGURE 11.48

RADIUS	XA VALUES SAFETY WALK AWAY FROM CURVE CENTER				
	0"	1"	2"	3"	4"
500'	7 3/4"	6 3/8"	4 7/8"	3 3/8"	2 1/8"
600'	7 1/2"	6 1/8"	4 3/4"	3 1/8"	1 7/8"
700'	7 3/8"	6"	4 5/8"	3"	1 3/4"
800'	7 3/8"	6"	4 1/2"	3"	1 3/4"
1000'	7 1/4"	5 7/8"	4 3/8"	2 7/8"	1 5/8"
1200'	7 1/8"	5 3/4"	4 3/8"	2 3/4"	1 1/2"
1400'	7 1/8"	5 3/4"	4 1/4"	2 1/2"	1 1/2"
1600'	7"	5 5/8"	4 1/4"	2 5/8"	1 3/8"
1800'	7"	5 5/8"	4 1/8"	2 5/8"	1 3/8"
2000'	7"	5 5/8"	4 1/8"	2 5/8"	1 3/8"
2500'	7 1/2"	6 1/8"	4 5/8"	3 1/8"	1 7/8"
3000'	7 3/8"	6"	4 1/2"	3"	1 3/4"
4000'	7 1/4"	5 7/8"	4 3/8"	2 7/8"	1 5/8"
5000'	7 1/8"	5 3/4"	4 1/4"	2 3/4"	1 1/2"
6000'	7"	5 5/8"	4 1/4"	2 5/8"	1 3/8"
7000'	7"	5 5/8"	4 1/8"	2 5/8"	
8000'	6 7/8"	5 5/8"	4 1/8"	2 5/8"	
9000'	6 7/8"	5 1/2"	4 1/8"		
10000'	7"	5 1/2"	4 1/8"		
15,000'	7 1/8"	5 1/2"	4"		
20,000'	7 1/4"	5 1/2"			
25,000'	7 3/8"	5 3/8"			
TANGENT	7 1/2"				

S.E.	0"	1"	2"	3"	4"
M_T	6'-2 1/2"	6'-5"	6'-6 3/4"	6'-8 3/4"	6'-10 1/2"

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SINGLE TRACK–ROCK TUNNEL
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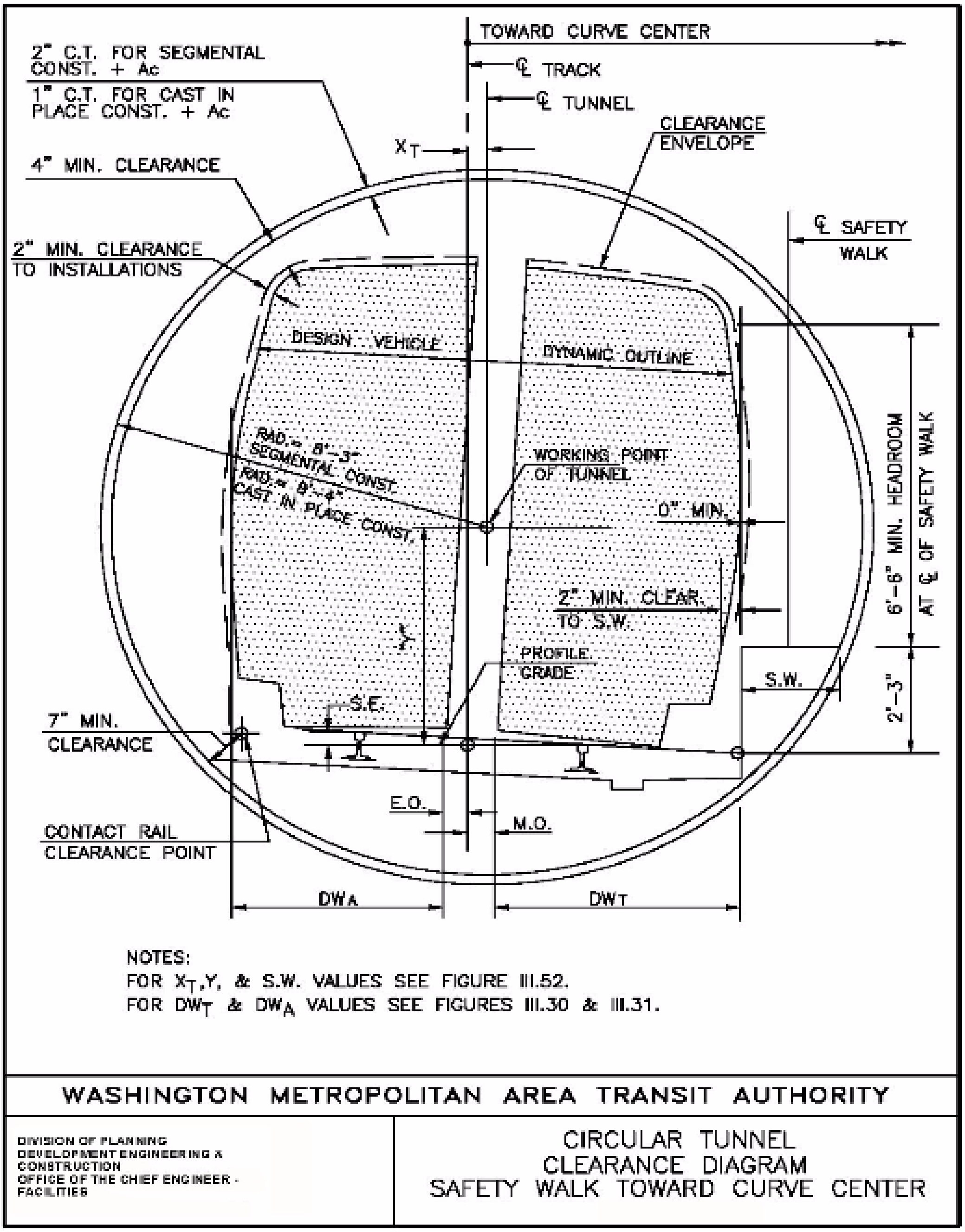
FIGURE 11.49


TOWARD CURVE CENTER
2" C.T. FOR SEGMENTAL CONST. + Ac
1" C.T. FOR CAST IN PLACE CONST. + Ac
℄ TRACK
℄ TUNNEL
CLEARANCE ENVELOPE
XT
4" MIN. CLEARANCE
℄ SAFETY WALK
2" MIN. CLEARANCE TO INSTALLATIONS
DESIGN VEHICLE
DYNAMIC OUTLINE
RAD.= 8'-3" SEGMENTAL CONST.
RAD.= 8'-4" CAST IN PLACE CONST.
WORKING POINT OF TUNNEL
0" MIN.
6'-6" MIN. HEADROOM AT ℄ OF SAFETY WALK
2" MIN. CLEAR. TO S.W.
Y
PROFILE GRADE
S.W.
2'-3"
S.E.
7" MIN. CLEARANCE
E.O.
M.O.
CONTACT RAIL CLEARANCE POINT
DWA
DWT
NOTES:
FOR XT,Y, & S.W. VALUES SEE FIGURE III.52.
FOR DWT & DWA VALUES SEE FIGURES III.30 & III.31.
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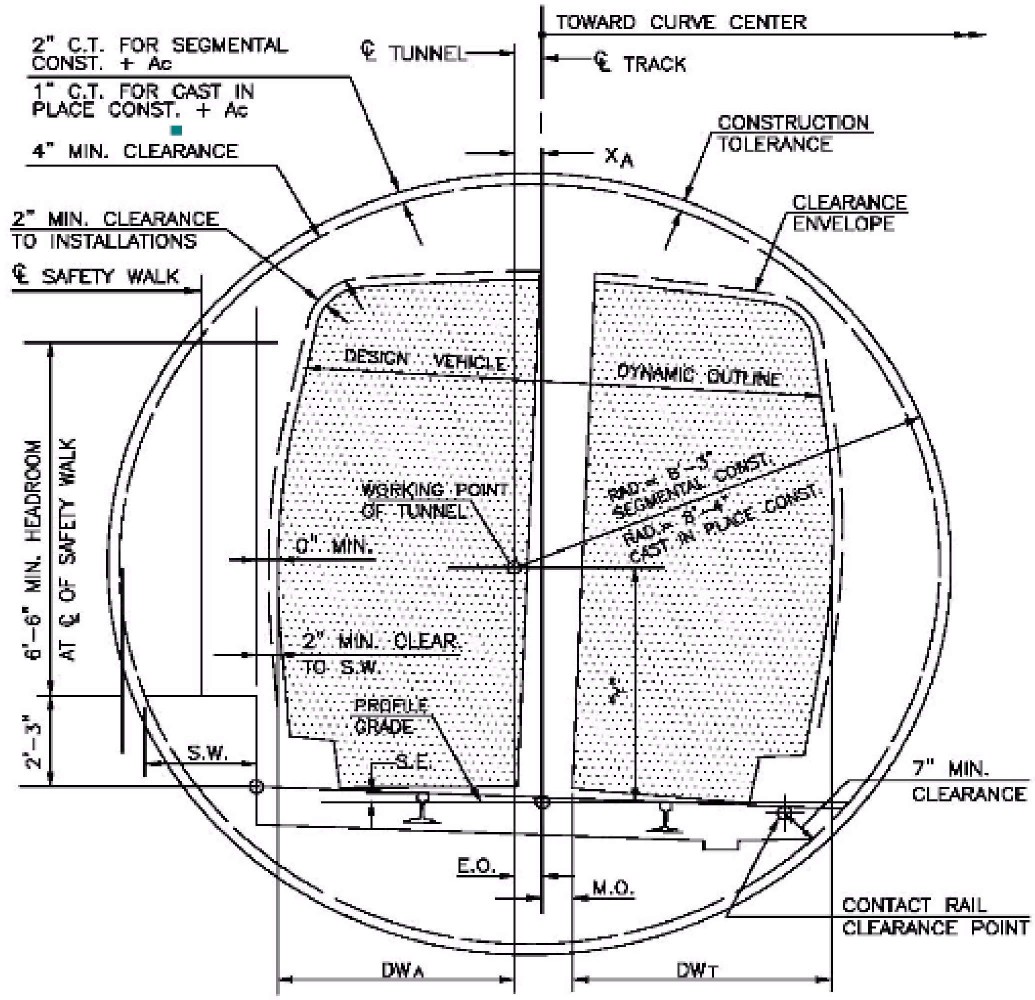
CIRCULAR TUNNEL CLEARANCE DIAGRAM SAFETY WALK TOWARD CURVE CENTER

FIGURE 11.50



NOTES:
FOR X_A, Y, & S.W. VALUES SEE FIGURE III.53.
FOR DW_T & DW_A VALUES SEE FIGURES III.30 & III.31.

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FIGURE 11.51

SAFETY WALK TOWARD CURVE CENTER

RADIUS	SUPERELEVATION = 0"			SUPERELEVATION = 1"			SUPERELEVATION = 2"		
	X_T	Y	SW	X_T	Y	SW	X_T	Y	SW
700'	4 1/4"	5'-4"	1'-11"	5 7/8"	5'-4"	1'-10 5/8"	7 1/4"	5'-4"	1'-11"
900'	4 1/4"	5'-4"	2'-0"	5 7/8"	5'-4"	2'-0"	7 1/8"	5'-4"	2'-0"
1200'	3 1/2"	5'-4"	2'-0"	5 1/8"	5'-4"	2'-0"	6 3/8"	5'-4"	2'-0"
1600'	2 1/2"	5'-4"	2'-0"	4 1/4"	5'-4"	2'-0"	5 1/2"	5'-4"	2'-0"
2000'	2 1/8"	5'-4"	2'-0"	3 3/4"	5'-4"	2'-0"	5"	5'-4"	2'-0"
3000'	1 1/2"	5'-4"	2'-0"	3 1/8"	5'-4"	2'-0"	4 3/8"	5'-4"	2'-0"
5000'	1"	5'-4"	2'-0"	2 5/8"	5'-4"	2'-0"	3 7/8"	5'-4"	2'-0"
20,000'	1/4"	5'-4"	2'-0"	2"	5'-4"	2'-0"	3 1/4"	5'-4"	2'-0"
TANGENT	0"	5'-4"	2'-0"						

RADIUS	SUPERELEVATION = 3"			SUPERELEVATION = 4"		
	X_T	Y	SW	X_T	Y	SW
700'	8 7/8"	5'-4"	1'-11"	10 1/8"	5'-4"	1'-9 1/2"
900'	8 3/4"	5'-4"	2'-0"	9 7/8"	5'-4"	1'-11 1/2"
1200'	8"	5'-4"	2'-0"	9 5/8"	5'-4"	2'-0"
1600'	7 1/8"	5'-4"	2'-0"	8 5/8"	5'-4"	2'-0"
2000'	6 5/8"	5'-4"	2'-0"	8 3/8"	5'-4"	2'-0"
3000'	6 1/8"	5'-4"	2'-0"	7 5/8"	5'-4"	2'-0"
5000'	5 1/2"	5'-4"	2'-0"	7 1/8"	5'-4"	2'-0"
20,000'	4 7/8"	5'-4"	2'-0"	6 1/2"	5'-4"	2'-0"

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CIRCULAR TUNNEL
DESIGN TABLES

FIGURE 11.52

SAFETY WALK AWAY FROM CURVE CENTER

RADIUS	SUPERELEVATION = 0"			SUPERELEVATION = 1"			SUPERELEVATION = 2"		
	X_A	Y	SW	X_A	Y	SW	X_A	Y	SW
700'	4"	5'-4"	1'-9 1/2"	4 3/8"	5'-4"	2'-0"	2 1/2"	5'-4"	1'-11 1/2"
900'	4 1/4"	5'-4"	2'-0"	3 5/8"	5'-4"	2'-0"	2 1/2"	5'-4"	2'-0"
1200'	3 1/2"	5'-4"	2'-0"	2 3/8"	5'-4"	2'-0"	1 1/8"	5'-4"	2'-0"
1600'	2 5/8"	5'-4"	2'-0"	1 1/2"	5'-4"	2'-0"	1/4"	5'-4"	2'-0"
2000'	2"	5'-4"	2'-0"	1"	5'-4"	2'-0"	1/8"	5'-4"	2'-0"
3000'	1 1/2"	5'-4"	2'-0"	1/2"	5'-4"	2'-0"	0"	5'-4"	2'-0"
5000'	1"	5'-4"	2'-0"	0"	5'-4"	2'-0"	0"	5'-4"	2'-0"
20,000'	3/8"	5'-4"	2'-0"	0"	5'-4"	2'-0"	0"	5'-4"	2'-0"
TANGENT	0"	5'-4"	2'-0"						

RADIUS	SUPERELEVATION = 3"			SUPERELEVATION = 4"		
	X_A	Y	SW	X_A	Y	SW
700'	1/4"	5'-4"	1'-10 1/2"	0"	5'-4"	1'-10 1/2"
900'	1 1/8"	5'-4"	2'-0"	0"	5'-4"	2'-0"
1200'	3/8"	5'-4"	2'-0"	0"	5'-4"	2'-0"
1600'	0"	5'-4"	2'-0"	0"	5'-4"	2'-0"
2000'	0"	5'-4"	2'-0"	0"	5'-4"	2'-0"
3000'	0"	5'-4"	2'-0"	0"	5'-4"	2'-0"
5000'	0"	5'-4"	2'-0"	0"	5'-4"	2'-0"
20,000'	0"	5'-4"	2'-0"	0"	5'-4"	2'-0"

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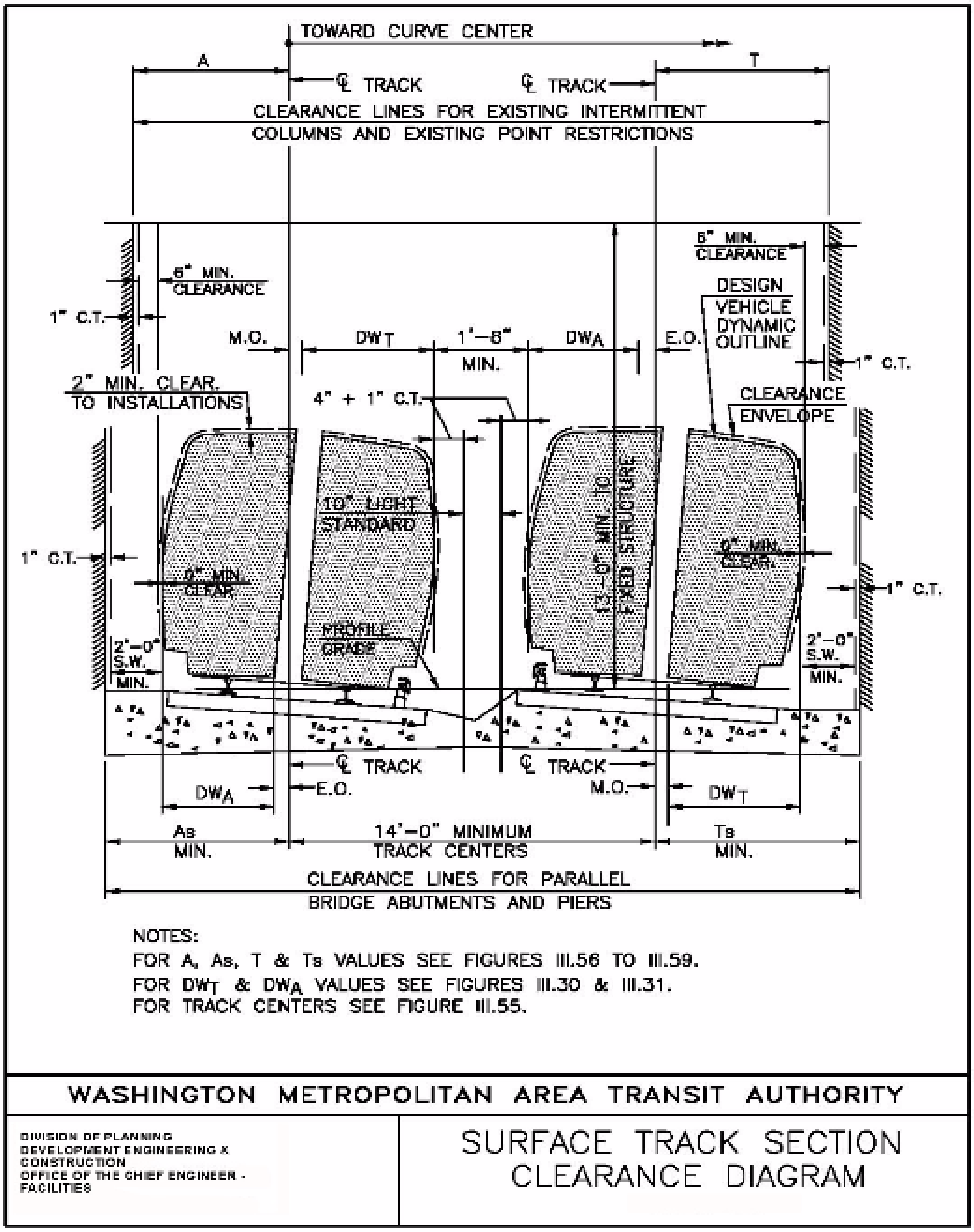
CIRCULAR TUNNEL
DESIGN TABLES

FIGURE 11.53


TOWARD CURVE CENTER
A
T
℄ TRACK
℄ TRACK
CLEARANCE LINES FOR EXISTING INTERMITTENT COLUMNS AND EXISTING POINT RESTRICTIONS
6" MIN. CLEARANCE
DESIGN VEHICLE DYNAMIC OUTLINE
1" C.T.
M.O.
DWT
1'-8" MIN.
DWA
E.O.
2" MIN. CLEAR. TO INSTALLATIONS
4" + 1" C.T.
CLEARANCE ENVELOPE
10" LIGHT STANDARD
13'-0" MIN. TO FIXED STRUCTURE
0" MIN. CLEAR.
PROFILE GRADE
2'-0" S.W. MIN.
E.O.
M.O.
As MIN.
14'-0" MINIMUM TRACK CENTERS
Ts MIN.
CLEARANCE LINES FOR PARALLEL BRIDGE ABUTMENTS AND PIERS
NOTES:
FOR A, As, T & Ts VALUES SEE FIGURES III.56 TO III.59.
FOR DWT & DWA VALUES SEE FIGURES III.30 & III.31.
FOR TRACK CENTERS SEE FIGURE III.55.
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SURFACE TRACK SECTION CLEARANCE DIAGRAM

FIGURE 11.54

RADIUS	TRACK CENTERS						
	SUPERELEVATION						
	0"	1"	2"	3"	4"	5"	6"
200'	16'-0"	16'-0 1/4"	16'-0 1/4"	16'-0 3/8"	16'-0 7/8"	16'-1 1/4"	16'-1 7/8"
300'	14'-10 1/4"	14'-10 1/2"	14'-10 1/2"	14'-10 5/8"	14'-11 1/8"	14'-11 1/2"	15'-0 1/8"
400'	14'-3 1/2"	14'-3 3/4"	14'-3 3/4"	14'-3 7/8"	14'-4 3/8"	14'-4 3/4"	14'-5 3/8"
500'	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-1 3/8"
600'	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"	14'-0"
TANGENT	14'-0"						

NOTE:
TRACK CENTERS INCLUDE MINIMUM 1'-8" DISTANCE BETWEEN DYNAMIC OUTLINES FOR INSTALLATION OF LIGHT STANDARDS.

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FIGURE 11.55

RADIUS	SUPERELEVATION=0"				SUPERELEVATION=1"			
	A	Ts (MIN.)	As (MIN.)	T	A	Ts (MIN.)	As (MIN.)	T
200'	7'-11"	9'-3"	9'-3"	7'-11"	7'-10"	9'-4 1/4"	9'-2"	8'-0 1/4"
300'	7'-4 1/8"	8'-8 1/8"	8'-8 1/8"	7'-4 1/8"	7'-3 1/8"	8'-9 3/8"	8'-7 1/8"	7'-5 3/8"
400'	7'-0 3/4"	8'-4 3/4"	8'-4 3/4"	7'-0 3/4"	6'-11 3/4"	8'-6"	8'-3 3/4"	7'-2"
500'	6'-10 3/4"	8'-2 3/4"	8'-2 3/4"	6'-10 3/4"	6'-9 3/4"	8'-4"	8'-1 3/4"	7'-0"
600'	6'-9 3/8"	8'-1 3/8"	8'-1 3/8"	6'-9 3/8"	6'-8 3/8"	8'-2 5/8"	8'-0 3/8"	6'-10 5/8"
700'	6'-8 3/8"	8'-0 3/8"	8'-0 3/8"	6'-8 3/8"	6'-7 3/8"	8'-1 5/8"	7'-11 3/8"	6'-9 5/8"
800'	6'-7 3/4"	7'-11 3/4"	7'-11 3/4"	6'-7 3/4"	6'-6 3/4"	8'-1"	7'-10 3/4"	6'-9"
1000'	6'-6 3/4"	7'-10 3/4"	7'-10 3/4"	6'-6 3/4"	6'-5 3/4"	8'-0"	7'-9 3/4"	6'-8"
1200'	6'-6"	7'-10"	7'-10"	6'-6"	6'-5"	7'-11 1/4"	7'-9"	6'-7 1/4"
1400'	6'-5 1/2"	7'-9 1/2"	7'-9 1/2"	6'-5 1/2"	6'-4 1/2"	7'-10 3/4"	7'-8 1/2"	6'-6 3/4"
1600'	6'-5 1/8"	7'-9 1/8"	7'-9 1/8"	6'-5 1/8"	6'-4 1/8"	7'-10 3/8"	7'-8 1/8"	6'-6 3/8"
1800'	6'-4 7/8"	7'-8 7/8"	7'-8 7/8"	6'-4 7/8"	6'-3 7/8"	7'-10 1/8"	7'-7 7/8"	6'-6 1/8"
2000'	6'-4 5/8"	7'-8 5/8"	7'-8 5/8"	6'-4 5/8"	6'-3 5/8"	7'-9 7/8"	7'-7 5/8"	6'-5 7/8"
2500'	6'-4 1/4"	7'-8 1/4"	7'-8 1/4"	6'-4 1/4"	6'-3 1/4"	7'-9 1/2"	7'-7 1/4"	6'-5 1/2"
3000'	6'-4"	7'-8"	7'-8"	6'-4"	6'-3"	7'-9 1/4"	7'-7"	6'-5 1/4"
4000'	6'-3 5/8"	7'-7 5/8"	7'-7 5/8"	6'-3 5/8"	6'-2 5/8"	7'-8 7/8"	7'-6 5/8"	6'-4 7/8"
5000'	6'-3 1/2"	7'-7 1/2"	7'-7 1/2"	6'-3 1/2"	6'-2 1/2"	7'-8 3/4"	7'-6 1/2"	6'-4 3/4"
6000'	6'-3 1/4"	7'-7 1/4"	7'-7 1/4"	6'-3 1/4"	6'-2 1/4"	7'-8 1/2"	7'-6 1/4"	6'-4 1/2"
7000'	6'-3 1/4"	7'-7 1/4"	7'-7 1/4"	6'-3 1/4"	6'-2 1/4"	7'-8 1/2"	7'-6 1/4"	6'-4 1/2"
8000'	6'-3 1/8"	7'-7 1/8"	7'-7 1/8"	6'-3 1/8"	6'-2 1/8"	7'-8 3/8"	7'-6 1/8"	6'-4 3/8"
9000'	6'-3 1/8"	7'-7 1/8"	7'-7 1/8"	6'-3 1/8"	6'-2 1/8"	7'-8 3/8"	7'-6 1/8"	6'-4 3/8"
10,000'	6'-3"	7'-7"	7'-7"	6'-3"	6'-2"	7'-8 1/4"	7'-6"	6'-4 1/4"
15,000'	6'-2 7/8"	7'-6 7/8"	7'-6 7/8"	6'-2 7/8"	6'-1 7/8"	7'-8 1/8"	7'-5 7/8"	6'-4 1/8"
25,000'	6'-2 3/4"	7'-6 3/4"	7'-6 3/4"	6'-2 3/4"	6'-1 3/4"	7'-8"	7'-5 3/4"	6'-4"
TANGENT	6'-2 5/8"	7'-6 5/8"	7'-6 5/8"	6'-2 5/8"				

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SURFACE TRACK SECTION
DESIGN TABLES

FIGURE 11.56

RADIUS	SUPERELEVATION=2"				SUPERELEVATION=3"			
	A	Ts (MIN.)	As (MIN.)	T	A	Ts (MIN.)	As (MIN.)	T
200'	7'-8 7/8"	9'-5 3/8"	9'-0 7/8"	8'-1 3/8"	7'-7 3/4"	9'-8 5/8"	8'-11 3/4"	8'-2 5/8"
300'	7'-2"	8'-10 1/2"	8'-6"	7'-6 1/2"	7'-0 7/8"	8'-11 3/4"	8'-4 7/8"	7'-7 3/4"
400'	6'-10 5/8"	8'-7 1/8"	8'-2 5/8"	7'-3 1/8"	6'-9 1/2"	8'-8 3/8"	8'-1 1/2"	7'-4 3/8"
500'	6'-8 5/8"	8'-5 1/8"	8'-0 5/8"	7'-1 1/8"	6'-7 1/2"	8'-6 3/8"	7'-11 1/2"	7'-2 3/8"
600'	6'-7 1/4"	8'-3 3/4"	7'-11 1/4"	6'-11 3/4"	6'-6 1/8"	8'-5"	7'-10 1/8"	7'-1"
700'	6'-6 1/4"	8'-2 3/4"	7'-10 1/4"	6'-10 3/4"	6'-5 1/8"	8'-4"	7'-9 1/8"	7'-0"
800'	6'-5 5/8"	8'-2 1/8"	7'-9 5/8"	6'-10 1/8"	6'-4 1/2"	8'-3 3/8"	7'-8 1/2"	6'-11 3/8"
1000'	6'-4 5/8"	8'-1 1/8"	7'-8 5/8"	6'-9 1/8"	6'-3 1/2"	8'-2 3/8"	7'-7 1/2"	6'-10 3/8"
1200'	6'-3 7/8"	8'-0 3/8"	7'-7 7/8"	6'-8 3/8"	6'-2 3/4"	8'-1 5/8"	7'-6 3/4"	6'-9 5/8"
1400'	6'-3 3/8"	7'-11 7/8"	7'-7 3/8"	6'-7 7/8"	6'-2 1/4"	8'-1 1/8"	7'-6 1/4"	6'-9 1/8"
1600'	6'-3"	7'-11 1/2"	7'-7"	6'-7 1/2"	6'-1 7/8"	8'-0 3/4"	7'-5 7/8"	6'-8 3/4"
1800'	6'-2 3/4"	7'-11 1/4"	7'-6 3/4"	7'-7 1/4"	6'-1 5/8"	8'-0 1/2"	7'-5 5/8"	6'-8 1/2"
2000'	6'-2 1/2"	7'-11"	7'-6 1/2"	6'-7"	6'-1 3/8"	8'-0 1/4"	7'-5 3/8"	6'-8 1/4"
2500'	6'-2 1/8"	7'-10 5/8"	7'-6 1/8"	6'-6 5/8"	6'-1"	7'-11 7/8"	7'-5"	6'-7 7/8"
3000'	6'-1 7/8"	7'-10 3/8"	7'-5 7/8"	6'-6 3/8"	6'-0 3/4"	7'-11 5/8"	7'-4 3/4"	6'-7 5/8"
4000'	6'-1 1/2"	7'-10"	7'-5 1/2"	6'-6"	6'-0 3/8"	7'-11 1/4"	7'-4 3/8"	6'-7 1/4"
5000'	6'-1 3/8"	7'-9 7/8"	7'-5 3/8"	6'-5 7/8"	6'-0 1/4"	7'-11 1/8"	7'-4 1/4"	6'-7 1/8"
6000'	6'-1 1/8"	7'-9 5/8"	7'-5 1/8"	6'-5 5/8"	6'-0"	7'-10 7/8"	7'-4"	6'-6 7/8"
7000'	6'-1 1/8"	7'-9 5/8"	7'-5 1/8"	6'-5 5/8"	6'-0"	7'-10 7/8"	7'-4"	6'-6 7/8"
8000'	6'-1"	7'-9 1/2"	7'-5"	6'-5 1/2"	5'-11 7/8"	7'-10 3/4"	7'-3 7/8"	6'-6 3/4"
9000'	6'-1"	7'-9 1/2"	7'-5"	6'-5 1/2"				
10,000'	6'-0 7/8"	7'-9 3/8"	7'-4 7/8"	6'-5 3/8"				
15,000'	6'-0 3/4"	7'-9 1/4"	7'-4 3/4"	6'-5 1/4"				

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FIGURE 11.57

RADIUS	SUPERELEVATION=4"				SUPERELEVATION=5"			
	A	Ts (MIN.)	As (MIN.)	T	A	Ts (MIN.)	As (MIN.)	T
200'	7'-7"	9'-7 7/8"	8'-11"	8'-3 7/8"	7'-6 1/4"	9'-9"	8'-10 1/4"	8'-5"
300'	7'-0 1/8"	9'-1"	8'-4 1/8"	7'-9"	6'-11 3/8"	9'-2 1/8"	8'-3 3/8"	7'-10 1/8"
400'	6'-8 3/4"	8'-9 5/8"	8'-0 3/4"	7'-5 5/8"	6'-8"	8'-10 3/4"	8'-0"	7'-6 3/4"
500'	6'-6 3/4"	8'-7 5/8"	7'-10 3/4"	7'-3 5/8"	6'-6"	8'-8 3/4"	7'-10"	7'-4 3/4"
600'	6'-5 3/8"	8'-6 1/4"	7'-9 3/8"	7'-2 1/4"	6'-4 5/8"	8'-7 3/8"	7'-8 5/8"	7'-3 3/8"
700'	6'-4 3/8"	8'-5 1/4"	7'-8 3/8"	7'-1 1/4"	6'-3 5/8"	8'-6 3/8"	7'-7 5/8"	7'-2 3/8"
800'	6'-3 3/4"	8'-4 5/8"	7'-7 3/4"	7'-0 5/8"	6'-3"	8'-5 3/4"	7'-7"	7'-1 3/4"
1000'	6'-2 3/4"	8'-3 5/8"	7'-6 3/4"	6'-11 5/8"	6'-2"	8'-4 3/4"	7'-6"	7'-0 3/4"
1200'	6'-2"	8'-2 7/8"	7'-6"	6'-10 7/8"	6'-1 1/4"	8'-4"	7'-5 1/4"	7'-0"
1400'	6'-1 1/2"	8'-2 3/8"	7'-5 1/2"	6'-10 3/8"	6'-0 3/4"	8'-3 1/2"	7'-4 3/4"	6'-11 1/2"
1600'	6'-1 1/8"	8'-2"	7'-5 1/8"	6'-10"	6'-0 3/8"	8'-3 1/8"	7'-4 3/8"	6'-11 1/8"
1800'	6'-0 7/8"	8'-1 3/4"	7'-4 7/8"	6'-9 3/4"	6'-0 1/8"	8'-2 7/8"	7'-4 1/8"	6'-10 7/8"
2000'	6'-0 5/8"	8'-1 1/2"	7'-4 5/8"	6'-9 1/2"	5'-11 7/8"	8'-2 5/8"	7'-3 7/8"	6'-10 5/8"
2500'	6'-0 1/4"	8'-1 1/8"	7'-4 1/4"	6'-9 1/8"	5'-11 1/2"	8'-2 1/4"	7'-3 1/2"	6'-10 1/4"
3000'	6'-0"	8'-0 7/8"	7'-4"	6'-8 7/8"	5'-11 1/4"	8'-2"	7'-3 1/4"	6'-10"
4000'	5'-11 5/8"	8'-0 1/2"	7'-3 5/8"	6'-8 1/2"	5'-10 7/8"	8'-1 5/8"	7'-2 7/8"	6'-9 5/8"
5000'	5'-11 1/2"	8'-0 3/8"	7'-3 1/2"	6'-8 3/8"	5'-10 3/4"	8'-1 1/2"	7'-2 3/4"	6'-9 1/2"
6000'	5'-11 1/4"	8'-0 1/8"	7'-3 1/4"	6'-8 1/8"				

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FIGURE 11.58

RADIUS	SUPERELEVATION=6"			
	A	Ts (MIN.)	As (MIN.)	T
200'	7'-5 5/8"	9'-10 1/4"	8'-9 5/8"	8'-6 1/4"
300'	6'-10 3/4"	9'-3 3/8"	8'-2 3/4"	7'-11 3/8"
400'	6'-7 3/8"	9'-0"	7'-11 3/8"	7'-8"
500'	6'-5 3/8"	8'-10"	7'-9 3/8"	7'-6"
600'	6'-4"	8'-8 5/8"	7'-8"	7'-4 5/8"
700'	6'-3"	8'-7 5/8"	7'-7"	7'-3 5/8"
800'	6'-2 3/8"	8'-7"	7'-6 3/8"	7'-3"
1000'	6'-1 3/8"	8'-6"	7'-5 3/8"	7'-2"
1200'	6'-0 5/8"	8'-5 1/4"	7'-4 5/8"	7'-1 1/4"
1400'	6'-0 1/8"	8'-4 3/4"	7'-4 1/8"	7'-0 3/4"
1600'	5'-11 3/4"	8'-4 3/8"	7'-3 3/4"	7'-0 3/8"
1800'	5'-11 1/2"	8'-4 1/8"	7'-3 1/2"	7'-0 1/8"
2000'	5'-11 1/4"	8'-3 7/8"	7'-3 1/4"	6'-11 7/8"
2500'	5'-10 7/8"	8'-3 1/2"	7'-2 7/8"	6'-11 1/2"
3000'	5'-10 5/8"	8'-3 1/4"	7'-2 5/8"	6'-11 1/4"
4000'	5'-10 1/4"	8'-2 7/8"	7'-2 1/4"	6'-10 7/8"

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SURFACE TRACK SECTION
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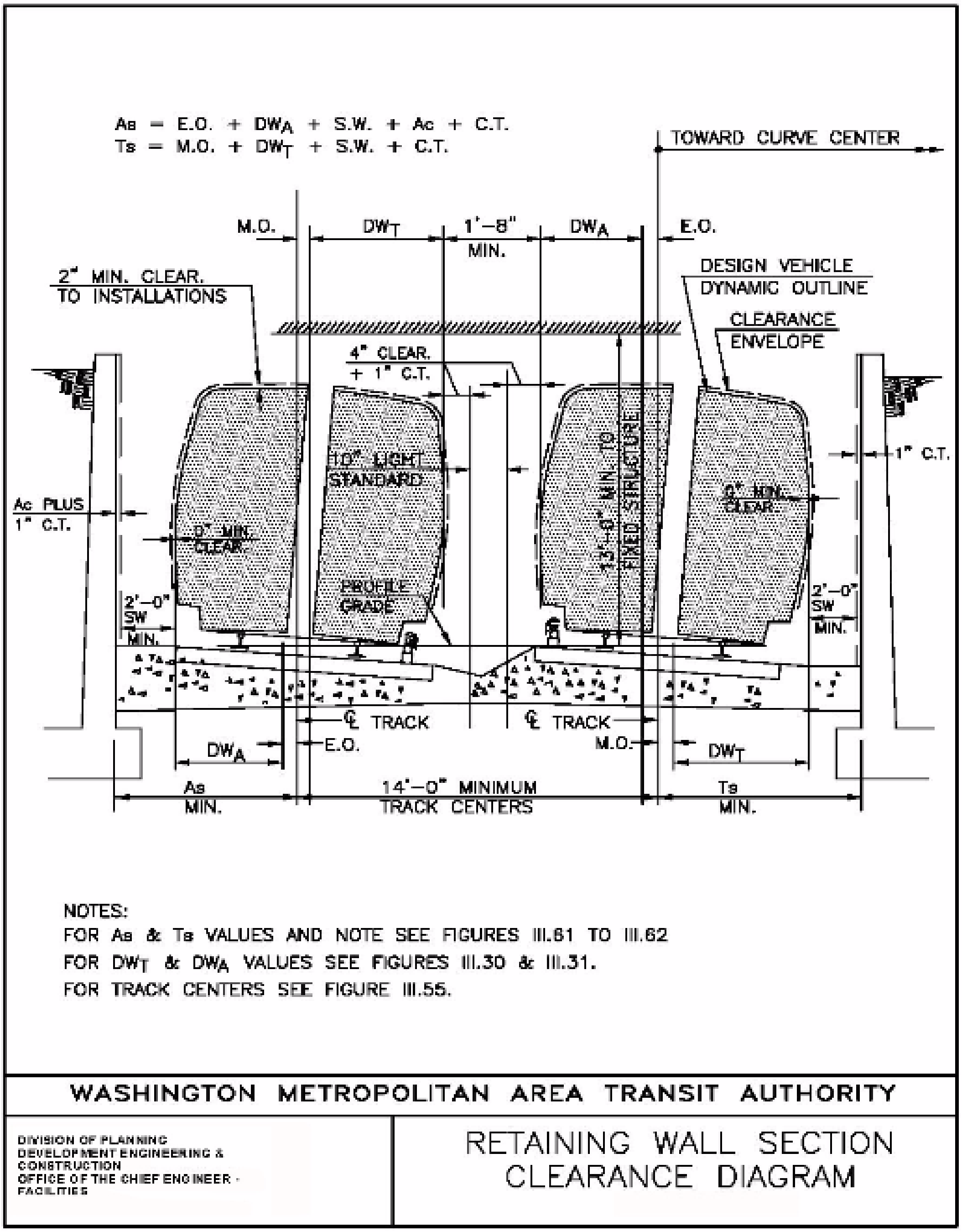
FIGURE 11.59


As = E.O. + DWA + S.W. + Ac + C.T.
Ts = M.O. + DWT + S.W. + C.T.
TOWARD CURVE CENTER
M.O.
DWT
1'-8" MIN.
DWA
E.O.
2" MIN. CLEAR. TO INSTALLATIONS
DESIGN VEHICLE DYNAMIC OUTLINE
CLEARANCE ENVELOPE
4" CLEAR. + 1" C.T.
1" C.T.
10" LIGHT STANDARD
13'-0" MIN. TO FIXED STRUCTURE
Ac PLUS 1" C.T.
0" MIN. CLEAR.
PROFILE GRADE
2'-0" SW MIN.
℄ TRACK
℄ TRACK
DWA
E.O.
M.O.
DWT
As MIN.
14'-0" MINIMUM TRACK CENTERS
Ts MIN.
NOTES:
FOR As & Ts VALUES AND NOTE SEE FIGURES III.61 TO III.62
FOR DWT & DWA VALUES SEE FIGURES III.30 & III.31.
FOR TRACK CENTERS SEE FIGURE III.55.
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RETAINING WALL SECTION CLEARANCE DIAGRAM

FIGURE 11.60

RADIUS	S.E.=0"		S.E.=1"		S.E.=2"		S.E.=3"	
	As (MIN.)	Ts (MIN.)	As (MIN.)	Ts (MIN.)	As (MIN.)	Ts (MIN.)	As (MIN.)	Ts (MIN.)
200'	9'-8 1/4"	9'-3"	9'-7 1/4"	9'-4 1/4"	9'-6 1/8"	9'-5 3/8"	9'-5"	9'-6 5/8"
300'	8'-11 1/2"	8'-8 1/8"	8'-10 1/2"	8'-9 3/8"	8'-9 3/8"	8'-10 1/2"	8'-8 1/4"	8'-11 3/4"
400'	8'-7 1/4"	8'-4 3/4"	8'-6 1/4"	8'-6"	8'-5 1/8"	8'-7 1/8"	8'-4"	8'-8 3/8"
500'	8'-4 3/4"	8'-2 3/4"	8'-3 3/4"	8'-4"	8'-2 5/8"	8'-5 1/8"	8'-1 1/2"	8'-6 3/8"
600'	8'-3"	8'-1 3/8"	8'-2"	8'-2 5/8"	8'-0 7/8"	8'-3 3/4"	7'-11 3/4"	8'-5"
700'	8'-1 3/4"	8'-0 3/8"	8'-0 3/4"	8'-1 5/8"	7'-11 5/8"	8'-2 3/4"	7'-10 1/2"	8'-4"
800'	8'-1"	7'-11 3/4"	8'-0"	8'-1"	7'-10 7/8"	8'-2 1/8"	7'-9 3/4"	8'-3 3/8"
1000'	7'-11 3/4"	7'-10 3/4"	7'-10 3/4"	8'-0"	7'-9 5/8"	8'-1 1/8"	7'-8 1/2"	8'-2 3/8"
1200'	7'-10 7/8"	7'-10"	7'-9 7/8"	7'-11 1/4"	7'-8 3/4"	8'-0 3/8"	7'-7 5/8"	8'-1 5/8"
1400'	7'-10 1/4"	7'-9 1/2"	7'-9 1/4"	7'-10 3/4"	7'-8 1/8"	7'-11 7/8"	7'-7"	8'-1 1/8"
1600'	7'-9 3/4"	7'-9 1/8"	7'-8 3/4"	7'-10 3/8"	7'-7 5/8"	7'-11 1/2"	7'-6 1/2"	8'-0 3/4"
1800'	7'-9 3/8"	7'-8 7/8"	7'-8 3/8"	7'-10 1/8"	7'-7 1/4"	7'-11 1/4"	7'-6 1/8"	8'-0 1/2"
2000'	7'-9 1/8"	7'-8 5/8"	7'-8 1/8"	7'-9 7/8"	7'-7"	7'-11"	7'-5 7/8"	8'-0 1/4"
2500'	7'-9 3/4"	7'-8 1/4"	7'-8 3/4"	7'-9 1/2"	7'-7 5/8"	7'-10 5/8"	7'-6 1/2"	7'-11 7/8"
3000'	7'-9 1/4"	7'-8"	7'-8 1/4"	7'-9 1/4"	7'-7 1/8"	7'-10 3/8"	7'-6"	7'-11 5/8"
4000'	7'-8 5/8"	7'-7 5/8"	7'-7 5/8"	7'-8 7/8"	7'-6 1/2"	7'-10"	7'-5 3/8"	7'-11 1/4"
5000'	7'-8 1/4"	7'-7 1/2"	7'-7 1/4"	7'-8 3/4"	7'-6 1/8"	7'-9 7/8"	7'-5"	7'-11 1/8"
6000'	7'-7 7/8"	7'-7 1/4"	7'-6 7/8"	7'-7 1/2"	7'-5 3/4"	7'-9 5/8"	7'-4 5/8"	7'-10 7/8"
7000'	7'-7 3/4"	7'-7 1/4"	7'-6 3/4"	7'-7 1/2"	7'-5 5/8"	7'-9 5/8"	7'-4 1/2"	7'-10 7/8"
8000'	7'-7 5/8"	7'-7 1/8"	7'-6 5/8"	7'-8 3/8"	7'-5 1/2"	7'-9 1/2"	7'-4 3/8"	7'-10 3/4"
9000'	7'-7 1/2"	7'-7 1/8"	7'-6 1/2"	7'-8 3/8"	7'-5 3/8"	7'-9 1/2"		
10,000'	7'-7 3/8"	7'-7"	7'-6 3/8"	7'-8 1/4"	7'-5 1/4"	7'-9 3/8"		
15,000'	7'-7 1/8"	7'-6 7/8"	7'-6 1/8"	7'-8 1/8"	7'-5"	7'-9 1/4"		
25,000'	7'-6 7/8"	7'-6 3/4"	7'-5 7/8"	7'-8"				
TANGENT	7'-6 5/8"	7'-6 5/8"						

NOTE: THE MINIMUM CLEARANCE BETWEEN ℄ OF TRACK AND FACE OF WALL SHALL BE 8'-6" IF A CLOSED DRAINAGE SYSTEM IS INSTALLED BETWEEN THE TRACK AND THE WALL.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING
DEVELOPMENT ENGINEERING & CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES

RETAINING WALL SECTION
DESIGN TABLES

FIGURE 11.61

RADIUS	S.E.=4"		S.E.=5"		S.E.=6"			
	As (MIN.)	Ts (MIN.)	As (MIN.)	Ts (MIN.)	As (MIN.)	Ts (MIN.)		
200'	9'–4 1/4"	9'–7 7/8"	9'–3 1/2"	9'–8"	9'–2 7/8"	9'–10 1/4"		
300'	8'–7 1/2"	9'–1"	8'–6 3/4"	9'–2 1/8"	8'–6 1/8"	9'–3 3/8"		
400'	8'–3 1/4"	8'–9 5/8"	8'–2 1/2"	8'–10 3/4"	8'–1 7/8"	9'–0"		
500'	8'–0 3/4"	8'–7 5/8"	8'–0"	8'–8 3/4"	7'–11 3/8"	8'–10"		
600'	7'–11"	8'–8 1/4"	7'–10 1/4"	8'–7 3/8"	7'–9 5/8"	8'–8 5/8"		
700'	7'–9 3/4"	8'–5 1/4"	7'–9"	8'–6 3/8"	7'–8 3/8"	8'–7 5/8"		
800'	7'–9"	8'–4 5/8"	7'–8 1/4"	8'–5 3/4"	7'–7 5/8"	8'–7"		
1000'	7'–7 3/4"	8'–3 5/8"	7'–7"	8'–4 3/4"	7'–6 3/8"	8'–6"		
1200'	7'–6 7/8"	8'–2 7/8"	7'–6 1/8"	8'–4"	7'–5 1/2"	8'–5 1/4"		
1400'	7'–6 1/4"	8'–2 3/8"	7'–5 1/2"	8'–3 1/2"	7'–4 7/8"	8'–4 3/4"		
1600'	7'–5 3/4"	8'–2"	7'–5"	8'–3 1/8"	7'–4 3/8"	8'–4 3/8"		
1800'	7'–5 3/8"	8'–1 3/4"	7'–4 5/8"	8'–2 7/8"	7'–4"	8'–4 1/8"		
2000'	7'–5 1/8"	8'–1 1/2"	7'–4 3/8"	8'–2 5/8"	7'–3 3/4"	8'–3 7/8"		
2500'	7'–5 3/4"	8'–1 1/8"	7'–5"	8'–2 1/4"	7'–4 3/8"	8'–3 1/2"		
3000'	7'–5 1/4"	8'–0 7/8"	7'–4 1/2"	8'–2"	7'–3 7/8"	8'–3 1/4"		
4000'	7'–4 5/8"	8'–0 1/2"	7'–3 7/8"	8'–1 5/8"	7'–3 1/4"	8'–2 7/8"		
5000'	7'–4 1/4"	8'–0 3/8"	7'–3 1/2"	8'–1 1/2"				
6000'	7'–3 7/8"	8'–0 1/8"						

NOTE: THE MINIMUM CLEARANCE BETWEEN ℄ OF TRACK AND FACE OF WALL SHALL BE 8'–6" IF A CLOSED DRAINAGE SYSTEM IS INSTALLED BETWEEN THE TRACK AND THE WALL.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES	RETAINING WALL SECTION DESIGN TABLES

FIGURE 11.62

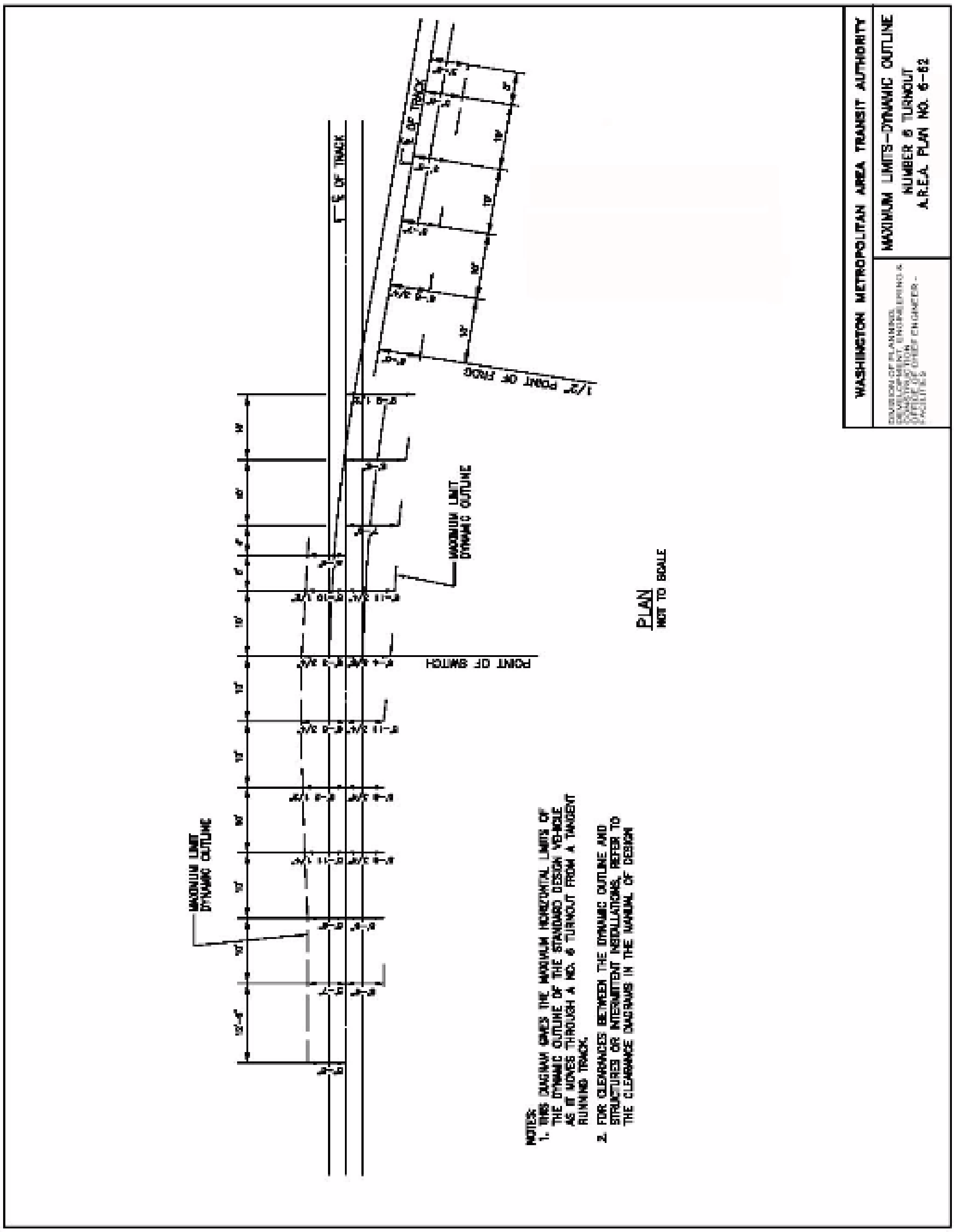

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
MAXIMUM LIMITS–DYNAMIC OUTLINE
NUMBER 6 TURNOUT
A.R.E.A. PLAN NO. 6-62
℄ OF TRACK
℄ OF TRACK
1/2" POINT OF FROG
POINT OF SWITCH
MAXIMUM LIMIT DYNAMIC OUTLINE
MAXIMUM LIMIT DYNAMIC OUTLINE
PLAN
NOT TO SCALE
NOTES:
1. THIS DIAGRAM GIVES THE MAXIMUM HORIZONTAL LIMITS OF THE DYNAMIC OUTLINE OF THE STANDARD DESIGN VEHICLE AS IT MOVES THROUGH A NO. 6 TURNOUT FROM A TANGENT RUNNING TRACK.
2. FOR CLEARANCES BETWEEN THE DYNAMIC OUTLINE AND STRUCTURES OR INTERMITTENT INSTALLATIONS, REFER TO THE CLEARANCE DIAGRAMS IN THE MANUAL OF DESIGN

FIGURE 11.63

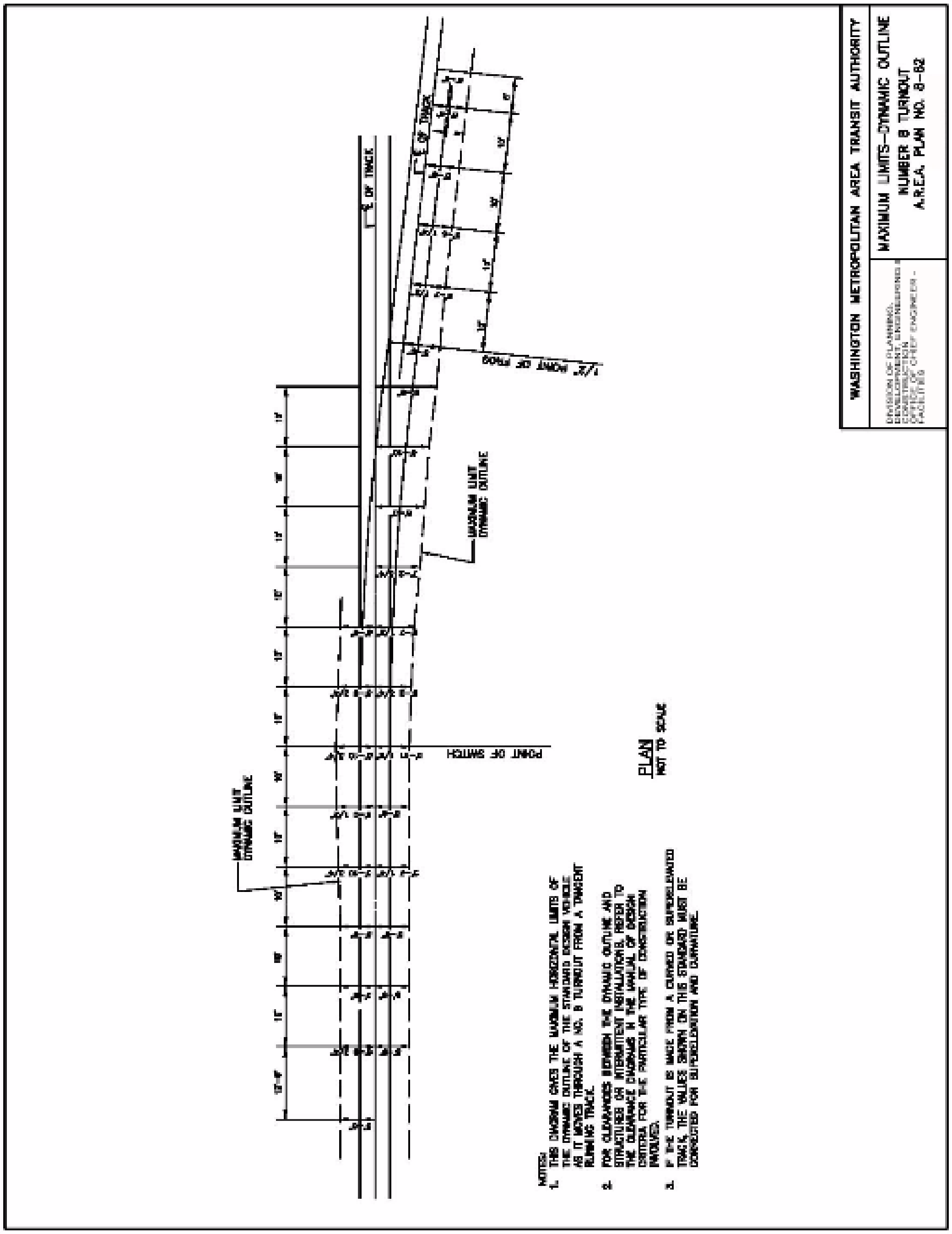

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
MAXIMUM LIMITS—DYNAMIC OUTLINE
NUMBER 8 TURNOUT
A.R.E.A. PLAN NO. 8-82
POINT OF SWITCH
1/2" POINT OF FROG
MAXIMUM UNIT DYNAMIC OUTLINE
PLAN
NOT TO SCALE

FIGURE 11.64

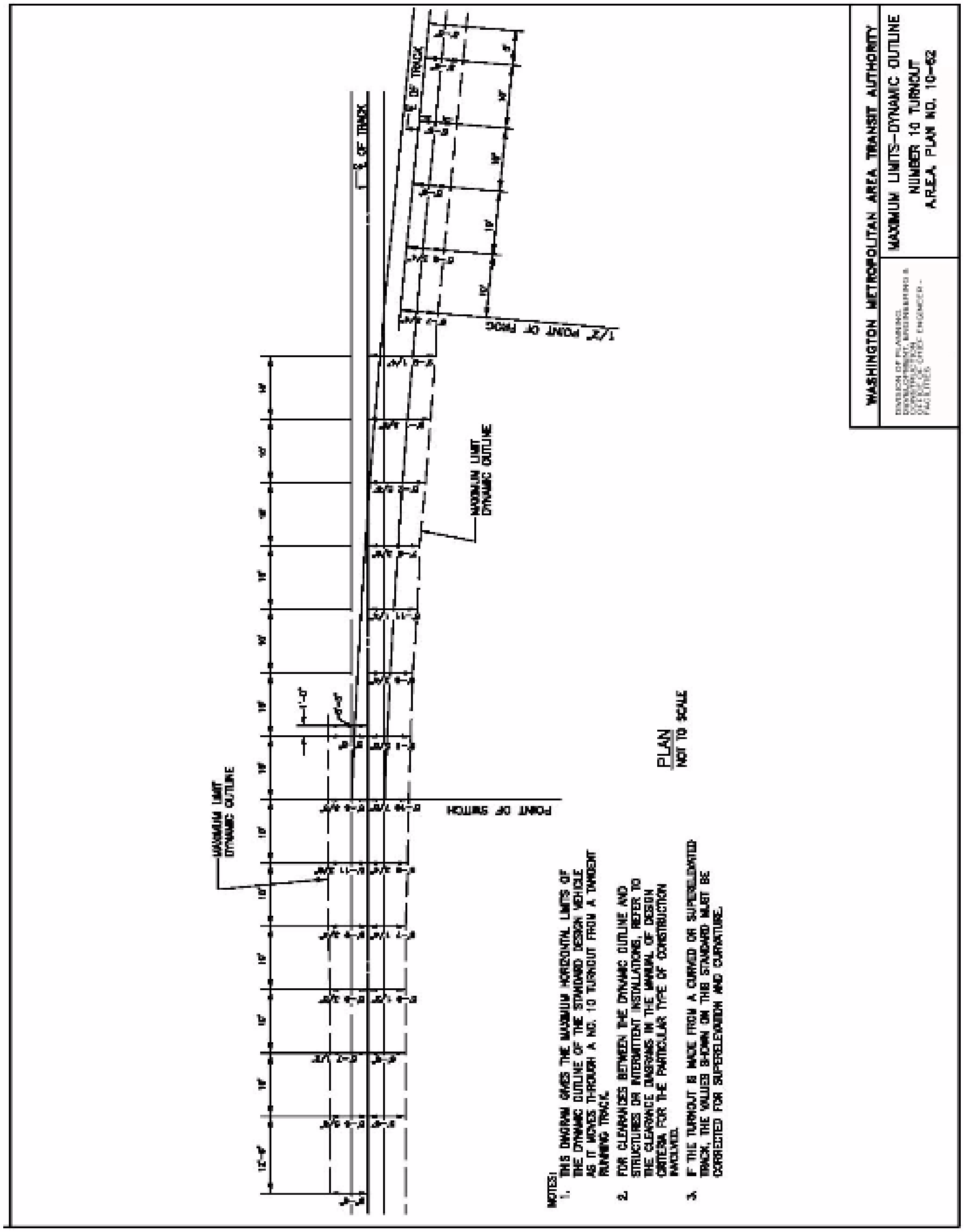

℄ OF TRACK
℄ OF TRACK
1/2" POINT OF FROG
MAXIMUM LIMIT DYNAMIC OUTLINE
MAXIMUM LIMIT DYNAMIC OUTLINE
POINT OF SWITCH
PLAN
NOT TO SCALE
NOTES:
1. THIS DIAGRAM GIVES THE MAXIMUM HORIZONTAL LIMITS OF THE DYNAMIC OUTLINE OF THE STANDARD DESIGN VEHICLE AS IT MOVES THROUGH A NO. 10 TURNOUT FROM A TANGENT RUNNING TRACK.
2. FOR CLEARANCES BETWEEN THE DYNAMIC OUTLINE AND STRUCTURES OR INTERMITTENT INSTALLATIONS, REFER TO THE CLEARANCE DIAGRAMS IN THE MANUAL OF DESIGN CRITERIA FOR THE PARTICULAR TYPE OF CONSTRUCTION INVOLVED.
3. IF THE TURNOUT IS MADE FROM A CURVED OR SUPERELEVATED TRACK, THE VALUES SHOWN ON THIS STANDARD MUST BE CORRECTED FOR SUPERELEVATION AND CURVATURE.
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
MAXIMUM LIMITS—DYNAMIC OUTLINE
NUMBER 10 TURNOUT
A.R.E.A. PLAN NO. 10-62

FIGURE 11.65

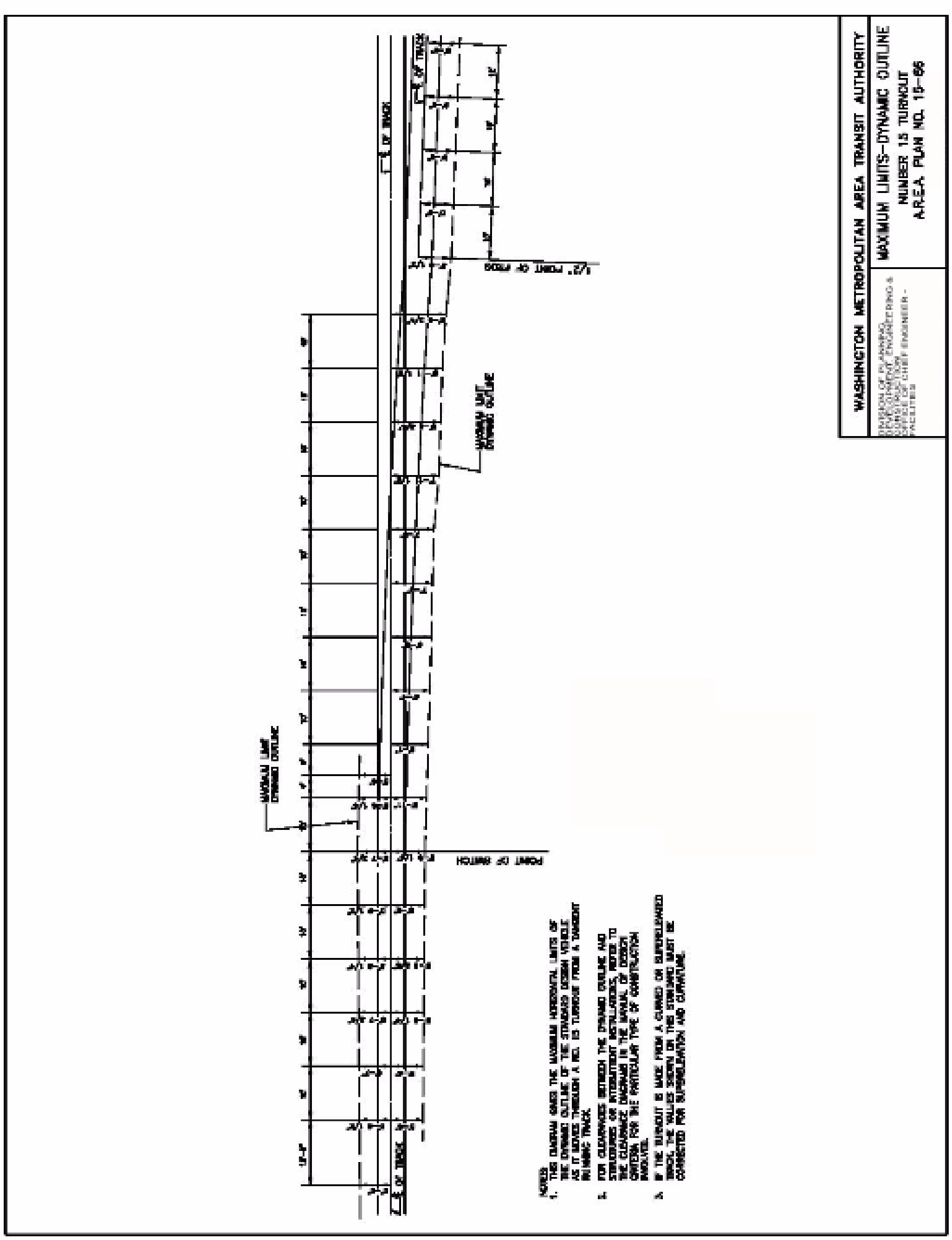
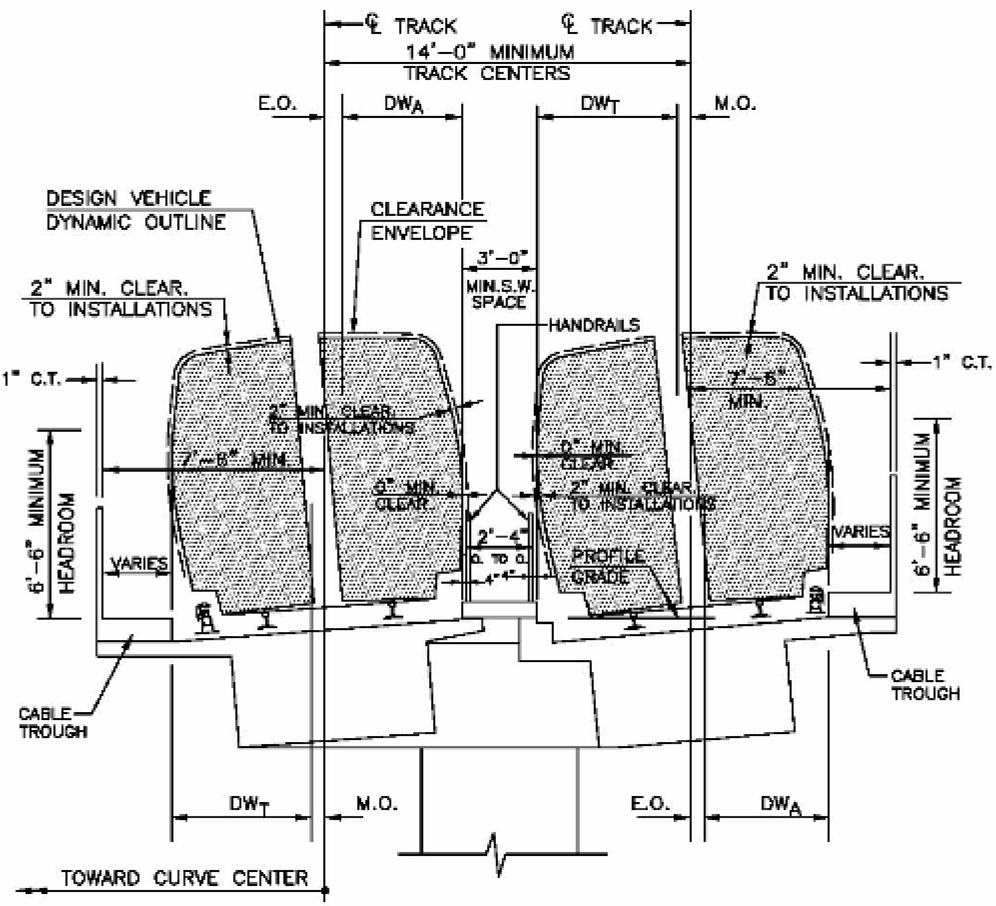

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
MAXIMUM LIMITS-DYNAMIC OUTLINE
NUMBER 15 TURNOUT
A.R.E.A. PLAN NO. 15-66
POINT OF SWITCH
1/2" POINT OF FROG

FIGURE 11.66



NOTES:
FOR TRACK CENTERS SEE FIGURES III.68.
FOR DW_T & DW_A VALUES SEE FIGURES III.30 & III.31.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES	AERIAL STRUCTURE DOUBLE TRACK SECTION CLEARANCE DIAGRAM

FIGURE 11.67

RADIUS	TRACK CENTERS						
	SUPERELEVATION						
	0"	1"	2"	3"	4"	5"	6"
500'	15'-3 1/2"	15'-3 3/4"	15'-3 3/4"	15'-3 7/8"	15'-4 3/8"	15'-4 3/4"	15'-5 3/8"
600'	15'-0 3/4"	15'-1"	15'-1"	15'-1 1/8"	15'-1 5/8"	15'- 2"	15'-2 5/8"
700'	14'-10 3/4"	14'-11"	14'-11"	14'-11 1/8"	14'-11 5/8"	15'-0"	15'-0 5/8"
800'	14'-9 1/2"	14'-9 3/4"	14'-9 3/4"	14'-9 7/8"	14'-10 3/8"	14'-10 3/4"	14'-11 3/8"
1000'	14'-7 1/2"	14'-7 3/4"	14'-7 3/4"	14'-7 7/8"	14'-8 3/8"	14'-8 3/4"	14'-9 3/8"
1200'	14'-6"	14'-6 1/4"	14'-6 1/4"	14'-6 3/8"	14'-6 7/8"	14'-7 1/4"	14'-7 7/8"
1400'	14'-5"	14'-5 1/4"	14'-5 1/4"	14'-5 3/8"	14'-5 7/8"	14'-6 1/4"	14'-6 7/8"
1600'	14'-4 1/4"	14'-4 1/2"	14'-4 1/2"	14'-4 5/8"	14'-5 1/8"	14'-5 1/2"	14'-6 1/8"
1800'	14'-3 3/4"	14'-4"	14'-4"	14'-4 1/8"	14'-4 5/8"	14'-5"	14'-5 5/8"
2000'	14'-3 1/4"	14'-3 1/2"	14'-3 1/2"	14'-3 5/8"	14'-4 1/8"	14'-4 1/2"	14'-5 1/8"
2500'	14'-2 1/2"	14'-2 3/4"	14'-2 3/4"	14'-2 7/8"	14'-3 3/8"	14'-3 3/4"	14'-4 3/8"
3000'	14'-2"	14'-2 1/4"	14'-2 1/4"	14'-2 3/8"	14'-2 7/8"	14'-3 1/4"	14'-3 7/8"
4000'	14'-1 1/4"	14'-1 1/2"	14'-1 1/2"	14'-1 5/8"	14'-2 1/8"	14'-2 1/2"	14'-3 1/8"
5000'	14'-0 3/4"	14'-1 1/4"	14'-1 1/4"	14'-1 3/8"	14'-1 7/8"	14'-2 1/4"	
6000'	14'-0 1/2"	14'-0 3/4"	14'-0 3/4"	14'-0 7/8"	14'-1 3/8"		
7000'	14'-0 1/4"	14'-0 1/2"	14'-0 1/2"	14'-0 5/8"			
8000'	14'-0"	14'-0 1/4"	14'-0 1/4"	14'-0 3/8"			
9000'	14'-0"	14'-0"	14'-0"				
10,000'	14'-0"	14'-0"	14'-0"				
15,000'	14'-0"	14'-0"	14'-0"				
20,000'	14'-0"	14'-0"					
25,000'	14'-0"	14'-0"					
TANGENT	14'-0"						

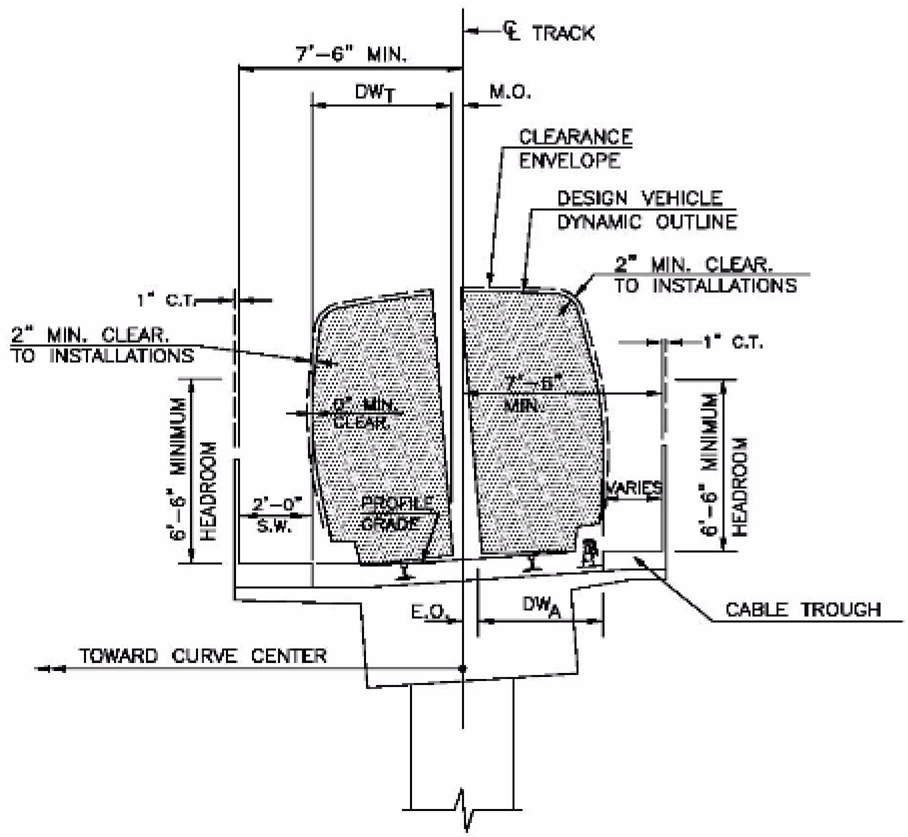
NOTE:
TRACK CENTERS INCLUDE MINIMUM 3'-0" DISTANCE BETWEEN DYNAMIC OUTLINES.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES

AERIAL STRUCTURE–DOUBLE TRACK
DESIGN TABLES

FIGURE 11.68



NOTES:

FOR DW_T & DW_A VALUES SEE FIGURES III.30 & III.31.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING DEVELOPMENT ENGINEERING & CONSTRUCTION OFFICE OF THE CHIEF ENGINEER - FACILITIES	AERIAL STRUCTURE SINGLE TRACK SECTION CLEARANCE DIAGRAM

FIGURE 11.69

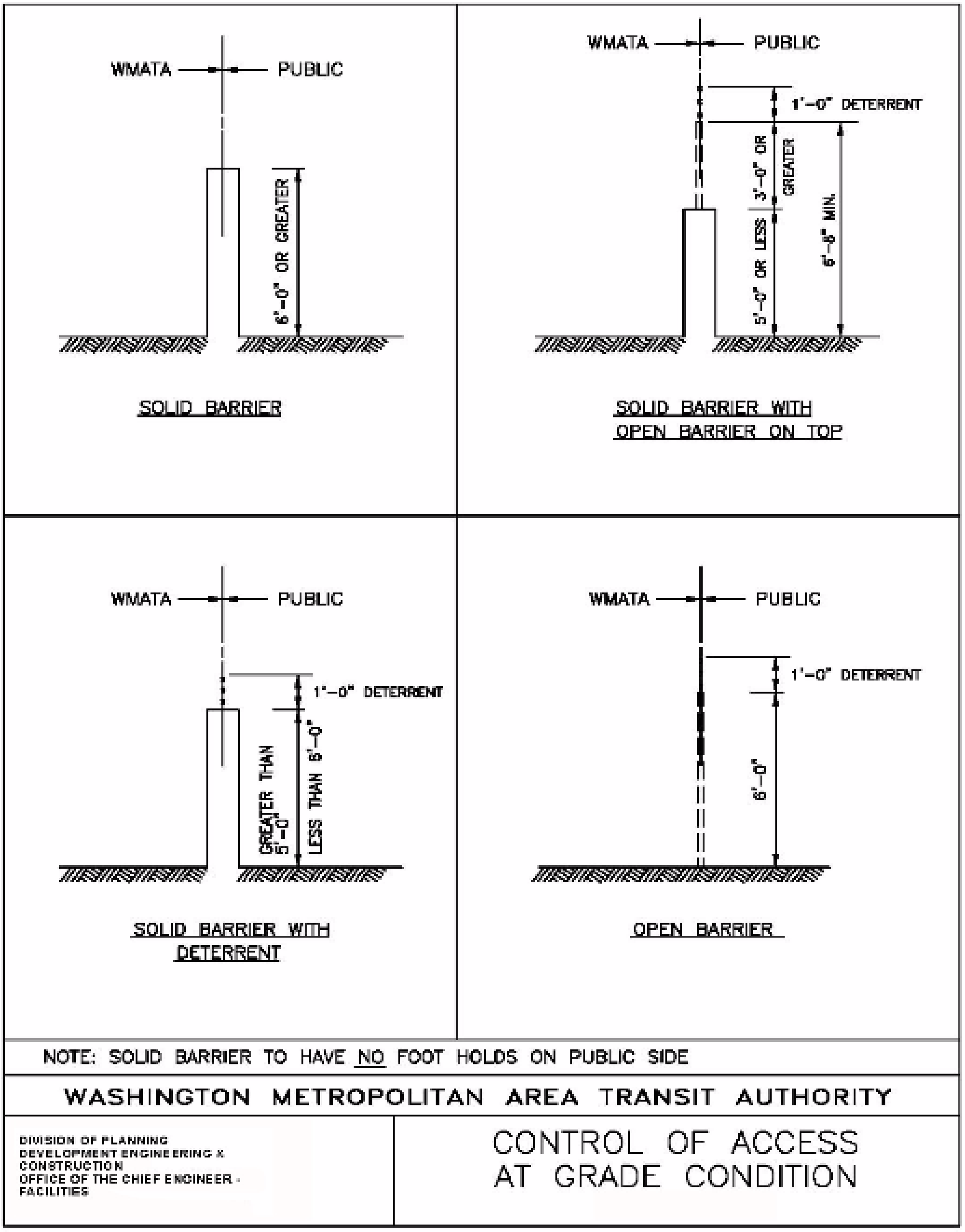

WMATA
PUBLIC
6'-0" OR GREATER
SOLID BARRIER
WMATA
PUBLIC
1'-0" DETERRENT
3'-0" OR GREATER
5'-0" OR LESS
6'-8" MIN.
SOLID BARRIER WITH OPEN BARRIER ON TOP
WMATA
PUBLIC
1'-0" DETERRENT
GREATER THAN 5'-0"
LESS THAN 6'-0"
SOLID BARRIER WITH DETERRENT
WMATA
PUBLIC
1'-0" DETERRENT
6'-0"
OPEN BARRIER
NOTE: SOLID BARRIER TO HAVE NO FOOT HOLDS ON PUBLIC SIDE
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING
DEVELOPMENT ENGINEERING &
CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER - FACILITIES
CONTROL OF ACCESS AT GRADE CONDITION

FIGURE 11.70

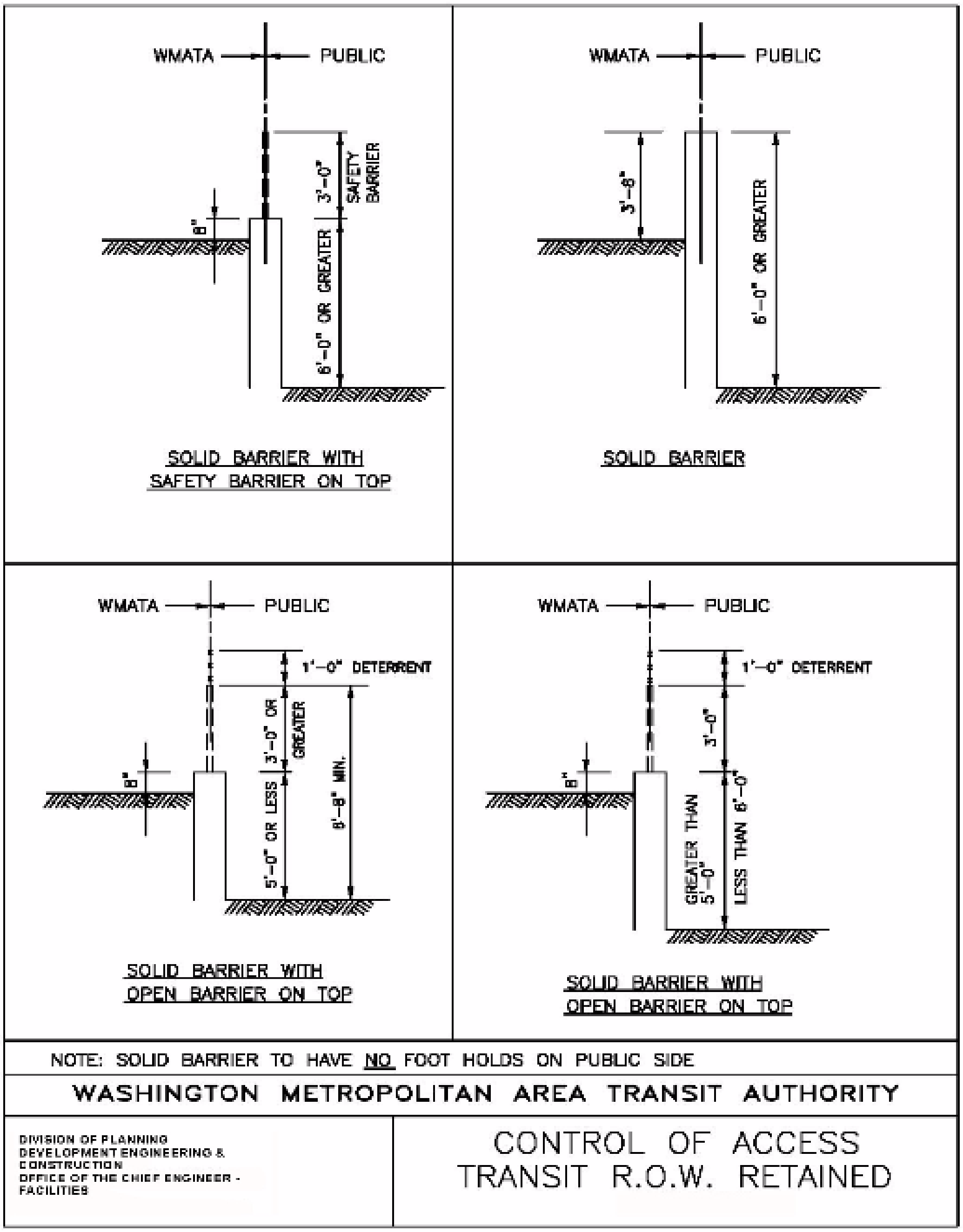
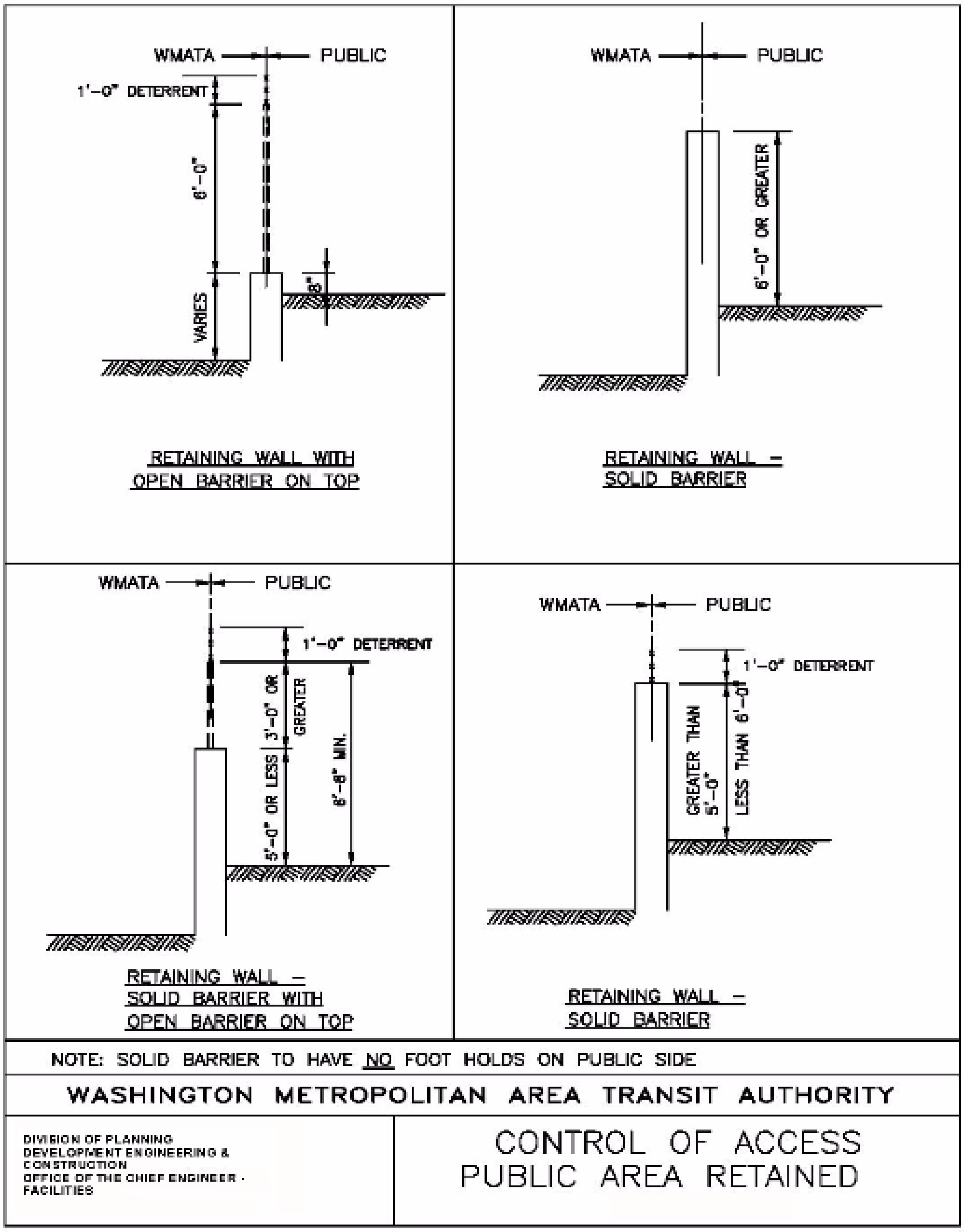

WMATA
PUBLIC
8"
3'-0"
SAFETY BARRIER
6'-0" OR GREATER
SOLID BARRIER WITH SAFETY BARRIER ON TOP
WMATA
PUBLIC
3'-8"
6'-0" OR GREATER
SOLID BARRIER
WMATA
PUBLIC
1'-0" DETERRENT
3'-0" OR GREATER
8"
5'-0" OR LESS
8'-8" MIN.
SOLID BARRIER WITH OPEN BARRIER ON TOP
WMATA
PUBLIC
1'-0" DETERRENT
3'-0"
8"
GREATER THAN 5'-0"
LESS THAN 6'-0"
SOLID BARRIER WITH OPEN BARRIER ON TOP
NOTE: SOLID BARRIER TO HAVE NO FOOT HOLDS ON PUBLIC SIDE
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING
DEVELOPMENT ENGINEERING &
CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER -
FACILITIES
CONTROL OF ACCESS
TRANSIT R.O.W. RETAINED

FIGURE 11.71



WMATA
PUBLIC
1'-0" DETERRENT
6'-0"
VARIES
8"
RETAINING WALL WITH
OPEN BARRIER ON TOP
WMATA
PUBLIC
6'-0" OR GREATER
RETAINING WALL -
SOLID BARRIER
WMATA
PUBLIC
1'-0" DETERRENT
3'-0" OR GREATER
5'-0" OR LESS
6'-8" MIN.
RETAINING WALL -
SOLID BARRIER WITH
OPEN BARRIER ON TOP
WMATA
PUBLIC
1'-0" DETERRENT
GREATER THAN 5'-0"
LESS THAN 6'-0"
RETAINING WALL -
SOLID BARRIER
NOTE: SOLID BARRIER TO HAVE NO FOOT HOLDS ON PUBLIC SIDE
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING
DEVELOPMENT ENGINEERING &
CONSTRUCTION
OFFICE OF THE CHIEF ENGINEER -
FACILITIES
CONTROL OF ACCESS
PUBLIC AREA RETAINED

FIGURE 11.72

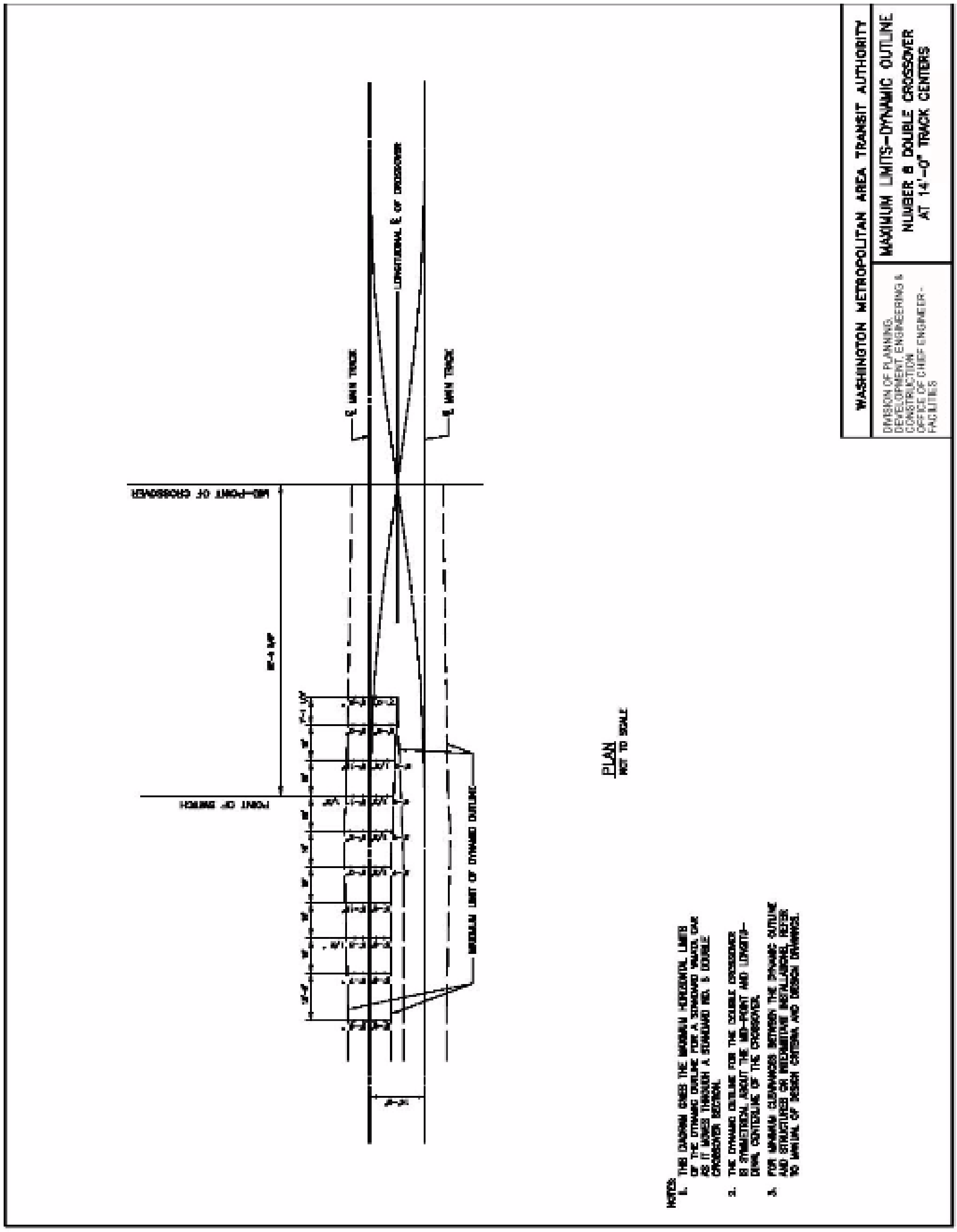

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING & CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
MAXIMUM LIMITS—DYNAMIC OUTLINE
NUMBER 8 DOUBLE CROSSOVER
AT 14'-0" TRACK CENTERS
PLAN
NOT TO SCALE

FIGURE 11.73

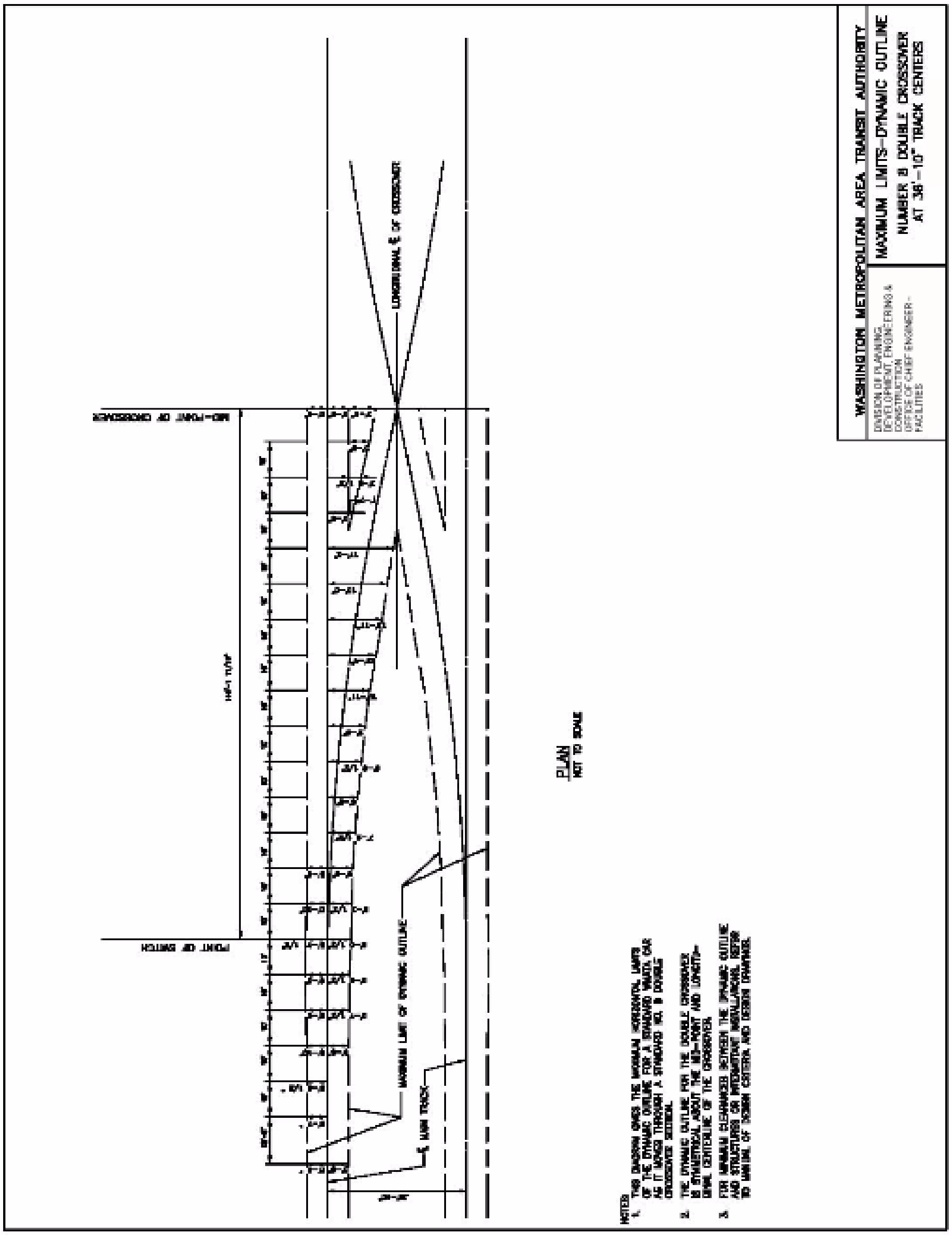

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
MAXIMUM LIMITS–DYNAMIC OUTLINE
NUMBER 8 DOUBLE CROSSOVER AT 38'-10" TRACK CENTERS
PLAN
NOT TO SCALE

FIGURE 11.74

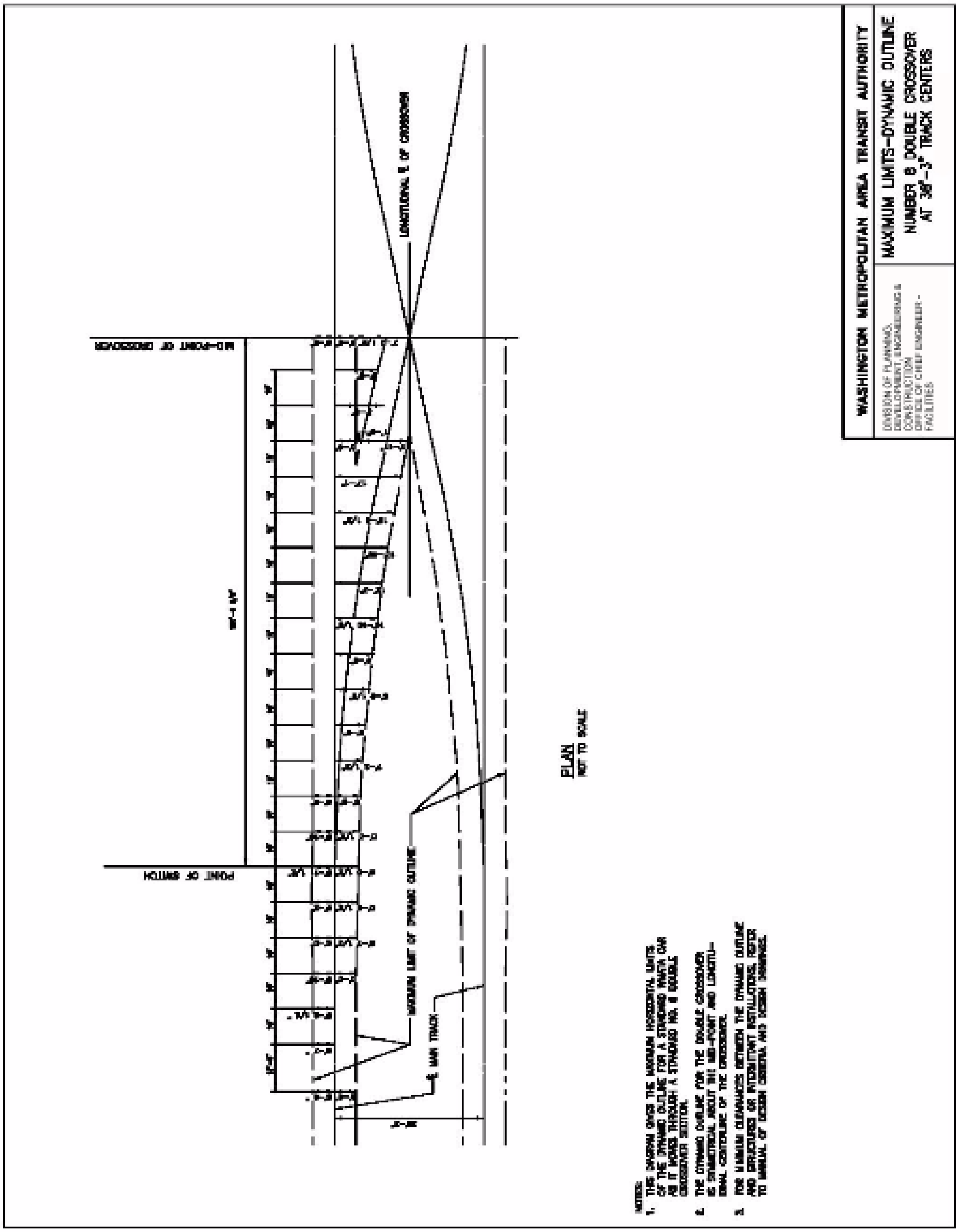

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
MAXIMUM LIMITS–DYNAMIC OUTLINE
NUMBER 8 DOUBLE CROSSOVER
AT 38'-3" TRACK CENTERS
PLAN
NOT TO SCALE
POINT OF SWITCH
MID-POINT OF CROSSOVER
MAIN TRACK

FIGURE 11.75

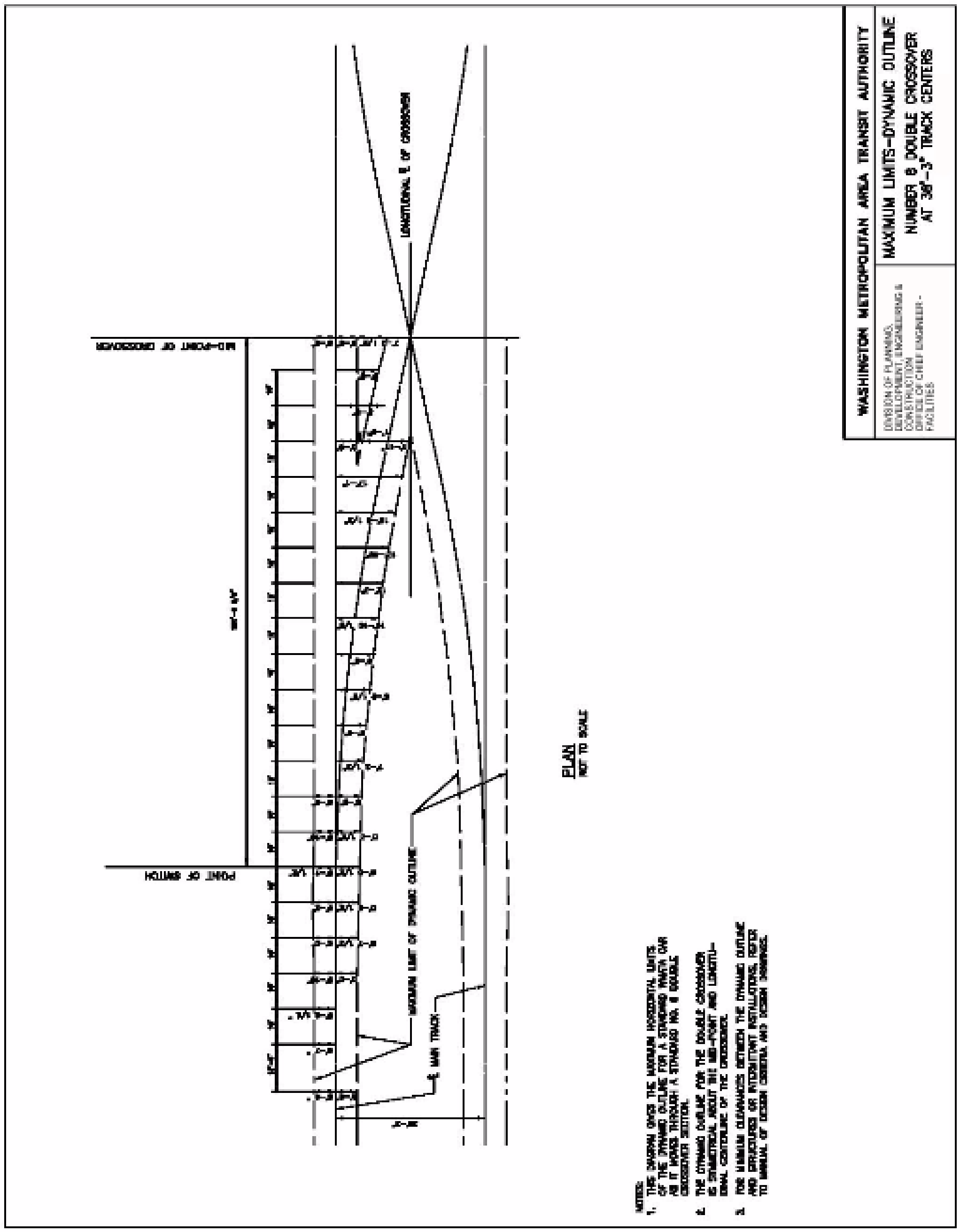

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
MAXIMUM LIMITS-DYNAMIC OUTLINE
NUMBER 8 DOUBLE CROSSOVER
AT 36'-3" TRACK CENTERS
PLAN
POINT OF SWITCH
MID-POINT OF CROSSOVER

FIGURE 11.75

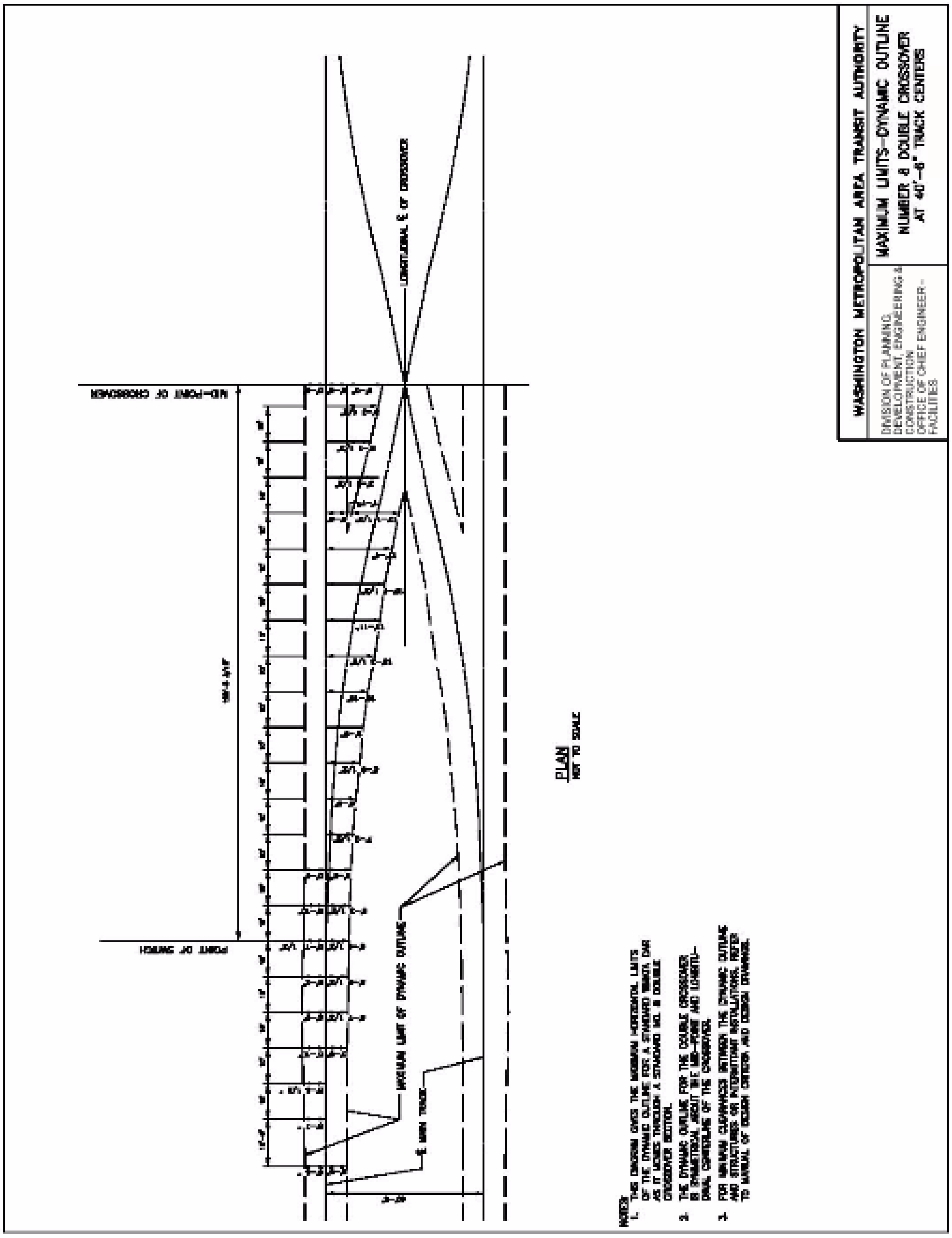

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
MAXIMUM LIMITS—DYNAMIC OUTLINE
NUMBER 8 DOUBLE CROSSOVER
AT 40'-6" TRACK CENTERS
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING & CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
PLAN
NOT TO SCALE
MAXIMUM LIMIT OF DYNAMIC OUTLINE
POINT OF SWITCH
MID-POINT OF CROSSOVER

FIGURE 11.76

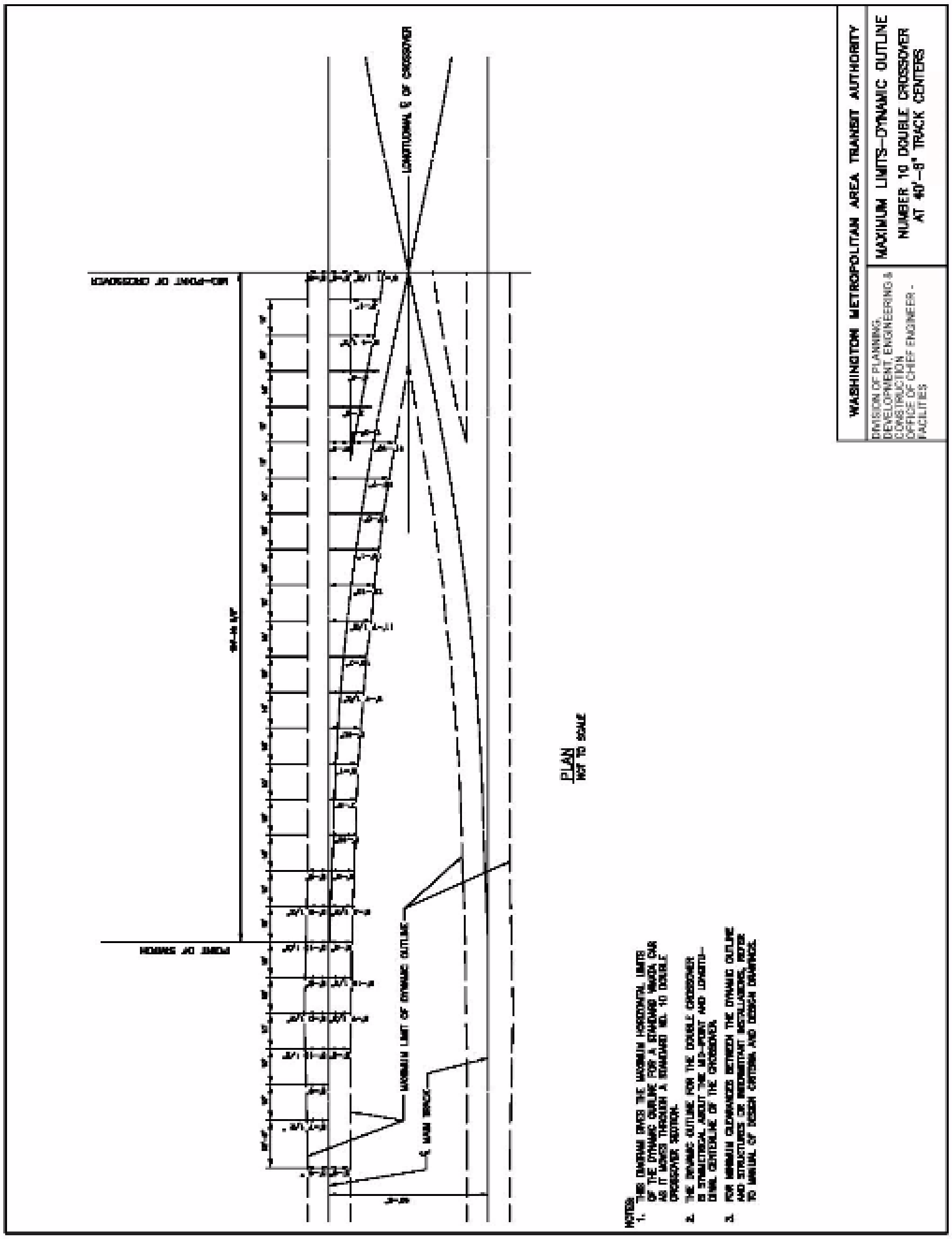

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
MAXIMUM LIMITS–DYNAMIC OUTLINE
NUMBER 10 DOUBLE CROSSOVER AT 40'–8" TRACK CENTERS
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING & CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
PLAN
NOT TO SCALE

FIGURE 11.77

SECTION 12 - UTILITIES

12.1 GENERAL

These criteria shall govern the maintenance, support, relocation, restoration and reconstruction of utilities encountered or affected by WMATA construction of the rail transit system, and the restoration of pavement and adjacent areas disturbed by such construction. In the design of the of the proposed work, due consideration shall be given to the needs of the transit system, the requirements and obligations of the utility organizations, traffic requirements, the service needs of abutting properties and policies established by WMATA. In cases where national codes, local codes, and WMATA standards conflict, the most stringent code or standard shall take precedence.

In all cases where WMATA maintains and / or owns the project utilities, then WMATA shall be the sole arbiter of the criteria requirements; such as analyses, design, material selection, installation methods, etc., and operational / maintenance requirements. No exceptions are allowed.

12.2 POLICY

WMATA is directed under Section 68 of Public Law89-774 to reimburse utility companies for the cost of relocations as follows:

"Notwithstanding the provisions of Section 67 of this Article XV, any highway or other public facility or any Facilities of a public utility company which will be Dislocated by reason of a project deemed necessary by the Board to effectuate the authorized purposes of this Title shall be relocated if such facilities are devoted to a public use, and the reasonable cost of Relocation, if substitute Facilities are necessary, shall be paid by the Board from any of its monies."

12.2.1 By definition utilities include facilities belonging to governmental agencies, public utility corporations and private parties, including service lines to adjoining properties.

12.2.2 Utilities encountered or close enough to be affected by transit construction shall be:

12.2.2.1 Supported and maintained complete in place during construction and continued in service following completion of transit facilities,

12.2.2.2 Temporarily relocated and maintained, then, upon completion of transit facilities, restored to service,

12.2.2.3 Temporarily relocated and maintained, then, upon completion of transit facilities, replaced by a new utility, or

12.2.2.4 Permanently relocated to a new location beyond the immediate limits of transit construction.

Utility service to abutting properties shall not be interrupted and, if temporarily relocated, shall be restored upon completion of work. Replacements for any existing utilities, including governmental facilities and pavements shall be designed to provide service essentially equal to that offered by the existing installations.

12.2.3 Betterments are enhancements to relocated facilities such as upgrades in materials.

Increases in diameter of pipe, number of conduits in a duct bank, width and thickness of pavement for pavement restoration and the like are considered to be Betterments. Betterments shall not be included in the project design until the additional cost of the betterment(s) is funded by the utility. A signed contract on the reimbursement shall be in hand and formally approved by WMATA.

All designs involving maintenance, support, relocation, or other utility work shall be in accordance with the requirements of the affected Utility entities. The Designer shall submit utility designs to the concerned corporation or agency for final review and approval.

Record elevation of all utilities shall be corrected to the project datum and identified on each utility drawing. Pertinent utility elevations and locations shall be checked by field survey, and where critical to design, by digging test pits at such locations as may be approved by WMATA.

Designers shall consider plans developed or being developed by others in adjoining sections to ensure that the overall utilities systems will be comparable to those existing before start of construction and that the systems will be compatible with the transit system.

For all sections within the District of Columbia which involve cut-and-cover construction of line and/or station segments, the Designer shall determine the requirements for replacing in-kind utilities affected by Metro construction and define where additional utilities will be required prior to the release of the construction permit for general re-paving in the construction area. If these additional facilities can be agreed upon as Betterments to be constructed by the Metro contractor, their alignment and construction shall be designed by the Designer and included in the contract documents. If these additional utilities are to be built by the utility owner, their alignment shall be defined on the composite utilities plans with the notation "NIC".

12.3 UTILITIES SUBSIDENCE ANALYSIS

In areas of potential subsidence above earth tunnels, the design handling of selected critical utilities shall be based upon a comprehensive analysis of anticipated settlement, structural integrity, and essential need of utility continuity. The specific utilities which are to receive this analysis will be identified in the Section Designer/Design Engineer's Scope of Services. The comprehensive analysis shall be accomplished as follows:

12.3.1 The subsidence potential will be evaluated and quantified. Available information will be extracted from the geotechnical report. Additional subsurface investigation shall be requested as necessary.

12.3.2 Assess the structural capability of the utility structure including a joint physical inspection with utility owners to assure agreement with respect to present condition. Document condition of the facility by taking photographs and recording location and extent of cracks, settlements, distortion of section, and other pertinent data.

12.3.3 Examine the feasibility and estimated cost of alternative forms of handling such as grouting (cement or chemical), underpinning, later repair, replacement, etc. Pre-coordinate the acceptability of outages or calculated risks with the utility owner.

12.3.4 Provide specific recommendations including instrumentation to measure and assure that such settlement remains within the predetermined allowable limits.

12.4 WETLANDS AND WATERS OF THE UNITED STATES

12.4.1 Definition: The U.S. Army Corps of Engineers (Federal Register 1982) and the Environmental Protection Agency (Federal Register 1980) jointly define wetlands as:

"Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas."

Wetlands are a subset of "Waters of the United States" which include deep-water aquatic habitats and special aquatic sites as well as wetlands. Waters of the United States are defined in the Federal Register 1982 as:

The territorial seas with respect to the discharge of fill material.

Coastal and inland waters, lakes, rivers, and streams that are navigable waters of the United States, including their adjacent wetlands.

Tributaries to navigable waters of the United States, including adjacent wetlands. Interstate waters and their tributaries, including adjacent wetlands.

All other waters of the United States that are not a part of a tributary system to interstate waters or navigable waters of the United States, such as isolated wetlands and lakes, intermittent streams, prairie potholes, and other waters, the degradation or destruction of which could affect interstate commerce.

Wetlands and Waters of the U.S. in the project area shall be field delineated using the three parameter approach, as outlined in the Corps of Engineers' Wetlands Delineation Manual, or any other method that the Corps requires. The three parameter approach requires positive evidence of hydrophytic vegetation, hydric soils, and wetland vegetation for determining that an area is a wetland.

12.4.2 Coordination

Cumulative wetland impacts associated with an entire route extension are to be coordinated as one package with the Corps of Engineers. WMATA will select one of the Section Designer/Design Engineer to perform the coordination; the other Section Designer/Design Engineer will provide all information necessary to assist in this coordination.

For projects in the District of Columbia and Maryland coordination must be made with the Baltimore District of the Corps of Engineers. For projects in Virginia, coordination must be made with the Norfolk District.

A Section 404 Permit, as required by the Clean Water Act, (33 U.S.C. 1344), shall be acquired. The objective of the Act is to maintain and restore the chemical, physical and biological integrity of the waters of the United States. The Corps of Engineers is authorized to issue permits for the discharge of dredged or fill material into waters of the United States, including wetlands.

12.4.3 Mitigation

The Metro facilities should be located to avoid, minimize and mitigate wetlands impacts. Mitigation can take the form of:

12.4.3.1 on-site restoration of wetlands disturbed during construction,

12.4.3.2 on-site restoration of wetlands that are not in good condition,

12.4.3.3 off-site restoration of wetlands that are not in good condition, or

12.4.3.4 on-site or off-site wetland creation

12.4.3.5 off-site replacement of wet lands of the same water shed

The Corps of Engineers will determine the type of mitigation required and the mitigation ratio, i.e. 1:1, 2:1, etc.

12.5 FLOOD PLAINS

12.5.1 General

The design of Metro shall take into consideration the protection of the system against local flooding resulting from stream lacustrine overflows and surface flooding based upon the more stringent requirements of FEMA and Flood Insurance Agency(FIA)and jurisdictions 100 year flood maps and the jurisdictional rainfall intensity for the 100-year storm (or the U.S. Weather Service 100-year intensity if such not adopted and published by the jurisdiction). A vertical clearance of 4'-4" between top of rail and flood level is desirable and 3'-0" is minimum unless an exception is approved. The Designer shall submit findings and recommendations to the WMATA for approval while in the preliminary stages of work. Final design shall not be undertaken prior to such approval.

Flood protection shall involve station entrances, portals, vent and fan shafts, power substations, chiller plants and any other facilities and openings into the system, such as drain inlets, electric conduits or other pipes.

12.5.2 Floodplain Development

Where the Metro lines, the station complexes, ancillary structures, or parking lots will encroach upon any stream channel or overbank area designated as a floodplain, the design shall take into account all ordinances and criteria governing development in floodplains of the appropriate jurisdictional agency. Requirements may include, but shall not necessarily be limited to, the design of provisions for the maintenance of floodwater storage capacity; the preparation of comparative flood water surface profiles; and the presentation of definitive studies to the agency and at public hearings.

12.5.3 Criteria

The Designer will perform all 100-year floodplain analyses required by the approving agency for the project.

12.5.3.1 District of Columbia

12.5.3.1.1 District Department of the Environment

1200 First Street, NE
Washington, D.C. 20002
202-535-2600

12.5.3.2 Virginia

12.5.3.2.1 Virginia Department of Environmental Quality

P.O. Box 1105
Richmond, VA 23212
1-804-698-400

12.5.3.3 Maryland

12.5.3.3.1 Montgomery County

Dept. of Environmental Protection

255 Rockville Pike Suite 120
Rockville, MD 20850-4166
240-777-7715

Department of Permitting Services

255 Rockville Pike
2nd Floor, Station 8
Rockville, Maryland 20850-4166
240-777-0311

12.5.3.3.2 City of Rockville

Community Planning and Development Services

111 Maryland Avenue
Rockville, Maryland 20850
240-314-8200

12.5.3.3.3 Prince George's County

Department of Environment

1001 McCormick Drive
Suite 500
Largo, Maryland 20774
301-883-5810

12.5.3.3.4 Maryland State Highway Administration Department of Natural Resources Waterway Resources

110 College Ave.
Annapolis, MD 21411
410-260-8770

12.6 TREE CONSERVATION

12.6.1 Definitions

Afforestation is the establishment of a tree cover in an area from which it has always or very long been absent, or the planting of open areas which are not presently in forest cover.

Forest or Woodland means a biological community dominated by trees or other woody plants covering an area of 10,000 square feet or more. This also includes forests that have been cut, but not cleared.

Forest Management Plans are prepared by a registered professional forester for timber management.

12.6.1.1 Mitigation is the off-setting of forest values lost due to development and/or construction activities by replanting woodlands or other agreed upon means.

12.6.1.2 Reforestation means the replanting of trees on recently forested land.

12.6.1.3 Specimen tree means a particularly impressive or unusual example of a species due to its size, shape, age, or any trait that epitomizes the character of the species.

12.6.2 The Designer shall perform all field delineations and plans required by the approving agency, if any, for the project.

12.6.2.1 District of Columbia

12.6.2.2 Virginia

12.6.2.2.1 Arlington County

12.6.2.2.2 Fairfax County

12.6.2.2.3 Loudoun County

12.6.2.2.4 City of Alexandria

12.6.2.3 Maryland

12.6.2.3.1 Montgomery County

12.6.2.3.2 City of Rockville

12.6.2.3.3 Prince George’s County

A Forest Stand Delineation plan and Tree Conservation plan need to be submitted to the Maryland-National Capital Park and Planning Commission, Natural Resources Division.

12.7 ARCHEOLOGICAL/HISTORIC PRESERVATION

The Designer shall perform all necessary research and records check to determine if any sites of archeological or historic significance will be impacted during the construction of the proposed Metro facilities. The Designer shall submit a report of findings to WMATA for review.

12.8 SEWERS AND DRAINAGE

12.8.1 General

All maintenance, relocation, restoration, and construction of sewers and drainage facilities shall be in strict conformance with the current specifications and practices of the approving agencies in the affected jurisdictions. All plans must be approved by the appropriate utility agency.

Construction of sewer laterals to abutting properties shall comply in every respect with all applicable area codes.

12.8.2 Design Criteria - General

In general, the replacement of impacted sewers and drainage facilities shall be “replacement-in-kind”. The redesign of the existing sewers and drainage facilities to be relocated and modified must be in accordance with requirement, criteria, standards and codes of the national and local agency with jurisdiction and/or owner of the sewers and drainage facilities.

Service to adjoining properties shall be maintained by supporting in place, by providing alternate temporary facilities or by diverting to other points.

Adequate closed flumes shall be provided to handle flows of sewers temporarily removed.

No surface drainage from adjoining areas shall be connected to the subway system track drains.

12.8.3 Sanitary Sewers

12.8.3.1 District of Columbia:

12.8.3.1.1 District of Columbia - The latest edition of the Plumbing Code of the Washington Metropolitan Area, as prepared by the Metropolitan Washington Council of Governments and supplements, shall be adhered to.

12.8.3.2 Maryland

12.8.3.2.1 Montgomery County - The Washington Suburban Sanitary Commission Standards shall apply to all sanitary sewers in Montgomery County. Plans must be prepared to meet their requirements as well as those of WMATA. The composite utility plans can be used as a base sheet in preparing the sanitary sewer plans. A supplementary WSSC title block will need to be added to the drawing.

The Plumbing and Gas Fitting Regulations of the Washington Suburban Sanitary Commission will apply.

12.8.3.2.2 Prince George’s County-The Washington Suburban Sanitary Commission Standards shall apply to all sanitary sewers in Prince George’s County. Plans must be prepared to meet their requirements as well as those of WMATA. The composite utility plans can be used as a base sheet in preparing the sanitary sewer plans. A supplementary WSSC title block will need to be added to the drawing.

The Plumbing and Gas Fitting Regulations of the Washington Suburban Sanitary Commission will apply.

12.8.3.3 Virginia

12.8.3.3.1 Arlington County - The Virginia, the Plumbing Code of the Washington Metropolitan Area, as prepared by the Metropolitan Washington Council of Governments, supplemented by the amendments adopted by Arlington County, effective January 1, 1968, shall be adhered to.

12.8.3.3.2 Fairfax County - The Plumbing Code of Fairfax County shall be complied within Fairfax County.

12.8.3.3.3 City of Alexandria - The Plumbing Code of the City of Alexandria shall apply in the City of Alexandria.

12.8.3.3.4 Loudon County - The plumbing Code of Loudon County and DC Water shall be complied with.

12.8.3.4 Storm Sewers

12.8.3.4.1 District of Columbia

When the rational formula is used for design, rainfall intensity shall be based on a 15-year design storm. In critical locations, such as drainage pockets where flooding would result in heavy damage, 25year storm shall be used.

12.8.3.4.2 Maryland

12.8.3.4.2.1 Maryland State Highway Administration (MSHA) - Where storm sewers are under the jurisdiction of the MSHA, replacement shall be in kind and shall comply with the latest MSHA standard drawings and specifications, and hydraulic criteria based on the classification of the roadway.

12.8.3.4.2.2 Montgomery County - The Montgomery County Department of Public Works has responsibility for the storm drainage systems in Montgomery County, exclusive of state roads. The County adopted drainage design criteria is applicable. Montgomery County Standards are to be used for applicable storm facilities, exclusive of state roads.

12.8.3.4.2.3 Prince George’s County-The Prince George’s County Department of Environmental Resources, Watershed

Protection Branch, has responsibility for the storm drainage systems in that County, exclusive of state roads. County Standards are to be used for applicable storm facilities, exclusive of state roads.

12.8.3.4.2.4 City of Rockville - Plumbing and Gas Fitting Regulations of the Washington Suburban Sanitary Commission apply in Rockville, Maryland, but the permit will be granted by the city.

12.8.3.4.3 Virginia

12.8.3.4.3.1 Virginia Department of Transportation - Where storm sewers are under the jurisdiction of the Virginia Department of Highways the replacement of these facilities shall be in kind and shall comply with the Virginia Department of Highways' standard drawings and specifications.

12.8.3.4.3.2 Arlington County - Storm sewers in Arlington County will comply with all criteria of that County.

12.8.3.4.3.3 Fairfax County - Storm sewers in Fairfax County will comply with the criteria in the Fairfax County Public Facilities Manual.

12.8.3.4.3.4 City of Alexandria - Any elevations shown on drawings received from Alexandria must be verified in the field as being correct. Many elevations on the city drawings are of varying datum planes. Due to lack of records, utilities within the property of CSX Railroad will require field location. All entry onto CSX property must be cleared with the CSX Railroad.

12.8.3.4.3.5 Loudon County - Loudon Water has responsibility for all storm water facilities.

12.8.3.5 Combined Sewers

12.8.3.5.1 District of Columbia - Combined sewers are only in the District of Columbia. Close coordination must be made with WASUA when work is to be performed on combined sewers.

12.9 STORMWATER MANAGEMENT

Maryland Water Resources Administration, under the Department of Natural Resources, has adopted new regulations under a chapter entitled COMAR 26.17.02 STORMWATER MANAGEMENT with an effective date of July 16, 2000 (RE: MD. R. Doc. No. 83-R-151-F). The regulations require that all land development have an approved stormwater management plan from the approving agency. A grading or building permit may not be issued for a property unless a stormwater management plan has been approved. The minimum requirements for stormwater management are:

Montgomery and Prince George's Counties and their incorporated municipalities require that the post-development peak discharges for a 2- and 10-year frequency storm event be maintained at a level equal to or less than the respective 2- and 10-year predevelopment peak discharge rates, through stormwater management techniques that control the volume, timing, and rate of runoff. Alternative minimum control requirements may be adopted subject to Administration approval. The Administration shall require a demonstration that alternative requirements will control flood damages, accelerated stream erosion, water quality, and sedimentation, including if necessary, comprehensive watershed studies.

If detention or retention structures are used, they must be in accordance with the Administration regulations for off-site structures, velocity dissipation, downstream analysis, and small ponds.

An operation and maintenance plan shall be required as a condition of stormwater management plan approval.

The Administration's latest requirements must be verified prior to the start of design and incorporated into the design following the precedence order given in Section 12.1.

12.10 WATER QUALITY

12.10.1 General

Urbanization has had adverse consequences on streams due to an increase in flooding, stream bank erosion and pollutant export. Pollutants include sediment, nutrients (e.g. nitrogen and phosphorus), bacteria, a depletion of dissolved oxygen, oil and grease, trace metals (including arsenic, chromium, copper, mercury, nickel, lead, zinc), toxic chemicals (including paint thinners and pesticides) and chlorides. Removal of these urban pollutants from stormwater runoff is important to protect the downstream wildlife. A series of Best Management Practices (BMPs) have been developed which not only control nonpoint source pollution from urban areas but also provide effective stormwater management.

12.10.2 Methods

12.10.2.1 Extended Detention Ponds - An extended detention pond is dry before a storm event. A portion of the total runoff, called the first flush, (frequently ½" to 1" per acre) is released at a rate that will detain it for about 24 hours. Pollutants are removed from the runoff by settling. A wetland marsh should be created in the bottom of an extended detention pond, wherever possible, to help remove pollutants that cannot be removed by conventional settling.

12.10.2.2 Wet Ponds - Wet ponds, also known as retention ponds, are an effective means of removing sediment, nutrients, and trace metals. They require a steady source of water and may be a high maintenance item. They require a relatively impermeable soil for the bottom and sides.

12.10.2.3 Infiltration Trenches - Infiltration trenches are designed to remove soluble and particulate pollutants but not to trap coarse sediments. Grass buffers must be installed to capture coarse sediment before it enters the trench. Trenches can provide groundwater recharge, low flow augmentation and localized streambank erosion control. They are only feasible when soils are permeable and the watertable and bedrock are well below the bottom of the trench.

12.10.2.4 Infiltration Basins - Infiltration basins are effective in removing soluble and particulate pollutants but not to trap coarse sediments. Coarse sediment should generally be removed before it enters the basin. Basins can provide groundwater recharge, low flow augmentation and localized streambank erosion control. They are only feasible when soils are permeable and the watertable and bedrock are well below the bottom of the trench.

12.10.2.5 Water quality inlets - also known as oil/grit separators, are designed to remove sediment and hydrocarbon loadings from parking lot runoff before they are conveyed to the storm drainage network.

12.10.3 Criteria

The Designer will perform all analyses required by the approving agency for the project.

12.11 WATER

12.11.1 Codes and Standards

All maintenance, relocation, restoration, and construction of water mains and appurtenances shall be in strict conformance with the current specifications and practices of the approving agencies concerned.

Construction of water services to abutting properties shall comply in every respect with applicable area codes as follows:

In the District of Columbia and Arlington County, Virginia, the Plumbing Code of the Washington Metropolitan Area, as prepared by the Metropolitan Washington Council of Governments, supplemented by the following:

12.11.1.1 The 1967 Plumbing Code of the District of Columbia

12.11.1.1.1 Amendments adopted by Arlington County, effective January1, 1968.

12.11.1.2 In Montgomery and Prince George's Counties, Maryland, the Plumbing and Gas Fitting Regulations of the Washington Suburban Sanitary Commission.

12.11.1.3 Plumbing and Gas Fitting Regulations of the Washington Suburban Sanitary Commission also apply in the City of Rockville.

12.11.1.4 The Plumbing Code of Fairfax County shall apply in Fairfax County.

12.11.1.5 The Plumbing Code of the City of Alexandria shall apply in the City of Alexandria.

12.11.1.6 The Plumbing Code of Loudoun County shall apply in Loudoun County.

12.11.2 Design Criteria - District of Columbia

12.11.2.1 All designs shall be according to WASUA standards.

12.11.2.2 No water main or fire hydrant shall be taken out of service without prior approval of the affected utility owner.

12.11.3 Design Criteria - Virginia

12.11.3.1 Arlington County

12.11.3.1.1 Arlington County standards shall apply in all instances for water mains in areas controlled by the county, and for service mains in park areas.

12.11.3.1.2 In the event Metro construction requires adjustment or reconstruction of 30"diameterand smaller water mains serving the Pentagon Building and National Airport, pipe shall conform to that of existing installation and work shall meet the requirements of the Washington Aqueduct, 5000 MacArthur Boulevard, N.W., Washington, D.C.

12.11.3.2 **City of Alexandria** - Where possible, the jurisdiction’s water provider will perform the construction or reconstruction of all water mains within the area of the Metro System prior to the Metro Contractor's entry on the job. If it becomes necessary for the Metro Contractor to perform any work on the water facility, prior approval must be obtained from City of Alexandria water provider.

12.11.3.3 Fairfax County - The jurisdiction's water provider has responsibility for all water facilities in the areas of Fairfax County.

Where possible, all construction or reconstruction of water mains caused by Metro excavation shall be performed by the Fairfax County water provider contractor. If the Metro Contractor is required to perform any work on the water facilities in the county, prior approval must be obtained from jurisdiction's water provider.

12.11.3.4 Loudoun County – Loudoun Water has responsibility for all storm and water facilities.

Where possible all construction or reconstruction of water mains caused by Metro construction shall be performed by Loudoun Water or its contractor. If the Metro contractor is required to perform any work on the water facilities in the county, prior approval from Loudoun Water must be obtained.

12.11.4 Design Criteria - Maryland

12.11.4.1 Montgomery County

12.11.4.1.1 The Washington Suburban Sanitary Commission Standards shall apply to all water mains and appurtenances in Montgomery County.

12.11.4.1.2 City of Rockville

The Washington Suburban Sanitary Commission Standards shall apply for water facilities in the City of Rockville.

12.11.4.2 Prince George's County

The Washington Suburban Sanitary Commission's Standards shall apply to all water mains and appurtenances in Prince George's County.

12.12 NATURAL GAS

12.12.1 Codes and Standards

All work throughout the Metro system (including park areas in Virginia and Pentagon Grounds) on or adjacent to gas lines shall comply with standards of the Washington Gas Company and the Gas Transmission and Distribution Standards of the American Society of Mechanical Engineers.

12.12.2 Design Criteria - General

Construction of temporary gas mains and replacement of cast iron mains may be performed by the Washington Gas Company, by a contractor under contract to the gas company or by the Authority's contractor, as provided for in the Master Agreement between the gas company and the Authority. Consideration shall be given as to the most efficient of these options for this project.

The Designer will inform the Washington Gas Company where the design for the transit system will affect the company's facilities.

12.13 ELECTRIC

12.13.1 Codes and Standards

All support, maintenance, relocation and restoration of electric lines throughout the Metro system shall be in strict conformance with current practices of the Potomac Electric Power Company or the Dominion Virginia Power, Baltimore Gas and Electric Company, the requirements of the Electrical Code of the approving jurisdictions and agencies, and the National Electric Safety Code.

12.13.2 Design Criteria - General

General Design shall be based on the following:

Maintain electric facilities complete in place providing that the support system can satisfactorily retain the line/grade of the facility and retention of the duct structures is practical within the limitations contained herein. Support of vitrified clay and asbestos cement ducts must necessarily be independent of the Metro decking system and in no way exposed to the vibration of same. Due to the fragility of these vitrified clay and asbestos-cement ducts and their susceptibility to damage from movement, misalignment and vibration, any such ducts maintained complete in place will be subject to critical inspection (preferably by mandrel test in any available open ducts) before acceptance as a permanent structure.

As dictated by space limitations or cost, relocate electric facilities to areas outside the limits of Metro excavation and its system of trench support.

Temporarily support electric facilities to be maintained in service until such time as replacement facilities shall be provided, either within or beyond the limits of Metro excavation. Remove existing duct structures and manholes where cables in these facilities are to be kept in service during and after construction of Metro. Environmental requirements when working with asbestos-cement ducts must be complied. Provide temporary split duct systems and manholes 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 men. The number of temporary ducts will be minimized by coordination with the utility to assure utilization of maximum temporary capacity without unnecessary spare ducts.

Split duct when encased for permanent retention shall represent a straight-rigid conduit line as is practical without bends or curves. Generally, split duct will only be acceptable for retained facilities up to a minimum of four ducts housing secondary, street light, and/or traffic signal cables.

Pipe conduits carrying high-voltage lines shall be supported during construction. Upon completion of work, pipes shall be permanently supported on compacted backfill and surrounded by thermally acceptable sand.

Consult with the owners of electric facilities in the preparation of designs, plans, and specifications to assure that the method of handling facilities is the most economical, consistent with needs of Metro, and service requirements. Additional factors to be considered shall include limitations that maybe imposed by decking and excavation support systems and the type and material of facilities involved.

When circumstances justify, relocated or maintained utilities maybe permanently supported on concrete posts tied to the roof of the Metro structure. Each such posting, however, must be separately approved by the Authority.

12.13.3 The Utility Company Will:

12.13.3.1 Perform all cable work, including removal of existing cable.

12.13.3.2 Furnish cast iron manhole frames and covers, precast manhole roofs, gratings, pulling-in-irons and inserts for installation to be made by the Contractor.

12.13.4 WMATA Contractor Shall:

12.13.4.1 Where required, maintain and support duct banks, manholes and vaults.

12.13.4.2 Install and support temporary split ducts, manholes and vaults when existing facilities cannot be maintained.

12.13.4.3 Where required, construct new ducts (including split duct to be retained), manholes and vaults.

12.13.4.4 Provide concrete foundation beneath facilities maintained in place or constructed on compacted fill.

12.13.4.5 Furnish all conduit (split or whole), spacers, couplings and end bells.

12.13.4.6 Furnish concrete encasement around all permanent duct systems including split duct being retained.

12.13.4.7 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, but also to protect the "Somastic" coating around pipes from puncture and vibrational damage.

12.13.4.8 Provide special backfill around pipe conduit carrying high voltage cable.

12.14 TELEPHONE AND CABLE TV

12.14.1 Codes and Standards

All maintenance, relocation, and support of telephone and cable TV lines throughout the Metro system (including park areas in Virginia and the Pentagon grounds) shall be in strict conformance with current practices of the affected telephone and cable TV companies.

12.14.2 Design Criteria - General

Design shall indicate which telephone lines are to be maintained complete in place; which ducts are to be removed; cables temporarily supported and, upon completion of work, replaced by a new system of ducts and cables; and any rerouting or new construction. Abandoned lines and those to be abandoned shall also be indicated.

12.15 TELEGRAPH

12.15.1 Standards

All restoration of **TELEGRAPH** lines shall provide service essentially equal to that offered by the existing installations. No Betterments shall be included unless formally approved by WMATA.

12.15.2 Design Criteria - General

Design shall include manholes of same size as now exist. Concrete maybe used instead of brick. Pipes and conduits shall be temporarily supported and, upon completion of work, placed on compacted backfill.

12.16 OVERHEAD UTILITY LINES

12.16.1 Abandonment, relocation, restoration, and extension of overhead utility lines, poles, and appurtenances, including service lines to adjoining properties, will be performed by the owners in accordance with laws and regulations of the concerned jurisdiction, owners' standards, and the National Electrical Safety Code.

12.16.2 Protection and support of overhead utility lines, including poles, appurtenances, and services shall be provided by the Metro Contractor.

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

12.16.3.1 Electric Cables

12.16.3.2 Telephone Cables

12.16.3.3 Cable Television

12.16.3.4 TELEGRAPH Lines

12.16.3.5 Railroad Communication Lines

12.16.3.6 Police, Fire Alarm, and other Government Lines

12.16.3.7 Street Lights and Traffic Signals

12.16.4 The Designer shall coordinate his efforts with those of the owners to assure that Metro plans include designs mutually acceptable to the owners and the Authority.

12.16.5 Overhead utility work will normally be accomplished by the utility involved at no cost to the Contractor. Any additional work performed by the owner for the convenience of the Contractor shall be arranged by the Contractor at no expense to the Authority.

12.16.6 Plans shall denote general type of service provided by overhead lines in accordance with the symbology of Standard Drawing ST-U-14.

12.16.7 Certain jurisdictions have restricted the use of overhead lines in specific areas.

The Designer shall reflect these requirements in project design.

12.16.8 Clearances shall be in accordance with jurisdictional codes and standards adopted by the utilities involved, and those specified in the National Electrical Safety Code shall be considered the minimum requirement with respect to Metro right-of-way crossings and structures.

12.16.9 The Designer shall evaluate the need for relocation of existing overhead high voltage electric lines, including transmission lines, due to hazards from Metro construction or train operations. Findings and recommendations shall be submitted to WMATA for approval before including any such work in Metro contract documents

12.17 UTILITIES MARKERS

The presence of utility lines, including drains and culverts, crossing right-of-way below at grade and embankment sections of Metro, shall be indicated on the site by markers placed at the points where the centerline of the utilities intersect the boundaries of the right-of-way. Markers shall identify each utility, its owner, Metro route, and survey station and depth, as shown on Standard Drawing ST-U-66.

Typically, markers shall be placed just inside of Metro fences, with the face of targets parallel with and facing the adjoining track. They shall not encroach on safety walks, clearance areas, ditches, and service roads.

When circumstances prevent markers being placed on the centerline of the utility, they shall be placed as close thereto as practicable with the direction and offset from marker to utility indicated as shown on Standard Drawing ST-U-66.

The depth of utilities shall be indicated on marker targets to the nearest 0.5'. Whether the marker is on the centerline of the utility or offset therefrom, the depth shall be that from the surface above the installation to the top of the facility.

Style of lettering and numerals on target face shall be Helvetica-Medium.

No markers shall be placed for Metro-owned facilities parallel with or within clearance areas of those crossing rights-of-way and having readily visible manholes and inlets.

12.18 UTILITIES CROSSINGS OF METRO

12.16.3.1 Codes and Standards

All pipeline and conduit crossings beneath at-grade embankment and trench sections and lead and yard tracks of Metro shall be encased in a larger pipe or conduit in accordance with the applicable provisions of Chapter 1, Part 5 of the “Manual of Railway Engineering” of the American Railway Engineering Association, and current practices of the owners of the concerned crossings. All pipeline and conduit crossings, including access for service there to, shall meet the requirements of "A Policy on the Accommodation of Utilities on Freeway Rights-of-Way" by AASHTO, latest edition.

Where Metro tracks are parallel with or contiguous to tracks of any of the several railroads operating in the Washington Metropolitan Area, and a utility installation may necessitate crossing the rights-of-way of Metro and railroad, the utility and casement pipe on Metro property shall be compatible with the portion on railroad property.

Appropriate mitigation measures for stray current will be implemented.

12.16.3.2 Design Criteria

Casement pipes shall be provided for all pipelines carrying oil, gas petroleum products, other flammable or volatile substances, steam, water or other nonflammable substances under pressure. Electric duct, telephone conduit, gravity flow sewer and drain crossings will not require encasement where the strength of the facility is capable of withstanding Metro loading.

Casement pipes or protection structure shall include seals and vents, as set forth in the above reference manual. Where Metro is contiguous to railroad tracks and pipelines and casement pipes are continuous beneath both track installations, seals and vents shall be provided at the ends of the continuous system. The Designer shall coordinate his design with the concerned railroad.

The top of casement pipe crossing Metro shall be a minimum of 6.5' below top of rail. The presence of Metro drainage pipes, power cables, and communication lines, or coordination with contiguous railroads may require that this dimension be increased.

Where Metro might be constructed above utilities to be retained in service, the facilities shall be uncovered and encased prior to placing track or, if more economical, replaced by a new system with a jacked casement pipe.

12.19 SOIL EROSION AND SEDIMENT CONTROL

12.19.1 General

It is the policy of WMATA to comply with all jurisdictional requirements

12.19.2 District of Columbia

All construction is to be designed in accordance with the “District of Columbia Erosion and Sediment Control Handbook”, latest edition.

12.19.3 Maryland

The “Maryland Standards and Specifications for Soil Erosion and Sediment Control” (latest edition) as published by the Maryland Water Resources Administration is to be adhered to during the preparation of the plans.

12.19.3.1 Montgomery County - The Montgomery Soil Conservation District or the Maryland Department of the Environment is to approve all soil erosion and sediment control plans.

12.19.3.2 Prince George’s County - The Prince George’s Soil Conservation District or the Maryland Department of the Environment is to approve all soil erosion and sediment control plans.

12.19.3.3 Maryland State Highway Administration - The Maryland Department of the Environment is to approve all soil erosion and sediment control plans.

12.19.4 Virginia

All construction is to be designed in accordance with the “Virginia Erosion and Sediment Control Handbook," latest edition.

12.19.4.1 Arlington County - Adopted "Erosion and Sediment Control" chapter of Arlington County, Virginia (6-27-76,

12.19.4.2 Fairfax County- Fairfax County has adopted an ordinance which requires that measures of a temporary or permanent nature shall be applied at all phases of construction to alleviate the harmful or damaging effects of erosion and sedimentation during and after development. Measures for control of erosion and sedimentation meeting County requirements shall be included on the plans when these are submitted for review. To assist designers, the County has published an Erosion-Siltation Control Handbook.

12.19.4.3 City of Alexandria - Adopted Section 10.32 of "Erosion and Sediment Control" amended to City Code chapter 10.

12.19.4.4 Virginia Department of Highways - Virginia Department of Environmental Quality oversees state and federal activities.

12.20 FIRE ALARM AND POLICE COMMUNICATION SYSTEMS

12.20.1 Codes and Standards -There are no codes or standards. Except for required protection and support of cables and restoration of ducts by subway contractor, all work in the District of Columbia will be performed by the Traffic and Electrical Services Division, Department of Highways and Traffic. Maryland and Virginia areas have no such specialized facilities.

12.20.2 Design Criteria - General

In the District of Columbia cables are located in ducts of the Verizon Telephone Co. and, to a limited extent, in ducts belonging to the District. Work by the District will be at no cost to the Contractor unless otherwise indicated on drawings and/or specifications.

Maryland and Virginia areas utilize normal telephone lines. There are no separate facilities.

12.21 PARKS

12.21.1 Codes and Standards

All relocation and restoration of underground utility lines, water mains, sewers, drains, catch basins, sprinkler systems, lights, pavements and other improvements shall be in accordance with requirements of the several governmental agencies and utility corporations as stipulated elsewhere in these criteria.

12.21.2 Design Criteria - General

Design for the various facilities shall be submitted to the National Park Service and Maryland National Capital Park & Planning Commission by the Designer for final approval.

Application to the National Park Service and Maryland National Capital Park & Planning Commission fora permit to constructing park areas shall be submitted by WMATA.

12.22 U.S. CAPITOL GROUNDS

12.22.1 Codes and Standards

All relocation and restoration of underground utility lines, water mains, sewers, drains, catch basins, sprinkler systems, lights, pavements and other improvements shall be in accordance with requirements stipulated elsewhere in these criteria for the several governmental agencies and utility corporations.

12.22.2 Design Criteria - General

Should location of transit facilities necessitate cutting of sidewalks with exposed aggregate surface, restoration shall be made in kind.

Designs for the various facilities will be submitted to the Architect of the Capitol by the Designer for final approval.

Application to the Architect of the Capitol for a permit to construct in the Capitol Grounds will be submitted by WMATA.

12.23 U.S. STEAM TUNNELS AND PIPES

12.23.1 Codes and Standards

All work in the District of Columbia and in Arlington (the Pentagon) shall comply with the practices and standards of the General Services Administration.

12.24 VAULTS

12.24.1 Codes and Standards

All remodeling, abandonment or other work involving private vaults extending from adjoining buildings into public space shall be in strict accordance with rules, regulations and practices which, in the District of Columbia, shall include the D.C. Building Code, the D.C. Electrical Code, the D.C .Plumbing Code and the National Electrical Safety Code, and applicable codes in other jurisdictions.

12.24.2 Design Criteria

Determination shall be made as to which vaults will be affected by transit construction. Details shall show portion of each vault to be excavated; new walls required to permit continued use of vaults outside of construction limits; new walls to accomplish complete abandonment of vaults, where required; the work required to restore vaults, including delivery chutes and freight elevators and the area available for permanent occupancy by the original owner upon completion of transit facilities.

The Designer shall also determine what goods or facilities must be removed from vault; how deliveries will be made to properties when existing vault entrances are required to be abandoned; and the time required to take each of the above enumerated steps. This information shall be forwarded to WMATA to arrange for permission to occupy the vault and make the necessary alterations. This information should be forwarded at earliest practicable date so that WMATA may take prompt action and avoid possibility of construction being delayed.

12.25 PAVING RESTORATION

12.25.1 Codes and Standards

All pavement restoration in public streets shall be in strict conformance with the current specifications and practices of the several jurisdictions and agencies involved.

12.25.2 Design Criteria - General

Restored pavements shall be of materials and conform to widths prevailing prior to transit construction. No street, sidewalk or alley widening shall be included.

In the District of Columbia 8" granite curbs shall be used for all restoration and construction of arterial or through streets in accordance with the Master Agreement with the DC Department of Highways & Traffic. Existing 8" granite curbs, when removed, shall be stored and protected until reused. Existing 6" granite curbs, when removed, shall be disposed of and not reused. Additional curb required shall be furnished by the contractor.

Any catch basins disturbed or removed shall be replaced in kind, except that 15" minimum diameter pipe shall be used for any new connection. In jurisdictions other than the District of Columbia, replacements shall be in kind and in accordance with regulations and established policies of the concerned agency.

Designs shall be submitted for owners' final approval by the Designer.

12.26 PARKING METERS RESTORATION

12.26.1 Codes and Standards

Does not apply, since work will not involve new meters, only removal and restoration of existing facilities.

12.26.2 Design Criteria - General

The affected agencies within their jurisdictions will remove and restore meter heads; the contractor shall remove, store and reinstall posts, depending upon parking restrictions during Metro construction and upon interference with Metro construction. Work by the agencies will be at no cost to the contractor unless otherwise indicated on drawings and/or specifications.

12.27 PASSENGER CAR AND BUS PAVEMENTS

12.27.1 General

This criteria applies to the design of all paved areas which are to be constructed on Metro station property as part of the rail rapid transit system. Metro parking facilities shall also comply with the Americans with Disabilities Act Accessibility Guidelines (ADAAG). Where this criteria differs from jurisdictional codes and standards, waivers shall be sought or differences resolved during design. For additional related information, refer to the Standard Drawings.

12.27.1.1 Lane Widths See Chapter 2, Station Site and Access Planning Manual

12.27.1.2 Roadway Geometric Design: See Chapter 2, Station Site and Access Planning Manual.

12.27.2 Soils Investigations

At the request of the Designer, subject to the contractual conditions, WMATA will provide soils tests in those areas which are designated for paving and will provide the soils information which is necessary for pavement design (including classification, ground water conditions, and properties).

12.27.3 Passenger Car Areas

This criteria includes areas designated for passenger cars only, such as certain entrance and access roads, "Kiss-and-Ride" parking areas, and all other passenger car parking areas.

12.27.3.1 Grades: See Chapter 2, Station Site and Access Planning Manual.

12.27.3.2 Drainage:

Design shall be based on a 10-year storm and shall be coordinated with jurisdictional requirements. Pavements shall be sloped to drain to gutter, swales, and inlets, preventing ponding in foot traffic areas and where passengers enter or leave cars. Inlets shall be sized and placed to limit gutter flows to 4-foot spread at crosswalks, 6 feet where adjacent to sidewalks, and 8 feet at all other places.

12.27.3.3 Soils:

CBR of natural subgrade and improved soil areas should be estimated from the available soil test data. The pavement sections presented on the Civil Standard Drawings have been designed for a subgrade strength of CBR-9. If the local soil conditions do not meet this strength requirement, the Section Designer/Design Engineer shall either devise a construction method to improve the soil subgrade to CBR-9 or provide new pavement design.

12.27.3.4 Pavement:

Design shall be based upon a 20-year design period, initial daily two-direction traffic of 1000 cars, a Design Traffic number between 10 and 50, and Asphalt Institute Design Charts (including handbooks MS-4 and MS-1). The minimum total pavement thickness shall be as shown on the Civil Standard Drawings. Motorcycle parking areas shall be paved with reinforced portland cement concrete.

12.27.3.5 Parking Spaces:

Standard park-and-ride parking space widths shall be given in See Chapter 2, Station Site and Access Planning Manual

Standard kiss-and-ride parking space widths shall be given in See Chapter 2, Station Site and Access Planning Manual.

Accessible parking spaces for the physically challenged shall be given in See Chapter 2, Station Site and Access Planning Manual.

Drive aisles in kiss-and-ride facilities shall be given in See Chapter 2, Station Site and Access Planning Manual.

Motorcycle parking spaces shall be given in See Chapter 2, Station Site and Access Planning Manual,

12.28 ENTRANCE/EXIT ROADWAYS AND BUS AREAS

This criteria applies to bus stalls, exclusive bus entrance or exit roads, entrance or exit roads used jointly by buses and passenger cars, and other areas where bus traffic can be expected. If the passenger car area is not clearly separated from that provided for bus traffic, utilize the bus design requirements.

12.28.1 Grades:

See Chapter 2, Station Site and Access Planning Manual.

12.28.2 Drainage:

Design shall be based on a 10-year storm and shall be coordinated with the requirements of local jurisdictions. Pavement shall be sloped to drain away from passenger loading areas.

12.28.3 Soils:

12.28.3.1 CBR of natural and improved subgrade soil areas should be estimated from the available soil test data. The pavement sections presented on the Civil Standard drawings have been designed for a subgrade strength of CBR-9. If the local soil conditions do not meet this strength requirement, the Section Designer/Design Engineer shall either devise a construction method to improve soil subgrade to CBR-9 or provide a new pavement design.

12.28.4 Pavement:

Design shall be based upon a 20-year design period, a maximum peak-hour frequency of 200 buses and an AASHTO equivalent single axle loading of 25,000 pounds. All entrance roadways shall be asphalt pavement except that all bus areas shall be concrete pavement. Asphalt pavements shall be designed in accordance with Asphalt Institute's Design Manual MS-1, "Thickness Design -Full Depth Asphalt Pavement Structures for Highways and Streets." The minimum total pavement thickness shall be as shown on the Civil Standard Drawings

12.28.4.1 Concrete pavements shall be designed in accordance with the Portland Cement Association Publication entitled, "Thickness Design for Concrete Pavements." The minimum total pavement thickness shall be as shown on the Civil Standard Drawings. The Designer shall design a rigid pavement joint layout plan, adhering to the Portland Cement Association's recommended criteria.

12.29 RAMPS AND CURB CUTS

12.29.1 Codes and Standards

12.29.1.1 The design and construction of assessable ramps in areas controlled by WMATA shall follow the direction given in Section 2, WMATA Manual of Design Criteria, Facilities.

12.29.1.2 Curb cuts in public space shall conform to the standards of the controlling agency of the involved jurisdiction.

12.29.2 Design Criteria - General

12.29.2.1 Curb cuts are to be included when curbs in public space are constructed or restored as part of a Metro contract.

12.29.2.2 The Designer shall obtain from the appropriate agency of the local jurisdiction the locations of curb cuts in public spaces.

12.29.2.3 Curbs shall be unpainted except where stipulated by applicable codes.

12.29.2.4 Where more than one accessible ramp is to be provided, the entire length of sidewalk and curb is to be depressed rather than providing individual accessible ramps.

12.30 STREET AND TRAFFIC LIGHTS

12.30.1 Codes and Standards

All relocations, temporary or permanent, and restoration of these facilities shall be in strict accordance with the practices of the agencies involved.

12.30.2 Design Criteria - District of Columbia

Street and traffic lights are usually served by cables located in ducts of the Potomac Electric Power Company. In some instances street lights are served by cables laid behind curb lines.

Work on street light and traffic signal facilities is to be performed as follows:

12.30.2.1 Potomac Electric Power Company will:

12.30.2.1.1 Remove and restore existing facilities.

12.30.2.1.2 Install temporary facilities except for those to be installed by the Contractor.

12.30.2.1.3 Maintain the electrical service during construction.

12.30.2.2 District of Columbia will:

12.30.2.2.1 Furnish temporary and permanent facilities.

12.30.2.2.2 Adjust traffic signal controllers.

12.30.2.3 WMATA's Contractor will:

12.30.2.3.1 Install and ultimately remove conduits and standards for temporary traffic signals which are placed over construction decking.

12.30.2.3.2 Install and ultimately remove the complete temporary streetlight facility when installation is required over construction decking.

12.30.3 Design Criteria - Virginia

12.30.3.1 Arlington County

Criteria is dependent upon the type of fixtures and area of County involved and shall be secured from County or state authorities, and, for the Pentagon, from the General Services Administration.

All work involving street lights, except certain privately owned poles, shall be handled by PEPCO and Dominion Virginia Power at no cost to Contractor.

The Contractor shall be responsible for and handle any work involving lights owned by private parties.

All work involving traffic lights controlled by Arlington County will be performed by County forces. Work on facilities of VDOT will be performed by contractors engaged by the owners. All of this work will be at no cost to the Metro contractor. In decked areas, temporary poles, lights and ducts shall be furnished, erected and removed by the Authority's contractor.

12.30.3.2 Fairfax County

Work involving installation, removal and maintenance of street and traffic lights within Fairfax County, excluding state highways, will be performed by Dominion Virginia Power personnel at no cost to the Metro contractor.

Street and traffic lights located along state highways will be serviced by state crews or by contractors engaged by VDOT.

The contractor shall handle and be responsible for any work involving lights owned by private parties.

In decked areas, temporary poles, lights and ducts shall be furnished, erected and removed by the Authority’s contractor.

12.30.3.3 City of Alexandria

All work involving street lights within the City of Alexandria will be handled by Dominion Virginia Power at no cost to the contractor.

The contractor shall handle and be responsible for any work involving lights owned by private parties.

Traffic light poles and guying of the poles in the City are to be handled by Dominion Virginia Power with the signal heads and wiring to be done by forces of the City of Alexandria, all at no cost to the Metro contractor.

In decked areas, temporary poles, lights and ducts shall be furnished, erected and removed by the Authority’s contractor.

12.30.3.4 Virginia Department of Transportation

Where streetlights belonging to the Virginia Department of Transportation are to be relocated, the replacement of these facilities shall be in kind and shall comply with VDOT standard drawings and specifications.

12.30.4 Design Criteria - Maryland

12.30.4.1 Montgomery County

Relocations, restorations and other work involving street and traffic lights shall meet the standards of Montgomery County and the Maryland State Highway Administration.

All work involving abandonment, relocation, restoration and temporary installation of street lights will be handled by PEPCO without cost to the Metro contractor.

The Montgomery County Department of Public Works will handle all work involving traffic lights and appurtenances on County and state roads at no cost to the Metro contractor. However, final approval of any work on state roads shall be directed through State Roads Commission.

In decked areas, temporary poles, lights and ducts shall be furnished, erected and removed by the Authority's contractor.

12.30.4.2 Prince George’s County

Relocation, restoration and other work involving street lights and traffic lights shall meet the standards of Prince George’s County and the Maryland State Highway Administration.

The State Highway Administration is responsible for all work involving abandonment, restoration, relocation and temporary installation of streetlights and traffic lights on state roads. The Prince George’s County Department of Public Works is responsible for all work on County roads, although maintenance of some of the traffic lights and street lights on state roads is accomplished by the County. However, final approval of any work on state roads shall be directed through the State Highway Administration. The Section Designer/Design Engineer shall coordinate with MSHA, Prince George’s County Department of Public Works and other affected municipalities to determine jurisdictional responsibility.

Work by the agencies will be at no cost to the contractor.

In decked areas, temporary poles, lights and ducts shall be furnished, erected, maintained and removed by the Authority's contractor.

SECTION 13 - ELECTRICAL

13.1 GENERAL

These design criteria include functional and design requirements for the supply and supervision of all auxiliary power to the Washington Metropolitan Area Transit Authority (WMATA) electrical system. The information provided in this manual shall be used in the development of design / construction plans, specifications, and calculations that shall serve as the minimum electrical design requirements for design-build, design-bid-build, and all other types of Contracts. Project conditions may dictate the need for a design that exceeds these minimum requirements.

It is expected that electrical systems designed with the use of this manual shall meet their primary objective stated in the contractual Scope of Work (SOW). The electrical system shall provide power to all WMATA's facilities in a safe, reliable, and energy efficient manner that will allow for continuous operation of the entire system. In order to provide the latitude needed for new technologies and concepts, technical deviations from this manual maybe made only if a safe, reliable, and energy-efficient design shall result. However, such deviations **SHALL** be approved by WMATA.

13.2 RESPONSIBILITY

All work and services performed on WMATA's electrical system shall be done in accordance with the contract, good engineering practices, WMATA standards and project-specific requirements (if any), and all applicable codes.

13.3 COORDINATION

All work performed on WMATA's electrical system shall be coordinated with all relevant disciplines, such as, architectural, structural, civil, fire protection, mechanical, and others as applicable.

Design of the primary electrical system shall be coordinated with the requirements of the local power companies having jurisdiction in Washington, D.C., Maryland or Virginia. Details of all correspondence and minutes of meetings with the utility company shall be provided.

13.4 CODES AND STANDARDS

All support, maintenance, relocation and restoration of electrical equipment and systems throughout WMATA shall be in strict conformance with current practices of the affected power company, the requirements of the National Electric Code, the

National Electric Safety Code, the electrical codes of the local jurisdiction, and all other applicable codes and standards.

13.5 STANDARD TERMINOLOGY

In general, definitions applied to electrical power shall conform to definitions listed in ANSI/IEEE C37.100. Basic electrical terminologies used in these criteria, which are not defined in the ANSI/IEEE reference are to be interpreted in their normal usage.

13.6 TECHNICAL SPECIFICATIONS

To compliment these design criteria a set of WMATA's standard technical specifications shall be used in the designing and or modification of the electric system. Based upon the scope of work to be performed, modification to these specifications maybe warranted. All modifications to WMATA's standard technical specification shall be clearly identified and submitted for review and approval.

13.7 DESIGN DRAWINGS AND SUBMISSION REQUIREMENTS

Design drawings shall include the listing and detailing of all the drawings, calculations, and specifications required for a complete design package. Submission shall be in accordance with WMATA's "Section 01330 - Submittal Procedures".

13.8 WMATA CADD Standard

WMATA's CADD Manual shall be adhered to in the developing of design drawings.

13.9 SEQUENCE OF ELECTRICAL DRAWINGS

- Symbols and Abbreviations
- Demolition Plans (if any)
- Electrical Site Plan(s)
- Lighting Plans
- Power Plans
- Lightning Protection Plans (maybe combined with roof and ground floor/site powerplans on projects with few lightning protection components

- One-line Diagrams and Riser Diagrams
- Details
- Schedules, Summary Load Studies, Luminaries Schedule

13.10 Calculations

Calculations shall be provided based on type of design work performed. Calculations shall justify lighting designs, panelboard / switchboard size, conductor / feeder size, overcurrent protective device, transformer, generator, etc. Not all calculation types shall be required for all projects. WMATA reserves the right to request additional calculations to suit the project.

13.11 AUXILIARY ELECTRICAL SYSTEMS

This section identifies the requirements for installation and operation of all auxiliary electrical equipment and lighting circuits in the WMATA System. Specific criteria for lighting systems required for proper illumination of the passenger stations and connecting structures are covered more fully in subsequent sections.

13.12 SCOPE

The following criteria covers all AC power electrical systems required to serve auxiliary electrical, lighting and mechanical equipment throughout all parts of the system. In general this includes:

13.12.1 Bus Facilities

13.12.2 Commercial / Office Buildings

13.12.3 Emergency Power Systems

13.12.4 Escalators and Elevators

13.12.5 Fare Collection Equipment

13.12.6 Heating, Ventilating and Air Conditioning Equipment

13.12.7 Illuminated Signs

13.12.8 Kiosks

13.12.9 Lighting

13.12.10 Parking Facilities

13.12.11 Pumps (drainage, sewage, etc.)

13.13 AC ROOM POWER SUPPLY

13.13.1 Power Source

The utility company will provide the source of power within the territory served by each company.

Nominal service voltage to WMATA facilities will generally be either 13.8kV or 34.5kV. In some areas and facilities (e.g., chiller plants which are located at considerable distances from the nearest passenger stations), service at480/277V may be economically preferred. Final determination of the type of service at such sites will be made by WMATA. Design of facilities for 480/277V services shall comply with local codes and Utility Company requirements.

In general, each passenger station has either two AC switchgear rooms (one at each end of the station), or one combined AC switchgear room with both AC switchgears located in the room. Each switchgear lineup will receive a separate primary service from the power company serving the area and will transform and distribute the power to loads within the station and adjacent facilities as shown on General Plans.

In 13.8kV power areas, supply one primary dedicated underground power service to each AC switch gear lineup. In 34.5kV power areas, supply one dedicated underground primary power service to each AC switch gear lineup. One normally open tie breaker shall connect the two switchgear secondary buses in the combined AC switchgear room, and two normally open tie breakers shall connect the two switchgear buses in the physically separated AC switchgear rooms to form a secondary selective network as indicated on the Electrical Design Drawings.

Minimum clearance in front of and at the rear of incoming service switchgear shall be coordinated with the utility company as applicable.

13.13.2 Metering

In a 13.8kV service area, the switchgear shall include provisions for the power company metering in accordance with their requirements. Provisions shall be made in the combined AC switchgear room or in one of the two AC switchgear rooms at a passenger station for mounting a meter cabinet on the wall. The metering current and voltage transformers and meter panels will be furnished by the power company. These transformers shall be installed in the revenue metering switch gear cubicle by the WMATA Contractor. Minimum clearance in front of the metering cabinet shall be coordinated with the utility company.

The power consumption of each passenger station shall be totaled. Details of the meter tie conduit requirements for this purpose are shown on the Electrical Design Drawings. A 120V, 15A dedicated normal circuit and a voice grade telephone line shall be provided to the metering locations.

13.13.3 Remote Monitoring

Provide remote monitoring of electrical equipment as described elsewhere in the criteria.

13.13.4 Service Ducts

Cable ducts for primary power service shall be provided in the WMATA facility structures as required and approved by the Utility Company. Primary cable ducts shall generally extend from the switchgear room through the outside wall or roof to a point three feet below ground level and a minimum of five feet beyond the outside of the structure or to the WMATA right-of-way limit and then capped.

The Utility Company will furnish and install the ductwork from their manhole or substation to connect to the ductwork from the structure and will furnish and install the service cables.

13.13.4.1 For 13.8 kV Services:

FRE conduits shall be installed as follows:

- To single AC switchboard rooms: 2-5"
- To combined AC switchboard rooms: 4-5"

13.13.4.2 For 34.5 kV Services:

PVC conduits shall be installed as follows:

- To single AC switchboard rooms: 2-8" conduits if the service feeder is not looped and 4-8" conduits if the service feeder is looped
- To combined AC Switchboard rooms: 4-8" conduits if the service feeder is not looped and 6-8" conduits if the service feeder is looped

Provide OZ/Gedney Type CSBE bushings or equal to plug empty Utility Company service ducts.

The design of incoming primary service cable ducts shall be included in the design of facilities by the Section Designer/Design Engineer and shall be coordinated with the Utility Company to obtain their approval.

13.13.4.3 For Other Services:

When the Utility Company is required to supply480/277V power to a pumping station or chiller plant, the service ducts quantity, size, and routing shall be coordinated and be approved by the power company and shall comply with all local codes.

13.14 UNIT SUBSTATIONS

AC unit substations shall be housed in free-standing, ventilated, indoor, metal enclosure with the necessary clearance at the front, back, and end of the switchgear as required by the servicing power company.

AC unit substations shall contain incoming primary switchgear (including revenue metering cubicle for 13.8kV service), distribution transformer, 480V switchgear, and switchboard; and shall form a dead front assembly.

13.14.1 Equipment for 15kV Primary Service Area

13.14.1.1 AC Incoming 15kV Primary Switchgear

One incoming cubicle with primary circuit breaker rated at 1200A, 15kV indoor, draw-out, vacuum breaker, 3 phase, 60 hertz, having short circuit rating of at least 31.5kA, rms (750MVA) of the stored energy type, with relays, current and voltage transformers. The primary service breaker shall be provided with local control and both local and supervisory status indication. Tripping and closing mechanisms shall draw power from a local 125V DC source.

All medium-voltage primary draw-out circuit breakers in the AC switchgear of 13.8kV or higher shall be located near the floor of the cubicle. Separate handling devices for removal or insertion of the circuit breaker, other than transfer truck or fifth-wheel steering bar, are prohibited.

13.14.1.1.1 Revenue Metering Cubicle

There shall be one revenue metering cubicle with provisions for mounting and connecting metering voltage transformers and current transformers for each primary service. The voltage and current transformers shall be furnished by the Utility Company.

13.14.1.2 Transformer

The transformer shall be indoor, ventilated, cast coil, dry type, 13.8kV, 3 phase, 60 hertz, delta primary, 480Y/277V, 4-wire secondary. The use of other type of transformers, such as VPI, shall be specifically approved by WMATA.

It shall have sufficient self-cooled capacity to serve the total demand load (largest of winter or summer) of both switchgears, plus 20% for future growth.

To the extent practicable, the demand loads supplied by both switchgear lineups supplying a passenger station or other WMATA facilities shall be balanced within 7.5%. Where unusual demand loads occur, (such as a chiller plant load near one end of a passenger station, or a fan shaft on one side of a passenger station but not on the other) which results in a large difference in the demand loads of the two unit substations, a written request for variance shall be submitted for WMATA approval.

In passenger stations, the unit substation shall be designed wherein all loads are connected to the main secondary bus. The transformer shall have sufficient self-cooled capacity to serve the total demand load of the entire station plus 20% for future load growth.

13.14.2 Equipment for 34.5kV Primary Service Area

13.4.2.1 AC Incoming 34.5kV Primary Switchgear

One incoming cubicle with primary circuit breaker rated at 1200A, 38kV, indoor, draw-out, vacuum break,3 phase,60 hertz, having short circuit rating ofatleast40kA, rms (1500 MVA) of the stored energy type, with relays, current and voltage transformers. The primary service breaker shall be provided with local control and both local and supervisory status indication. Tripping and closing mechanisms shall draw power from a local 125 volt DC source.

13.4.2.1.1 Revenue Metering

Metering equipment is typically located at the utility source substation.

13.4.2.2 Transformer

The transformer shall be indoor, ventilated, dry type, 34.5kV, 3 phase, 60 hertz, delta primary, 480Y/277V, 4 wire secondary.

It shall have sufficient self-cooled capacity to serve the total load demand (largest of summer or winter). To the extent practicable, the demand loads supplied by both switchgear lineups supplying a passenger station or other WMATA facilities shall be balanced within 7.5%.

13.4.2.3 480V Switchgear and Switchboard

Secondary main and tie breakers shall be rated at 480V, 3 phase, 60 hertz; and they shall be draw-out type low voltage power circuit breakers with stored energy closing mechanisms. These circuit breakers shall be manually actuated close with manual and electrically operated trip; except that the tie breakers shall include electrically actuated close.

Each secondary main and tie breaker shall be equipped with a solid-state tripping system consisting of three current sensors, microprocessor-based controlled phase over current trip device and flux-transfer shunt trip, ground fault protection, position indicating lights, spare auxiliary contacts for DTS, accessories and interlocks. The trip device shall have long-time and short time elements, communication interface, power metering and non-volatile memory for protective settings. The trip unit shall be equipped with an energy monitoring function processor to provide at a minimum; Phase Current (amps), Peak Demand (kilowatts), Present Demand (kilowatts) and Energy Consumption (kilowatts-hours).

All breakers shall have short circuit interruption capacity as determined by short circuit calculations and approved by WMATA. Feeder breakers in switchboard shall be ambient compensated and shall be molded case bolt-on type. Integrally fused circuit breakers maybe used where necessary to obtain suitable protection of down-stream equipment and wiring.

Time coordinated ground fault protection on secondary main, tie breakers and feeder breakers shall be provided. Single point grounding shall be provided as indicated on the electrical design drawings.

480V switchgear buses and secondary main circuit breaker frame sizes shall be based on transformer forced air-cooled capacity. Breaker trip ratings shall be based on calculated initial loads plus allowance for future 20% growth.

13.4.2.4 Breaker Operation

Control power shall be provided at125V DC, and shall be fed using a minimum of two No. 6 AWG wires. Unit substations for 34.5kV or 13.8kV service through metal-clad switchgear shall have the following control operation:

- Primary breaker is tripped by primary under voltage or overvoltage conditions detected by 27/59 function of primary protective relay for 13.8kV service. For the 34.5kV service, the primary breaker is tripped by primary under voltage conditions detected by the 27 function of the primary protective relay. Primary breaker is tripped and locked out by phase and ground overcurrent conditions detected by 50/51 or50N/51N functions of primary protective relay for both 13.8kV and 34.5kV services. Primary breaker is closed via manually operated switch or HMI.

- Secondary main breaker is tripped automatically by tripping of primary breaker.
- Secondary main breaker is closed via manually operated switch.
- When the secondary main breaker is tripped by the primary breaker due to an under voltage or overvoltage condition at the primary service, and if the other lineup secondary main breaker is closed, the tie breaker(s) shall automatically close. Closing of the tie breaker(s) is blocked if the primary breaker or secondary main breaker has tripped because of phase or ground overcurrent conditions; closing of the breaker(s) is also blocked if both secondary main breakers in a passenger station are closed.
- Second stage transformer over temperature device shall trip the primary breaker.
- Where two tie breakers are required due to switchgear lineups being located in separate switchgear rooms, both tie breakers shall close simultaneously, and the tripping of either tie breaker shall instantaneously trip the other tie breaker.
- PLC shall be provided to coordinate the operation of primary breakers, secondary main breakers and tie-breakers.

13.4.2.5 Digital Power Metering System

For each primary breaker, provide a Digital Power Meter follows:

- Provide Digital Power Metering to measure the real-time RMS values of phase currents, ampere demand and phase and line voltages plus power measurements including kW, kW demand, kW-hours, kVA, kVAR-hours. Power factor and frequency shall also be measured. Resettable minimum and maximum values for each measured value shall be recorded in a nonvolatile memory. The digital power meter shall derive power from a separate 125V AC or DC source, and includes the following:
- Internal illuminated display for reading all real-time and min/max measured values as well as programming initial configuration and any relay set points.
- Three programmable relay outputs shall be provided to activate and

release based on threshold and time-delay values associated with any of the measured parameters.

- Communications module to remotely read real-time and min/max measured values, interrogate the event log, reset min/max and kW/kVAR-hours, program configuration and any relay set points.
- Extended memory
- Portable Interface Device
- Software

13.4.2.6 Quick Connect System

At each passenger station provide an emergency generator quick connect system with the following requirements:

- Quick connect breaker shall be capable to handle up to 500 kW power from an emergency diesel generator.
- Provide a normally open quick connect circuit breaker in the three phase, 480V AC switchboard that feeds the normal side of the UPS system.
- The generator quick connect system shall be an 800A, 4-pole plug with a ground plug. The receptacle shall be installed outside the building but close to the station entrance as possible in an area suitable to park a 500kW mobile generator. The cable from the generator to the receptacle should not exceed 25 feet in length.
- Provide "warning nameplate" on quick connect circuit breaker that reads "Generator Quick Connec tCircuit Breaker- Do not Close without Permission from Maintenance Operating Center.

13.4.2.7 Provision for System Growth

AC power service facilities shall be designed to permit an increase of 20% in load. This includes all switchboards, distribution transformers, feeders, panelboards, and motor control centers. Space shall be provided at each unit substation for the installation of one additional switchboard cubicle.

13.4.2.8 Provisions for Substation Maintenance Equipment

In each AC switchgear room; provide the following:

- 72" x 36" x 36" heavy-duty metal storage cabinet with 4 shelf arrangement.

- Eight (8) foot fiberglass step ladder.
- Full set of as-built, half-size, Electrical Contract and Equipment Shop Drawings bound in stiff cover resistant to oil, water and wear. Drawings shall be capable of being stored in the metal cabinet.
- 22" x 34" wall mounted maintenance map/single line diagram.
- Mounting frame shall be metal with lexan or plexiglass. Mount frame as directed by the Engineer.
- 30" x 48" heavy-duty metal work bench with reinforced steel top and task stock.
- Work bench shall be 34" high with one No. 12 gauge steel shelf, full width and depth of bench with back turned up 2 inches. Provide 1/4" rubber matting to cover entire top of work bench.

13.15 GENERAL ELECTRICAL CHARACTERISTICS

13.15.1 Utilization Voltages

AC auxiliary power shall be nominal 480Y/277V, 3 phase, 4 wire, 60 hertz. Where other than this voltage is required for utilization, such voltages shall be obtained by use of dry type transformers. Utilization voltages for devices and equipment requiring AC power shall conform to the following characteristics:

13.15.2 Fluorescent Lights

277 volts (preferred) or 120 volts single phase

13.15.3 CFL Lights

Maintenance Lights	120V, single phase controlled manually
Lights at Platform	277V, single phase canopies, Type A 1 pylons, passageways, fare gates and escalator / stair landings

13.15.3.1 LED Lights

General	120V and 277V, single phase

Platform Edge	120V, single phase lights controlled by flasher and dimmer control unit
Maintenance Lights	120V, single phase controlled manually
Lights at Platform	277V, single phase canopies, Type A 1 pylons, passageways, fare gates and escalator / stair landings

13.15.3.2 Metal Halide Lights

General	277V, single phase
Lights Equipped	120V, single phase lights controlled with medium base 277V, single phase lamp holder

13.15.3.3 Convenience Outlets

120V, single phase

13.15.3.4 Motors

3/4 to 200 HP	460V, three phase
½ HP and Below	115 V, single phase

13.15.3.5 Motor Control Power

120V, single phase

13.15.3.6 Duct Heaters and Unit Heaters

Below 4kW	277V, single phase
4kW and Above	480 V, three phase

13.15.3.7 Wall Convectors

Below 4kW	277V, single phase
4kW and Above	480 V, three phase

13.15.3.8 Water Heaters

6 GPH Recovery	120V, single phase
Above 6 GPH	480 V, three phase

13.15.3.9 Chillers

480V, three phase

13.15.3.10 Air Conditioning

10,000 BTU and Below	115V, single phase
Over 10,000 BTU up to 36,000 BTU	208V, single phase
Over 36,000 BTU	480 V, three phase

13.15.3.11 Large Motor Starters

For 460V, three phase continuous operation motors, starter shall include a control transformer. Across-the line motor starter shall be used for motors up to and including 50 HP.

For460V intermittent motor operation, the starters shall be Variable Frequency Drives (VFD) equipped for By-Pass operation and harmonic mitigation; unless otherwise approved by WMATA.

All other continuous operation motors over this limit shall be equipped with reduced voltage starters of the auto-transformer, 2-

step, closed transition type, unless otherwise approved by WMATA. All remotely located motor control centers (such as fan shafts, pumping stations or chiller plants) shall be provided with main incoming breakers.

13.15.3.12 Load Classification

Typically, load requirements are classified into three categories:

- Normal loads
- Emergency loads
- Critical / UPS Loads

13.15.3.12.1 Normal Loads

- Pumping stations
- Fan shafts
- Escalators and associated heaters(site specific)
- Elevators (site specific)
- Parking lot entrance equipment
- Kiosk air conditioning/heating and lighting
- Under platform exhaust (UPE) and dome exhaust (DE) systems and control
- Utility Company metering equipment
- Control air compressor
- Heat trace for piping
- Map lights
- Heating
- Air conditioning
- Ejectors
- Miscellaneous mechanical equipment (motors, heaters, ventilation fans)
- Water heaters
- Receptacles

- Mezzanine-to-platform escalators

Note: In maintenance facilities all loads shall be treated as normal loads except those requiring connection to emergency power.

13.15.3.12.2 Emergency Loads

- UPS system (rectifier/charger and by-pass circuit)
- Battery Room ventilation fan
- Generator quick connect
- Train control equipment
- Lighting (station areas,ancillaryspaces, parking lots,fan and ventshafts,and tunnels)
- Flasher dimmer control panels
- Fare collection equipment
- Escalators and associated heaters(site specific)
- Elevators (site specific)
- Load centers
- Sump pumps

13.15.3.12.3 Critical / UPS Loads

- Communications.
- Exit lighting and 20% of indoor and tunnel lighting.
- Emergency trip station lights.
- Kiosk emergency panel.
- Elevator car light, fan, and controls.
- Escalator newel and comb lights, 10% of balustrade lights, and entrance escalator controls.
- Fire suppression systems.
- Train control equipment (normal feeder).
- Public Service Radio System.

- Chemical detector.
- Passenger Information Display System (PIDS) Data for these loads are provided elsewhere in this Section.

13.15.4 Panelboard Designations

13.15.4.1 The designation of each panelboard shall indicate the following information about the panelboard:

- General location of the panelboard in a passenger station -- (N) north, (S) south, (E) East, and (W) west.
- Specific location of the panelboard in a passenger station - whether in AC switchgear room or electrical room, on mezzanine, or in a mechanical room.
- Identity of panel source -- normal or emergency. Service voltage - 480Y/277V AC or 208Y/120V AC, or 125V DC.

13.15.4.1.1 Panelboards

The panelboards shall be designated and located as shown in Table 13.1. All circuits shall be identified with the panel identity and the branch circuit number. Thus a circuit fed by breaker #3 in panelboard NE is identified NE-3. The top of all panelboards shall be located 6'-6" maximum from the floor level.

13.15.4.1.2 No panelboards are to be located in cleaner's rooms, sewage ejector rooms, wash rooms and locker rooms.

TABLE 13.1 Locations and Identities of Panelboards

AC Switchboard or Electrical Room		NORTH	EAST	SOUTH	WEST
480/277V	Normal	NES	EES	SES	WES
208/120V	Normal	NESS	EESS	SESS	WESS
480/120V	Emergency	NE	EE	SE	WE
208/120V	Emergency	NEE	EEE	SEE	WEE
125V DC		ND	ED	SD	WD
Mezzanine (Where only one mezzanine exists in a station the first letter of the designation (N, E, S or W) may be omitted.		NORTH	EAST	SOUTH	WEST
480/277V	Normal	NMES	EMES	SMES	WMES
208/120V	Normal	NMESS	EMESS	SMESS	WMESS
480/120V	Emergency	NME	EME	SME	WME
208/120V	Emergency	NMEE	EMEE	SMEE	WMEE
Mechanical Room		NORTH	EAST	SOUTH	WEST
480/277V	Normal	NAES	EAES	SAES	WAES
208/120V	Normal	NAESS	EAESS	SAESS	WAESS
CHILLER PLANT					
480/277V	Normal	CH			
208/120V	Normal	CHH			
TUNNEL and FAN SHAFT load centers Tunnel - TLCL, TLC2, etc. as required for contract Fan Shaft - FLCL, FLC2, etc. as required for contract					

13.15.4.2 Panelboard Sizes

The following will serve as a guide in selecting panelboards sizes

Minimum Breaker Poles Connected	Number of Spare 20A Breakers	Unused Spaces	Panel Size Single Poles
Up to 8	2	2	12
9 to 12	4	2	18
13 to 22	4	4	30
22 to 28	4	4	36
29 to 36	4	4	42
Unused spaces shall be equipped with buswork and terminations for breakers.			

13.15.4.3 Demand Factors

Service	Demand Factor
Lighting and Signs	100% of Connected Load
Emergency Lighting	100% of Connected Load
Fare Collection Equipment	90% of Connected Load
Escalators	80% of Connected Load
Elevators	50% of Connected Load
Ventilation Equipment	70% of Connected Load
Air Conditioning Equipment	70% of Connected Load
Chiller Plant	80% of Connected Load
Heating	70% of Connected Load
Drainage Pumps and Ejectors	70% of Connected Load
Train Control Equipment	70% of Connected Load
Communications Equipment	70% of Connected Load
Convenience Outlets	1.5 amperes per receptacle

The designer shall indicate the calculated demand load total at each panelboard schedule for summer and winter.

13.15.4.4 DC Panelboard

This panel shall supply power for the medium voltage and low voltage switchgear and switchboard controls.

13.15.5 Emergency Power System

Provide an Uninterruptible Power Supply (UPS) system rated 62.5 kVA, 480/277 volt, three phase in at-grade or aerial passenger stations. Provide a UPS rated 62.5 kVA or 75 kVA, 480/277 volt, three phase in underground passenger stations. In some instances, a 100kVA UPS may be required.

Critical / UPS loads listed above shall be provided from a UPS system. The UPS output is backed up by an alternate feeder and automatic transfer switch. The rectifier/charger, inverter, and transfer switch shall be located in the AC Switchboard room adjacent to the battery room. The battery disconnect device (enclosed circuit breaker) shall be wall mounted outside and next to battery room entry door, if possible. The UPS shall be capable of operation from the power source of a mobile generator.

13.15.5.1 Rectifier/Charger

A silicon rectifier/charger shall be of adequate capacity to provide DC input to inverter to give rated output while simultaneously providing charge to battery at rate to give full charge in 12 hours after battery has been fully discharged, and to provide control power for high voltage and 480 volt switchgear.

13.15.5.2 Battery

Storage batteries characteristics:

- Shall be UPS cycle duty, industrial flooded lead acid cell.
- Have a discharge capacity capable of providing DC inverter input to give rated inverter output at unity power factor for three hours at 77EF while simultaneously providing DC continuous and final minute load for switchgear.
- Provide minimum battery terminal voltage of 105 volts under full load at end of three hour discharge period.

13.15.5.3 Battery Rack

The two tier battery rack is 1'-3" wide by 2'-6" long by 6'-4" high. Each rack has two cells per tier.

13.15.5.4 Battery Room

13.15.5.4.1 Aerial or At-grade Passenger Stations

The battery room in Aerial or At-grade Passenger Stations with 50 kVA UPS shall have 60 cells batteries. Where the load exceeds the capacity of 60 cells, a second set of 60 cells shall be connected in parallel.

Minimum battery room size in Aerial or At-grade Stations:

13.8 kV Area: 18'-0" long by 24'-0" wide by 12'-0" clear height

34.5 kV Area: 18'-0" long by 24'-0" wide by 16'-0" clear height

13.15.5.4.2 Underground Passenger Stations

The battery rooms in Underground Passenger Station with 62.5 kVA, 75 kVA or 100 kVA UPS systems shall have one set of 60 cell batteries. Where the load exceeds the capacity of 60 cells, a second set of 60 cells shall be connected in parallel.

Minimum battery room size in Underground Stations:

13.8 kV Area: 18'-0" long by 24'-0" wide by 12'-0" clear height

34.5 kV Area: 25'-0" long by 18'-0" wide by 16'-0" clear height

13.15.5.4.3 Ventilation

Each battery room shall be ventilated as stated in Design Criteria, Section 14.4.2.3. The ventilation fan shall run continuously from an emergency power source. Where required by local jurisdiction, interlock to charger shall be provided to prevent operation if fan is not operating.

13.15.5.5 Inverter

Inverter shall be of solid state design with 480/277V, 3 Phase, 4 wire, 60 Hertz output and capable of delivering rated kVA into load which has power factor of .8 lagging, minimum.

13.15.5.6 Automatic Transfer Switch

The switch shall be static type and capable of automatically transferring emergency power load to AC by-pass line under the following conditions:

- Inverter failure
- Inverter output voltage dropping to 80% of rated voltage.

The switch shall automatically retransfer emergency load from by-pass line to inverter when inverter output voltage returns to 90% of rated voltage.

13.15.5.7 Wiring

Emergency system wiring shall not occupy raceways common to other system wiring.

13.15.5.8 Conduit

Applications for the use of conduit shall include the following:

- Where access to wire or cable will not be available or required.
- Concealed wiring is required, such as in public areas.
- Where mechanical protection is required beyond that provided by armored cable.
- Where clearances are limited, buried conduits shall be used.

13.15.5.8.1 Conduit Types and Materials

15.15.5.8.1.1 Liquid-tight Flexible Metal Conduit

Flexible conduit shall be used where vibration isolation is required (e.g., motors, transformers) and for short connections between items of equipment whose alignment precludes the use of rigid conduit.

13.15.5.8.2 Rigid Galvanized Steel Conduit

Galvanized rigid steel conduit may not be embedded. It shall be used only for surface runs in areas including fan and vent shafts, on interior ceilings and walls, or concealed where conditions are normally dry, such as above drop ceilings, and in CMU walls.

13.15.5.8.3 Fiberglass Reinforced Epoxy (FRE) Conduit

All embedded conduit for incoming service (with the exception of Virginia Power) for train control, communications, and auxiliary AC power requirements shall be FRE. Conduit embedded in concrete structure is encased, while conduit embedded in earth shall have concrete encasement added.

Surface mounted conduit for traction power cable shall be FRE conduit with or without concrete encasement, or rigid aluminum as approved by the Authority.

Conduit directly buried in ballast for train control cable shall be

Heavy Wall FRE conduit, with minimum wall thickness of 0.095 inch.

All embedded incoming service conduits for 13.8 kV to WMATA facilities shall be fiberglass. Location and method of installation shall be coordinated with and approved by the Utility Company.

13.15.5.8.4 PVC / HDPE Conduit

Embedded: PVC conduit embedded in concrete structure shall be encased, while conduit embedded in earth shall have concrete encasement added.

Direct Burial: PVC conduit shall be schedule 80 and consist of a single conduit and a spare. Concrete encasement is required for conduit runs exceeding more than 2.

Directional Boring: HDPE conduit shall be schedule 80 and shall require the Authority's specific approval for its location and method of application.

13.15.5.9 General Requirements

Conduit size for train control and communications shall be as shown on electrical and train control Design or Standard Drawings.

Minimum size conduit shall be 3/4", and all conduits shall be sized in accordance with NEC Appendix 'C'.

Where non-metallic conduits are used for AC power cables, proper equipment grounding conductors shall be provided. Conduits shall not be installed in floating slabs unless absolutely necessary and shall do so only at right angles to the slab. Suitable isolation of conduit stub-ups shall be provided as indicated on Structural Design Drawings. Twenty percent spare conduits in embedded conduit runs and ductbank and sleeves in floors and walls shall be provided in the design for future needs.

13.15.5.9.1 Terminate empty conduits as follows:

For power service conduits provide O.Z. Gedney Push-Pull Tab Cups, Type PPC, or Ray flate Duct Sealing System or equal.

For conduits under 1.5 inch diameter, install heavy wall shrink tube as a seal.

13.15.6 Electrical Boxes

Boxes shall be provided where surface mounted multi-conductor cables interface with single conductor cable in embedded conduits for proper termination of cable and cable fittings. Boxes located in underground locations (except electrical equipment rooms) shall be fiberglass or stainless steel, watertight construction with threaded conduit hubs. Boxes located in outdoor above ground locations shall be of fiberglass, watertight construction with threaded conduit hubs. All other boxes should be provided with knockouts.

13.15.7 Conductors

13.15.7.1 Material and Insulation

Material and insulation shall comply with NFPA 130.AC power, lighting and grounding conductors shall be copper with flame retardant insulation and jacket. Minimum conductor size shall be No. 12 AWG, except for control and signal wiring.

Cables shall be low-smoke and have zero halogen generation characteristics for all Passenger Stations, Maintenance Yards, and all associated facilities such as Fan/Vent Shafts and Drainage Pumping Stations.

Fixture wire shall be stranded copper conductor of No. 16 AWG minimum size with Type SF-2 silicone rubber insulated or as necessary to suit temperature ratings of luminary, minimum of 90EC.

13.15.7.2 Voltage Drop

Voltage drop calculations shall be carried out on all circuits longer than 100 feet. Maximum voltage drop for branch circuits shall not exceed 3 percent.

13.15.7.3 Feeders

Fan shafts, jet fans and track drainage pumping stations shall be provided with dual feeders. These feeders shall originate from AC switchboard at passenger stations or traction power substations equipped with auxiliary power transformers.

Power supplies to fan shafts shall be connected to two power feeders from separate sources, such as AC normal switchboards in adjacent passenger stations. Each feeder shall originate from a different passenger station.

Power supplies to drainage pumping stations is similar to that of the fan shafts. If the Authority approves, both feeders could originate from two different normal switchboards located at a passenger station. Each feeder shall be routed in a separate tunnel. Pumping station shall be provided with “quick-connect” at conveniently accessible surface location

Feeders shall be physically separated as far as possible in fan shaft to avoid simultaneous failure from single accident or fire. Fan shaft feeder cables shall be installed in conduit embedded in concrete, and conform to NFPA 130 requirements. The dual feeders serving the fan shafts shall be terminated in a separate electric room at the fan motor level. The electric room walls and doors shall conform to NFPA 130 requirements. Electric equipment serving the fan shaft (such as disconnecting devices, automatic transfer switch, motor control center, panelboards and fan controls, etc.) shall be installed in the electric room.

When the nearest WMATA-owned power source is at an excessive distance from the facility to be served, consideration maybe given to use a separate utility service. The designer shall perform an economic evaluation to develop a recommended service scheme for these facilities. Final determination as to preferred service scheme will be made by the Authority, based on reliability and economics.

The neutral conductor shall be installed with three phase feeders only when required. An equipment ground conductor, sized in accordance with NEC, shall be provided with each feeder and cable assembly.

It is preferred that fan shaft motor feeders shall be protected using motor circuit protectors located in the motor control center.

13.15.7.4 Cable

In order to provide the most economical installation of power and lighting feeder circuits, multi-conductor type MC cable shall be installed on channel inserts in air plenum under station platforms, in cable trough at aerial and at-grade sections, in duct bank, and underfloor duct.

All cables shall be readily accessible for future maintenance and protected from mechanical damage. In general, surface mounted channel inserts shall be used throughout under platform air plenums at passenger stations for the support of cable and conduits. Cables which must be continued past adits and areas at fan shafts and drainage pumping stations open to both tunnels shall be routed past the opening in embedded conduits. Direct burial cables for stray current and cathodic protection shall be protected as specified in Standard Specification.

Cables shall be sized to accommodate 20% future growth in loads. Cables and conduit shall not be exposed in public areas.

Only one length of cable shall be used in any feeder as far as it practicable. Cable splices where required shall be made in junction boxes. Splice box shall be used at any transition between MC cables and single conductor cable in conduit.

13.15.7.5 Wiring methods

Wiring of emergency and normal AC systems, and DC systems shall each be independent of each other and shall not occupy common raceways or enclosures. In multi-conductor circuits, phase wiring shall alternate between the phases to prevent electromagnetic interference.

13.15.8 Wiring Devices

13.15.8.1 Switches

Snap switches shall be installed to control lighting in all service rooms. Switches shall be located inside the individual rooms, on the knob side of the door.

Switches shall be specification grade, 20A, 120 or 277V rated as required.

13.15.8.2 Receptacle (Convenience Outlets)

Receptacles shall be duplex, heavy-duty, 20A, 125 volt rated. Receptacles in tunnel and outdoor areas and in damp or wet locations shall have weather-proof enclosures and ground-fault circuit-interrupters for protection of personnel. Receptacles in wash rooms shall have ground fault circuit interrupters. Receptacles will be supplied from multi-wire branch circuits with dedicated neutral, feeding adjoining receptacles from different phases. No more than 6 receptacles shall be placed on each circuit. Receptacles in ancillary areas and maintenance facilities will generally be located on 20-footcenters unless otherwise indicated below. Receptacles at the station platform, mezzanine and passage-way areas and the multi-story parking garages shall be located such that a 100-foot electric cord can be used to reach any point on the floor. Elevation for receptacles at the passage-way area shall be coordinated with the Authority. Additional requirements are as follows:

13.15.8.2.1 Station platform area:

Flush mounted ground fault circuit interrupter receptacles shall be installed in parapets, in concrete supports for benches, and in concrete columns.

Receptacles shall not be installed in the floors or pylons.

13.15.8.2.2 Station entrance areas:

Flush mounted ground fault circuit interrupter receptacles shall be installed at the concrete wall on the interior side of the entrance door or the folding gate. For long passage-ways, an additional receptacle shall be provided on the wall near the mezzanine area.

13.15.8.2.3 Pedestrian walkways and bridges at station entrances:

Flush mounted ground fault circuit interrupter receptacles shall be installed on the entrance wall. Ground fault circuit interrupter receptacles maybe installed on the steel members so that any point in the walkway can be reached with a 100 foot cord.

13.15.8.2.4 Mezzanine areas:

One flush mounted receptacle shall be mounted in the base on the exterior wall of the kiosk and supplied from the kiosk panel. If required, receptacles shall also be mounted in parapets. Receptacles shall not be installed in the floors or on pylons.

13.15.8.2.5 Ancillary and service rooms:

TABLE 13.2 Ancillary and Service Rooms Convenience Outlet

Ancillary and Service Rooms	Convenience Outlet Requirements
Train Control Room	Receptacles shall be installed on 5-foot centers on each wall.
Communication room	Receptacles shall be installed on 12-foot centers with a minimum of one receptacle on each wall.
Dispatchers room	Six receptacles shall be installed. Three of these shall located above the desk level on the wall with the window facing the track.
AC switchboard room, electrical rooms, mechanical rooms, chiller plants	Receptacles shall be provided on 12-foot centers with a minimum of one receptacle on each wall.
Elevator machine rooms and hoistways	A minimum of two ground fault circuit interrupter (GFCI) receptacles shall be provided in elevator machine rooms. GFCI receptacles shall also be provided in hoistway as shown in the design drawings. Provide a Non-GFCI single outlet for Sump Pump provisions in the elevator pit
Battery room, maintenance room, trainsmen's room, operation's room and bus driver's room	A minimum of two receptacles shall be provided with on each opposite wall.
Wash rooms, cleaners room, water service room and locker room	A minimum of two ground fault circuit interrupter receptacles shall be provided.

Ancillary and Service Rooms	Convenience Outlet Requirements
Bell system room, cart storage room	One receptacle shall be provided. Receptacles in these areas need not be provided with ground fault circuit interrupters.
Track area between stations	In tunnel area along each safety walk receptacles shall be located on 80-foot center and one receptacle at each point of switch. Each of these receptacles shall be ground fault circuit interrupters, and connected to load center branch circuits in accordance with the design drawings.
Vent, fan and access shafts	Receptacles shall be installed so that at any point in the shaft can be reached with a 50-foot cord.
Multi-story parking structure	Surface mounted receptacles shall be installed on walls or columns spaced so that at any point in the parking structure can be reached with a 100-foot cord or as required by the local fire department.
Escalators / Elevators	Requirements are indicated in the escalator / elevator section

13.15.9 Service Requirements for Ancillary Spaces

13.15.9.1 Train Control Rooms (TCR)

Each Train Control Equipment Room shall be provided with two 208Y/120 volt, three phase, four-wire circuits, rated kVA as below, and terminated in disconnect switch.

For train control room at passenger station or remotely located on main line: 9 kVA.

At passenger stations, the transformers supplying the circuits shall be located in the nearest AC switchboard room or the combined AC switchboard room. The normal supply shall be from the emergency power panel. The reserve supply shall be from the AC Switchboard not used to feed the rectifier/charger in the UPS.

For remotely located train control rooms not adjacent to a Tie Breaker or Traction Power Substation, provide a separate electric room as part of the train control building. Provide a normal power source and emergency power source originating from the nearest passenger station AC switchboard room or a traction power substation equipped with an auxiliary power transformer.

The transformers, and panelboards supplying lighting and power circuits shall be located in this electric room. For train control transformers, the normal supply shall be from the emergency power panel, and the reserve supply shall be from the normal power panel. All other loads will be from a normal power source.

13.15.9.1.1 TCR in the S&I Shop or Yard (15 kVA):

13.15.9.1.1.1 Train Control Room in Yard Operation Building:

The transformers supplying the branch circuits shall be located in the Yard Operation Building, AC switchboard room.

13.15.9.1.1.2 TCR in the S&I Shop (15kVA):

The normal supply shall be from the emergency power panel. The reserve shall be from the normal switchboard not used to feed the rectifier/charger in the UPS. The transformers supplying the branch circuits shall be located in the Shop AC Switchboard Room.

13.15.9.1.1.3 Yard Tie Breaker Station or Traction Power Substation:

The normal supply shall be from the emergency supply. The reserve supply shall be from the 480V powersupply. The transformers supplying the branch circuits shall be located in the Tie Breaker or Substation.

Each feeder shall be routed in an individual conduit from its transformer and terminated in a disconnect switch in the Train Control Room. No transformers shall be located in the train control room.

The grounding conductors for the train control room ground bus and the transformer secondaries shall be connected to provide one point grounding in accordance with the Electrical Design Drawings.

13.15.9.1.2 Communications Rooms

Each Communications Room located ata station shall be provided with an emergency 208Y/120 volts, three phase, four wire circuit, rated kVA as below, and terminated in a disconnect switch.

For communications room at passenger station: 15 kVA transformer.

For communications room in S&Ishop or yard: 15 kVA transformer. The transformer supplying the circuit shall be located in the AC Switchboard room nearest to the Communication Room; and the transformer power source shall be from the emergency panel. One point grounding shall be provided as shown on the Electrical Design Drawings.

For Passenger Information Display System (PIDS) plug-in accessories: 120V, 1 kVA (from emergency panel).

13.15.10 Service Facilities and Requirements for Kiosk and Fare Collection

Multi-raceway underfloor duct shall be used to the maximum extent practicable to run power and control cabling to the Kiosk, Fare Collection equipment, Bus Transfer dispensers, and Map Case. Conduit shall be used where underfloor duct is not practicable. Sufficient space shall be maintained between ducts or conduits to ensure proper concrete bonding.

The underfloor raceway layout shall be similar to that shown on Electrical Design Drawings. Run between any two pull boxes shall be straight. Adequate junction boxes shall be provided wherever the raceways change direction. Underfloor raceway shall be used for normal power distribution, controls, and signal circuits, communications, and for collection equipment, as indicated on Design Drawings.

Requirements for normal power and emergency power from the Uninterruptible Power Supply (UPS) are as indicated below. For kiosk and fare collection equipment, normal power (280/120 volts, three phase, four wire) shall be provided from one 42-circuit panel fed by a 75 kVA transformer; or, if more capacity is required, use two 32-circuit panels fed by one 112.5 kVA transformer. Panel(s) shall include 20 ampere rated single-pole circuit breakers plus one 3 pole, 40 ampere breaker for kiosk panel feeder, and are to be located in ancillary area nearest to the mezzanine.

These panel(s) shall service the kiosk normal panel and the following equipment:

- Telephone/map lights - 200 W. each, 120V, single phase.
- Fare card vending machines, fare gate consoles, and bus transfer

dispensers – 1800 W. each 120V, single phase.

The kiosk normal panelboard (208/120V three phase, four wire) will have the following normal loads:

- Air conditioning condenser unit - 3200 VA, 208V, single phase.
- Heating - 4000 VA, 208V, single phase.
- Fan coil unit - 700 VA, 120V, single phase.
- Lighting - 1000 watts, 120V, single phase
- Convenience outlets - 800 VA, 120V, single phase.

Refer to Architectural drawings for exact quantities of kiosk, fare card vending machines, fare gate consoles and telephone/map cases.

Emergency power (208/120 volt, three phase, fourwire) from a transformer located in the AC switchboard room shall be provided for the kiosk emergency panel which shall accommodate the following emergency loads, all 120 volts, single phase:

- Lighting:

  below grade stations: 1300 watts

  above grade stations: 300 watts

- Data acquisition display system (DADS): 1500 watts
  - Fare gate bull's-eye lamps: 80 watts each console
  - Communications amplifiers: 240 watts
  - CCTV: 650 watts
  - Passenger Information Display System: 100 watts.

The following empty conduits shall be provided and stubbed up under the kiosk, for future cable installation.

SIZE	SOURCE
1"	AC switchboard room ground bus
1-1/2"(*)	AC emergency panel

(*) For long feeder lengths, increase wire size to compensate for voltage drop. Size conduit accordingly.

Provide the normal and emergency kiosk panels, the feeders to these panels, the ground bus, and the electrode grounding conductor to the kiosk ground bus.

13.15.11 Service Requirements for Escalators

A single 480V, 3-phase, 3-wire, 60 hertz feeder for each escalator wellway shall be provided to the machine room or upper pit area and terminated in fusible, lockable disconnect. (A wellway may contain more than one escalator.) This feeder shall be sized to include the total load of all escalator drive systems and escalators heating loads as specified below.

TABLE 13.3 POWER REQUIREMENTS FOR EACH ESCALATOR

Class	Rise	480-V, 3-PH 3W Drive Power Input kVA	480-V, 3-OH, 3-W Heating Load Kwf	
			#1	#2
A1	Up to 20 feet	15.5	9.0	18.0
A2	Above 20 feet to 24 feet	29.7	9.0	18.0
B2	Above 24 feet to 40 feet	30.5	18.0	24.0
B3	Above 40 feet to 60 feet	44.6	24.0	30.0
C4	Above 60 feet to 80 feet	62.9	24.0	30.0
C5	Above 80 feet to 100 feet	78.0	24.0	30.0
C6	Above 100 feet to 120 feet	93.2	24.0	30.0

#1 - Entrance and passage-way escalators to underground station only.

(There is no heat load for mezzanine to platform escalator at underground station.)

#2 - Aerial and at-grade station

Ampacity of the feeder phase conductor shall not be less than 125 percent of the total connected load. Neutral conductor shall be half the capacity of phase conductor. Trip setting of associated breaker shall not be less than 125 percent of the total load subject to a minimum of 50 amperes.

Normal power shall be provided for entrance and passage-way escalators to mezzanine at underground station and for Class B escalators at aerial and at-grade stations. Normal power shall be provided for mezzanine to platform escalators at underground stations and Class A escalators at aerial and at-grade stations.

The auxiliary electrical supply for each escalator wellway shall be a single normal feeder provided to the machine room or upper pit area and terminated in a fusible, lockable disconnect. It shall be a 208Y/120V, 3 phase, 4 wire service for entrance and passageway escalators with balustrade lights. The auxiliary supply feeder shall be sized for lighting and convenience outlets based on the following requirement:

13.15.11.1 Balustrade lights:

For light sources and illumination level requirements, see Section 4.

13.15.11.2 Maintenance lights:

Class A escalators--15-footcandles in each pit area and 30-footcandles in wellways. Class B and C escalators--30-footcandles in wellways and pit areas.

13.15.11.3 Receptacles:

Class A escalators - One row between every two adjacent escalators, including one at upper and lower pit areas on each escalator and every25 feet maximum along the truss.

Class B and C escalators - minimum of three in the machine room and one row between every two adjacent escalators, including one in the upper and lower pit area and one every 25 feet maximum along the truss.

13.15.11.4 Emergency Circuits

One or more emergency circuits, each rated 120 volts, 1800 watts maximum, shall be provided for each machine room and upper pit area of the wellway and shall be terminated in a fusible, lockable, disconnect box in the wellway or escalator control room. These circuits shall be based on the following requirements:

- comb plate lights (4-40W lamps per escalator)
- 10 percent of the maintenance lights
- 10 percent of the balustrade lights.

In addition the circuit load shall include a 75 watt allowance for escalator control on entrance escalators, and a 50 watt allowance for escalator fire suppression control for those underground stations having a single escalator entrance.

A 3/4-inch conduit with cables (No.14 AWG conductor) and limit switches rated for 120 volts shall be provided for each station entrance gate, where directed by the Authority, to the escalator control room and terminated in a junction box, as shown on the electrical design drawings.

A one-inch conduit per escalator between the machine room or controller space and the nearest kiosk shall be provided for control purposes. Two one inch conduit per escalator between escalator control room/controller space and the communications room shall be provided for fire alarm circuits and telephone.

Conduits, cables, and other electrical equipment shall be provided to each escalator machine room or controller space. All conduits, cables, disconnect switches or circuit breakers, panelboards, lighting, control, heating, and wiring devices to extend the incoming services within the escalator wellway for a complete installation shall be provided.

13.15.12 Service Requirements for Parking Lots, Bus Service, Kiss and Ride Areas

Each parking lot, bus service, kiss and ride area shall be served from a three-phase, four wire 480/277 volt normal panelboard located in the passenger stations. The loads will include control gates and lighting for the parking areas, bus passenger and supervisor shelters. Except for the control gates, all 120 volt circuits shall be fed from 208/120 volt panelboard located in passenger stations. Emergency lighting is not required for outdoor parking areas. Security lighting shall be provided for exterior areas.

Luminary types and locations shall be provided in accordance with requirements given in the WMATA Manual of Design Criteria, General Plans and Architectural criteria and standards.

Parking lot entrances and exits shall be equipped with control gates in accordance with parking lot general plans. The parking lot control gates may consist of any combination of combined entrance/exit, entrance only, or exit only gates. Site preparation for parking lot control gates shall be designed as per Parking Lot Control Gate Design Drawings.

The conduit requirements from the Metro station to the nearest control gate, between the control gates and the lot full sign shall be designed according to Design Drawings.

A separate three phase 15 kVA, 480 volts service shall be provided to each control gate whether a combined entrance/exit, entrance only, or exit only area. These services shall be terminated in the load center enclosure at the control gate.

Equipment for control gates, the load center for each control gate shall be provided by section contractor. The section contractor shall provide the luminaries at the control gate along with photoelectric control for automatic operation. Provisions shall be included for a manual override switch to be installed by the section contractor.

Control of lighting shall be in accordance with the requirements for outdoor lighting of the WMATA Manual of Design Criteria, Section 4.

Use of handholes, junction and pull boxes in parking lots, kiss and ride area shall be avoided. When necessary, only handholes with non-metallic covers and non-metallic junction and pull boxes shall be installed in landscaping or grassy areas.

13.15.13 Elevator Electrical Service Requirements

Three feeders are required for the elevator machine room as follows:

- 480 volts 3 phase 3 wire normal power feeder;
- 208/120 volt 3 phase 4 wire auxiliary normal feeder;
- 120 volt single phase emergency feeder

The 480 volt feeder shall be terminated near the doorway inside the machine room. It shall be a single feeder and sized for the total load of all elevator motor drive systems in accordance with Section 14.17.5 of Mechanical design criteria. A separate disconnecting means, in accordance with local codes, will be provided for each elevator drive unit.

The 208/120 volt auxiliary feeder shall be provided to the elevator machine room and terminated in a multi-circuit panelboard or other disconnecting means where required by local codes. The number of circuits in the panelboard shall be based on the following 120 volt circuits, as required for each elevator:

- Lighted signal system (100 watts);
- Hoistway lights;
- Hoistway GFCI receptacles;
- Canopy light

Conduit and cables for hoistway lighting and receptacles and canopy light shall be installed from the elevator machine room to and in the hoistway.

The 120 volt AC emergency feeder shall be installed to the elevator machine room and terminated in a separate disconnecting means for each elevator in accordance with local codes. For each elevator the load will include:

- 500 watts for elevator car lighting and exhaust fan;
- 125 watts for intercom;
- 300 watts future provision for elevator relay controls

Conduit and cables for elevator car lighting and exhaust fan shall be installed from the machine room to the hoistway pit and terminated in a junction box.

Conduits for all other functions shall be installed from the elevator machine room to the hoistway and to other areas in the passenger stations shown on the electrical design drawings.

Two one-inch diameter conduits per elevator between the machine room and the communications room shall be provided for fire alarm circuits and telephone circuits.

A 3/4 inch diameter conduit between the elevator machine room and the AEMS RTU in the AC switchboard room shall be provided for remote monitoring.

13.15.14 Suppression Systems Electrical Service Requirements

A 120 volt, 250 watt emergency power circuit shall be provided and terminated in a junction box adjacent to each Fire Suppression system control panel.

13.15.15 Passenger Information Display System (PIDS Electrical Power Service Requirements

13.15.15.1 Platform PIDS:

A. 2- pole, 480V, 20A circuit shall be provided from the nearest AC Switchboard Room's Fused Switch Emergency Panel and terminated in a NEMA 4X rated disconnect (safety) switch near where the PIDS will be located. The disconnect (safety) switch shall provide input power to a 5 kVA, single phase, 480/240-120V transformer which will supply the 120-volt power for the platform PIDS.

13.15.15.2 Mezzanine PIDS:

A. A 120V, 20A circuit shall be provided from the nearest Emergency Panel to where the mezzanine PIDS is located.

13.15.16 AC System and Equipment Grounding

13.15.16.1 AC Power Grounding System

A complete AC power grounding system shall be provided for the protection of property and human life. The grounding system shall comply with the National Electrical Code and with requirements in this criteria, guide specifications and design drawings. In addition to the grounding of all enclosures and raceways of the AC power and distribution system the grounding system shall provide a low impedance path to ground for all exposed metallic structures, railings, stairways, etc., in the vicinity of the AC power systems.

The grounding system shall be physically isolated from structural rebar and stray current systems, and cathodic protection systems. Intentional metallic contact or electrical bonding between the two systems is not permitted. Where soldier piles are used for AC power system grounding purposes, any number of soldier piles may be bonded together provided they are in the same row and are adjacent to each other. Soldier piles for grounding shall be isolated from other soldier piles which are bonded and connected to drainage circuits and from reinforcing bars in the structure.

13.15.16.2 Ground Grid

A ground grid shall be provided for each AC service at the following:

- Shop buildings
- Passenger stations
- Traction power substations
- Tie breaker stations
- Chiller plants
- Vent / Fan shafts
- Pumping stations

13.15.16.3 Ground Grid / Bus Resistivity

Ground grid resistance shall not exceed 5 ohms for AC passenger stations, electrical rooms, chiller plants, vent/fan shafts, and pumping stations. Where a traction power station or a tie breaker station is in close proximity to an AC passenger station, only one ground grid with resistance not exceeding 2 ohms is required.

Grid shall consist of bare or insulated copper conductors and ground rods conductors and ground rods buried in earth and in a pattern to suit the structure; a rectangular pattern is preferred. In at-grade locations grid shall be 30 inches minimum below grade. Where grid is below the bottom of the slab or near metallic objects, minimum 24 inches separation shall be maintained. In underground locations, grids may be installed under the structure. A minimum of 24 inches separation must be provided between grid and soldier piles used for stray current control between grid and cathodic protection systems. In soils of high resistivity and in rock construction where normal grounding grid design does not provide required resistance, alternate methods of ground grid design, or location, or soil treatment, etc., are to be submitted to WMATA for approval. Grounding of outdoor service transformers shall be provided by means of a grounding electrode conductor from the transformer pad to the nearest ground grid, as well as to the substation ground bus.

13.15.16.4 Soil Resistivity Testing and Validation

After locations for ground grid(s) are determined and staked by survey personnel, an engineering consultant will conduct a soil resistivity survey and report the data for use in design.

13.15.16.5 Main Ground Bus Ground Connections

Main ground bus on walls of substation rooms shall be used to ground the neutral of the secondary AC power distribution systems and to connect grounding sub-buses in kiosk, train control and communication rooms, dispatcher and Bell system rooms, escalator pits, escalator control room, elevator machine rooms and other grounding as required.

Ground bus shall be copper, approximately 24 inches above floor and mounted on insulators 1-1/2 inches from wall. Where there is insufficient clearance behind the electrical AC switchgear, install ground bus bar on the wall above the switchgear.

13.15.16.6 Train Control Room (TCR) and Communications (COM) Room Connection Requirements

- Requirements for installing grounding connections in train control and communication rooms shall be as follows:
- A dedicated ground sub-bus bar for train control and communication equipment grounding shall be connected to the AC switchboard room main ground bus bar.
- No other equipment or metallic structure shall be bonded to the ground sub-bus bar provided for train control and communications equipment.
- For other items requiring bonding and grounding, such as a transformer or electrical panel, a separate sub-bus bar shall be provided and be connected to the AC switchboard room main

ground bus bar.

13.15.16.7 Ground Bus Installation Requirements

The design and installation of Ground Bus varies with application. The following are bus customizations:

13.15.16.7.1 AC switchboard room:

1/4" x 2" main bus installed around the inside periphery of the room.

13.15.16.7.2 Chiller plants:

1/4" x 2" x 24" main bus installed on the wall adjacent to service equipment.

13.15.16.8 Train control room:

1/4" x 2" x 24" sub-bus near power supply switch and connected to AC switchboard room bus with No. 2/0 AWG insulated grounding conductor. The sub-bus insulated grounding conductor shall be connected to the AC switchboard room ground bus within 2" of the grounding conductor connection for the transformers supplying power to the train control room per electrical design drawing.

Sub-bus in train control rooms is dedicated exclusively to train control equipment and no other grounding to this bus is permitted.

13.15.16.9 Communications room:

1/4" x 2" x 24" sub-bus near power supply switch and connected to AC switchboard room bus with No. 2/0 AWG insulated grounding conductor. The sub-bus insulated grounding conductor shall be connected to the AC switchboard room ground bus within 2" of the grounding conductor connection for the transformer supplying power to the train control room per electrical design drawing.

Sub-bus in communications rooms is dedicated exclusively to communications equipment and no other grounding to this bus is permitted.

13.15.16.10 Kiosk:

1/4" x 2" x 12" sub-bus connected to ground bus in nearest AC switchboard room via No.2/0 AWG insulated ground conduct or in 1"conduit. The sub-bus insulated ground conductor shall be connected to the AC switchboard room ground bus within 2" of the grounding conductor connection for the transformer supplying power to the kiosk emergency panel. Provide a second ground path connecting the metallic structure to nearest ground bar bus using a

No. 2/0 AWG insulated ground conductor in 1" conduit. Leave 10 feet length of conductor coiled up at kiosk.

Sub-bus in Kiosk is dedicated to Kiosk equipment, and no other grounding to this bus is permitted.

13.15.16.11 Other Rooms:

Sub-bus in electrical and mechanical rooms, dispatcher and bell system rooms, as required for convenient grounding of separately derived AC power systems.

13.15.16.12 Tunnel:

One No. 4/0 AWG insulated copper ground conductor (sub-bus) shall be provided in each tunnel section, in each cable trough of aerial section, in duct bank of at-grade section of main line and in each cable tunnel or cable space located below station platform.

13.15.16.13 Fan Shafts:

1/4" x 2" x 24" main bus installed on the wall adjacent to the AC power equipment.

13.15.16.14 Drainage pumping stations:

1/4" x 2" x 24" main bus installed on the wall adjacent to the AC power equipment.

13.15.16.15 Escalator Control Room and Elevator Machine Rooms:

1/4" x 2" x 24" long grounding sub-bus bar installed on wall adjacent to AC power equipment.

13.15.16.16 Battery Rooms:

1/4" x 2" x 24" long grounding sub-bus bar located below battery disconnected device.

The complete AC power grounding system shall include ground bus in each distribution equipment enclosure such as switchgear, panelboards, motor control centers, and load centers, which shall be interconnected by insulated equipment grounding conductors that run with the feeders from the source panelboard or switchboard. Such conductors shall be identified by a continuous green color and be sized in accordance with NEC and shall run in a common conduit with the associated phase and neutral conductors. Multiple-conductor cables with metallic sheaths shall be provided with insulated or bare equipment grounding conductors; use of the metallic covering for grounding is not considered adequate.

13.15.16.17 Required Equipment / Services Grounding

Equipment grounding conductors shall be provided by means of insulated copper grounding conductors for the following services:

- All feeders.
- All branch circuits.

13.15.16.18 Grounding for Shock Hazards

Grounding for personnel safety shall be provided to minimize shock hazards as follows:

13.15.16.18.1 Substations, Electrical and Mechanical Rooms, Fan Shafts and Pumping Stations

All exposed metallic structures, motor frames, AC equipment enclosures, ductwork and metallic piping shall be bonded to the local main ground bus with an exterior No. 6 AWG minimum insulated grounding conductor.

13.15.16.18.2 Escalators, Elevators and Kiosks Metallic Structure

All shall be bonded to equipment grounding conductor in the AC feeder and to local ground bus bar. All electrical equipment (motor frames, AC equipment and luminaries enclosures) shall be provided with a minimum of two ground paths as follows:

13.15.16.18.3 Electrical Equipment

All motor frames, AC equipment and luminaries enclosures shall be provided with a minimum of two ground paths as follows:

- Bonding to green insulated equipment grounding conductor in the AC feeder/branch circuit.
- Connection to grounded metallic structure using metallic fasteners, metallic conduit and/or bonding jumper.

13.15.16.18.4 Escalators and Elevators

Provide a second ground path connecting trusses and guide rails using a No.1/0 AWG insulated ground conductor connected to ground bus bar in AC switchboard room. Leave a 20-foot length of conductor coiled up in pits or wellways.

13.15.16.18.5 Water Pipe Cathodic Protection

Where a dielectric water fitting is installed for cathodic protection of underground piping, only the exposed piping maybe grounded. Do not install jumper around the fitting. (The use of municipal water system as a grounding electrode is not permitted.)

13.15.16.18.6 Structural Metalwork

All exposed structural metalwork such as stairways, handrails and safety walk gratings within reach of AC power equipment (5'-0"+) shall be bonded to the nearest AC equipment ground bus or sub-bus.

13.15.16.18.7 Non-Structural Metalwork

Exposed metallic structures in open areas such as light standards, handrails, cable trough and metallic deck structures on aerial track, and fence on at-grade construction, shall be bonded and grounded to separate ground rods.

Handrails and cable troughs on aerial tracks shall be grounded at each pier and abutment to a ground rod or piles with an embedded insulated grounding conductor. All fencing shall be grounded at approximate 50-foot intervals to ground rods, and jumpers provided where required for grounding continuity. Fencing around transformer pads shall be suitably grounded. Flexible jumpers shall be provided at gates to ensure continuity.

13.15.16.19 Exposed Metallic Structure

Passenger and supervisor shelters equipped with luminaries or receptacles, illuminated diorama, pylon equipped with luminaries, map case and telephone enclosures shall be provided with a minimum of two ground paths as follows:

- Bonding to green insulated equipment grounding conductor in AC branch circuit.
- Connection to nearest ground bus in electrical room or sub-bus or to 5/8-inch diameter by 10-feet long ground rod buried adjacent to the structure, using a minimum No.6 AWG insulated grounding conductor.
- For metallic structures on station platforms bond to No.4/0 AWG ground conductor in cable space under the platform.

13.15.16.20 Grounding of Manholes, Handholes, Junction and Pull Boxes Metallic Body, Cover Frame and Cover:

- Metallic cover shall be bonded to metallic frame using a minimum No. 6 AWG insulated grounding conductor and a bronze or brass chain inside rubber hose.

- Metallic body and frame shall be grounded to 5/8-inch diameter by 10-feet long ground rod using a minimum No. 6 AWG insulated grounding conductor.
- When a cable is spliced or tapped in handhole, manhole and junction or pull box, metallic bodyand frame shall be also bonded to equipment grounding conductor.

13.15.16.21 Bonding Connections

Connections to metallic structure, safety walk grating, cable trough, stairway, hand railing, telephone and map case enclosures, fence, frame columns of shelters, pylon frame, diorama metallic cover and metallic body and metallic cover frame of hand hole, manhole and junction box shall be made by exothermic welding or gas torch brazing.

13.15.16.22 Exterior Structure Bonding Requirements

In outdoor public areas (passage-way, parking lot, kiss and ride area), use of manholes, handholes, junction and pull boxes shall be avoided. When necessary, only handholes with non-metallic cover and non-metallic junction and pull boxes shall be installed in landscape and grassy areas.

Cable splices and taps in outdoor handhole, manhole, junction and pull boxes shall be covered by watertight heat-shrinkable tubing or wraparound sleeve in accordance with Electrical Design Drawings.

13.15.17 Lighting Systems

13.15.17.1 General

This criteria establishes desirable standards for illumination and design requirements for electrical fixtures and control for the rail transit system.

13.15.17.2 Scope

The criteria covers lighting requirements for the following:

- Passenger Stations
- Shafts and Tunnels
- Parking Areas
- Traction Power Substations and Tie Breaker Stations

- Station Ancillary Spaces
- Car Storage Yards and Maintenance Facilities

The lighting of public areas of passenger stations, including entrances, escalators and passage-ways, and station exterior areas, such as parking facilities, ramps, walkways, and bus loops, are included within the scope of work of the architectural branch of CENF and Metrorail Station Lighting Criteria. Illumination levels and other criteria in this section shall govern.

13.15.17.3 Illumination Levels

Minimum maintained lighting levels for various areas shall be as indicated in Tables 13.3 and 13.4.

The method for calculating these levels shall be as outlined in the Illuminating Engineering Society (IES) Lighting Handbook. For indoor lighting the zonal cavity method shall be used. Lamp mean lumens or lamp depreciation as listed in the IES Lighting Handbook and the luminaire dirt depreciation factor classified as "Dirty" shall be assumed.

For outdoor lighting (car storage yards, parking lots, driveways, and bus loops) a light loss factor (maintenance factor) of 64% shall be assumed. In addition to level of lighting, it is normal that illumination on open sections of the transit system be designed to minimize glare which would tend to interfere with observation of track by the train attendant. Luminaires should be so selected, located and aimed so that while accomplishing their primary purpose they will produce a minimum of objectionable glare and interference with vehicular traffic and neighboring surroundings.

Where rapid transit tracks or yard areas are located adjacent to railroad operating tracks, particular attention shall be given to placement and direction of rapid transit illumination to avoid interference with railroad signals or operations.

13.15.17.4 Luminaries

Refer to the WMATA Manual of Design Criteria, Section 4; Architectural and Electrical Standard and Design Drawings for fixture types and applications. Luminaries shall be selected and located as follows:

13.15.17.4.1 Station Areas

Areas including Kiosks, passage-ways, Stairs, Escalator ways, Station Entrances and Elevators as per Architectural General Plans for individual stations and WMATA Manual of Design

Criteria, Section 4.

The fixture Type L-2 and S-15 should be equipped with HID lamps and ballasts.

13.15.17.4.2 Service Areas

Industrial Type fixtures as appropriate to give levels of illumination indicated in Table 13.3, and in Section 13.8.5 for emergency lighting.

Fluorescent fixture Types 1, 2, 3, 4 and 5 shall be equipped with energy saving ballasts and T8 lamps. Type 6 fixtures shall be equipped with compact fluorescent lamps. Exit light Type X shall have backlit light emitting diode (LED) as its lighting source.

In attic spaces metal halide fixtures (type 7A) shall be mounted over the train room arch at nominal forty foot centers along and within approximately five feet of the arch centerline.

13.15.17.4.3 Train Control and Communications Equipment Rooms

General illumination levels in accordance with Tables 13.3 & .13.4 Location of luminaries shall be coordinated with the preliminary layouts for equipment to be installed in these rooms.

13.15.17.4.4 Subway Sections between Stations

Single fluorescent luminary shall be mounted over each safetywalk and spaced at nominal 24'-0" centers.

In double-track tunnels with center safety walk, two-in-tandem fluorescent luminaries (type 4A) shall be mounted over the safety walk and spaced at nominal 24'-0" centers.

Lighting calculations shall be provided to verify the foot candle requirements shown in Table 13.3.

13.15.17.4.5 Passenger AC Substations

General lighting shall be provided by fluorescent luminaries. Such lighting shall be located to satisfactorily illuminate the vertical surfaces of all switchgear, panelboards, etc. Location of all luminaries shall be coordinated to avoid interference with overhead bus, cable trays, ducts or other major wiring and mechanical equipment, and shall not be located directly above switchgear, cable trays, or transformers. Approximately 10 percent of the inside substation lighting shall be connected to emergency power and controlled from emergency panel only. Remaining substation luminaries shall be controlled by a switch at the entrance doorway.

13.15.17.4.6 Escalator

No luminaries shall be installed on the ceiling above the escalators.

13.15.17.4.7 Special Trackwork in Subway

Fluorescent / MH /LED fixtures shall be located at nominal 20-foot centers in a staggered arrangement on either side of track where possible. Care shall be taken not to infringe on car clearances. Section Designer/Design Engineer shall submit lighting calculations verifying the foot candle requirements shown elsewhere in Criteria.

13.15.17.4.8 Interlocking lighting

Luminarie shall be fed from emergency circuit with local on/off switch.

13.15.17.4.9 Emergency Trip Station Locations

Special blue luminaries with mercury vapor lamp shall be located at all Traction Power emergency trip stations and special trackwork (crossovers).

13.15.17.5 Parking Lots, Bus Loops and Roadways

Fixtures and locations shall be defined by Architectural Standards and WMATA Manual of Design Criteria, Section 4.

13.15.17.6 Subway Tunnel Portal Areas

Areas shall be equipped with Type 4 fluorescent fixtures spaced at nominal 20-foot centers for a distance of 300 feet from the portal.

13.15.18 Control of Lighting

13.15.18.1 Indoor General Lighting

Lighting in indoor public areas and in tunnel areas shall be controlled by means of breakers on the panel-boards. Lighting in service areas, including maintenance and Service & Inspection shops, shall be manually controlled by switches.

13.15.18.2 Lighting for At-Grade and Aerial Stations

Lighting for platform canopies, open mezzanine areas and pylons shall be controlled by AEMS. The emergency lighting (twenty five percent of pylon lights and approximately10% of platform canopy and mezzanine lighting) shall be controlled by photoelectric control so that lights are on all night for security purposes. The control shall include manual override switches so they can be turned on any time manually. All lighting controls shall be located in AC switchboard rooms for interface with Automated Energy Management System (AEMS).

13.15.18.3 Attic Lighting

The lights shall be fed from a 277 volt panel at one end of the station and controlled via a single pole contactor wired to turn lights on or off from switches located at each entry point to attic.

13.15.18.4 Tunnel Portal Lighting

Photoelectric control shall be provided for tunnel portal lights indicated in paragraph 13.8.4.7, to turn all lights on during the day, and to turn off 50% of these lights (excluding emergency lights) at night. Emergency lights shall be on continuously.

13.15.18.5 Platform Edge Lights

Platform edge lights shall be fed from a 120/208 volt normal panel and be controlled for each track by AEMS and a flasher/dimmer control as follows:

- lights to remain off during non-revenue operation
- lights to be normally on at approximately 50 percent intensity during revenue operation.

Normally, platform edge lights shall be "on" (non-flashing mode) at 50% intensity. Sixty seconds before the arrival of the train at the passenger station, the flasher shall be energized by a 28 volt DC circuit and contact in the train control room, via DTS terminal cabinet provided in AC switchboard room. The flasher shall commence simultaneous flashing of all the lights on the train side of the platform edge at 60 flashes per minute between 50 and 100% intensity. On departure of the train, the flasher DC control shall be de-energize and the light shall revert to 50% intensity level (non-flashing mode). The light circuits shall be designed as shown on the electrical design drawings.

13.15.18.6 Exterior Lighting Controls

All exterior lighting shall be controlled by AEMS.

The AEMS shall turn on all lighting when north sky luminance falls below 5 foot lambert. The AEMS shall turn off 80% of the lighting during non-revenue hours. The remaining 20% of site luminaires, on a separate control and evenly distributed throughout the site, shall remain on all night for security. The security lights shall be turned off by the photocell when north sky luminance rises above 5 foot-lambert. The photocell shall be mounted on a light pole in the middle of a lot with an unobstructed view to the north sky.

Lighting system controls shall have auxiliary contacts for control by the Automated Energy Management System (AEMS).

13.15.18.6.1 Lighting Feeders

Where multi-phase branch circuits are used for feeding power to luminaries, adjacent fixtures shall be alternately connected to different phases and the protective devices shall be single-pole type to maintain a more uniform illumination with de-energization of one or two phases.

TABLE 13.4 - GENERAL ILLUMINATION LEVELS

AREA	AVERAGE ILLUMINATION LEVEL (Footcandles)		MINIMUM ILLUMINATION LEVEL (Footcandles)	LAMPS (2)
	Maintained	Inital	Inital	
1. Subway Tunnel Structures, platform plenum, cable spaces and mechanical chases	1.0	1.4	1.4	Fluorescent
2. Special Trackwork Areas	3.0	4.3	1.4	Fluorescent/ Metal Halide
3. Car Storage Yards Special Trackwork	3.0	4.3	1.4	Metal Halide
4. Car Storage Yards - Other Areas	1.0	1.4	0.15	Metal Halide
5. Bus Loops	(1)	(1)	(2)	(1)
6. Parking Areas	(3)	(4)	(5)	(2)
7. Bus Platforms	(6)	(7)	(8)	(3)
8. Fan and Vent Shafts	3.0	4.3	1.4	Metal Halide
9. Emergency Exit Shafts	5.0	7.1	1.4	Metal Halide
10.Pumping Stations & Ventilation Equipment Areas	15.0	21	5	Fluorescent
11.Interlocking Area	30.0	43	21	Metal Halide

NOTE: (1) - Fixtures and level of illumination to be used in this area are specified in Standard Architectural Details and Section 4 of WMATA Manual of Design Criteria.
(2) - As an alternative to the above lamps, suitable LED's will be considered.

TABLE 13.5 - ILLUMINATION LEVELS IN PASSENGERS STATIONS

AREA	AVERAGE LEVEL OF ILLUMINATION		MINIMUM ILLUMINATION	LAMPS (2)
	Maintained	Inital	Inital	
1. Station Platforms	(1)	(1)	(1)	(1)
2. Mezzanine	(1)	(1)	(1)	(1)
3. Fare Gates and Fare Collection Areas	(1)	(1)	(1)	(1)
4. Fare Collection Kiosk	(1)	(1)	(1)	(1)
5. Pedestrian passage ways	(1)	(1)	(1)	(1)
6. Escalator & Stairway Entrances	(1)	(1)	(1)	(1)
7. Electrical Service Rooms, including Substations & Tie Breaker Rooms	30.0	43	14	Fluorescent
8. Battery Rooms	30.0	43	14	Fluorescent
9. Train Control and Communications Rooms	50	71	21	Fluorescent
10. Dispatch and Trainmen's Rooms	50	71	21	Fluorescent
11. Staff Washrooms and Lobbies	50	71	21	Fluorescent
12. Mechanical Rooms	30	43	14	Fluorescent
13. Cleaner's and Service Rooms	15	21	5	Fluorescent

AREA	AVERAGE LEVEL OF ILLUMINATION		MINIMUM ILLUMINATION	LAMPS (2)
	Maintained	Inital	Inital	
14. Operations Rooms	50	71	21	Fluorescent
15. Elevator and Escalator Machine Room	30	43	19	Fluorescent

NOTE: (1) - Fixtures and level of illumination to be used in this area are specified in Standard Architectural Details and Section 4 of WMATA Manual of Design Criteria.
(2) - As an alternative to the above lamps, suitable LED's will be considered.

13.15.19 Emergency Lighting

Emergency lighting in stations and tunnels shall be provided by a percentage of the normal continuous burning luminaries to obtain the desired illumination levels. The designer shall submit lighting calculations verifying the level of illumination for each area listed below. Minimum maintained illumination for emergency purposes shall be provided as follows:

TABLE 13.6 AVERAGE LEVEL OF ILLUMINATION

AREA	AVERAGE LEVEL OF ILLUMINATION
Tunnels	0.2
Platforms	2.0
Washrooms	1.0
Communications Rooms	1.0
Train Control Rooms	1.0

AREA	AVERAGE LEVEL OF ILLUMINATION (Maintained footcandle)
AC Swithchgear / Switchboard	6.0
Traction Power Substation	6.0
Mechanical Room	6.0
Battery Room	6.0
Stairs, Escalators, Mezzanines	2.0
Emergency Exit	2.5
Fan and Vent Shafts	1.5
Kiosk	6.0
Elevator Car Lights	5.0

Approximately 50 percent of the luminaries in emergency exit shafts and stairways, and 20 percent of the indoor luminaries, shall be connected on emergency circuits. Outdoor luminaries shall not be connected on emergency circuits unless approved by the Authority.

In all cases the emergency lighting shall conform to the codes and regulations of all jurisdictional Authorities. Exit lights and normal signs shall be fed from the emergency power system.

Emergency lighting for the stairs and escalators shall be designed to emphasize illumination on the top and bottom steps or landings.

Provide emergency lighting in shafts with ladders for safety of incoming emergency and WMATA personnel who may be required to reach an incident site.

All escalator step (newel and comb) lighting shall be an LED type and use a power source on emergency 120 volt AC circuits.

Escalators shall have an LED lighting system with ten (10) percent of the balustrade and maintenance lighting on emergency 120 volt AC circuits. Emergency lighting circuits for blue lights at emergency trip stations (ETS) shall be rated at 277 volts for ETS units located in passenger stations and at trackside (remote from passenger stations).

13.15.20 Lighting Summary

General areas: Illumination levels shall be measured horizontally at 3 feet above the floor and at stair and escalator threads.

Egress areas: Illumination levels shall be measured 2 feet above floor level along the center of each aisle and escalator threads.

13.16 SUPERVISORY CONTROL AND INDICATION OF ELECTRICAL SYSTEMS

13.16.1 General

These design criteria include functional and design requirements for supervision and control of Traction Power and Auxiliary Electrical Systems of the Washington Metropolitan Area Transit Authority's rail rapid transit system.

The Electrical Supervisory Control System utilizes the Data Transmission System (DTS) installed under the Train Control Contract for transmission of all supervisory data between field controlled facilities and the Central Control Room. The Central Supervisory Display and Control Console is also designed and installed under the Train Control Contract. The design of these two systems must be closely coordinated, particularly with respect to interface details and locations.

13.16.2 Scope

The Electrical Supervisory Control System shall monitor, and in some instances have control of the traction power and other electrical equipment necessary for the continuous operation of the system. The following is included in the design of this system:

- Facilities required for control and supervision of Traction Power Substation and Tie Breaker Stations, except in yards and service and inspection shops.
- Facilities for monitoring of passenger station auxiliary equipment and AC power unit substations.

13.16.3 Glossary

Definitions pertaining to Supervisory Control are included in the General Glossary for Section 13.3 of this Criteria.

13.16.4 Standards

The Supervisory Control equipment for electrical functions shall embody modern designs which provide the highest degree of safety and reliability.

Whenever applicable, design of equipment for these functions shall be in accordance with ANSI, NEMA and IEEE Standards and Specifications. The functional principles of these specifications shall also be maintained where new devices or techniques are developed, even though the technicalities of the specifications may require modification.

13.16.5 Equipment and System Interfaces

13.16.5.1 Control Center Console

The Control Center located in the OCCB shall contain an Electrical Display and Control Console which shall give immediate alarm and visual indication of status changes, faults, or other abnormal conditions associated with traction power substations, tie breaker stations, AC switchboard rooms, ventilation fans, fan shafts, vent shafts, drainage/pumping stations, and chiller plants. This Control Console shall be further equipped to provide the operating attendant with the capability to control or adjust electric power systems (as indicated in Table 13.5 and Table 13.6) serving the transit facilities, to maintain continuous rapid transit operation.

Additional functions of the Control Console are described in subsequent sections of these criteria. This equipment is designed and installed under the Train Control and Communications contracts.

13.16.5.2 Remote Terminals and Interface to DTS

Passenger station AC switchboard rooms - Cabling and connections from the equipment to a terminal cabinet, and the terminal cabinet itself (located in the respective switchboard room)will be furnished and installed by the section contractor. Extension of wiring from the terminal cabinet to OCCB will be by the train control stage contractor.

Fan shafts, vent shafts, drainage/pumping stations, and chiller plants - Cabling and connections from the equipment to a terminal cabinet, and the terminal cabinet itself, will be furnished and installed by the section contractor. For fan shafts, vent shafts, drainage/pumping stations, and chiller plant located at passenger stations, the terminal cabinet shall be located in the nearest AC switchboard room and shall also serve the AC switchboard room equipment. For fan shafts, vent shafts, drainage/pumping stations, and chiller plants located remote from passenger stations, the terminal cabinet shall be located at the site to be monitored. Extension of wiring from the terminal cabinet to OCCB will be by the train control stage contractor.

13.16.5.3 System Functions

Local and supervisory control functions for these systems and for other equipment shall be as shown on electrical, mechanical and train control design and standard drawings.

13.17 MAINTAINABILITY AND CONSTRUCTIBILITY

The design of the electrical system comprising equipment, raceways, fixtures, devices, wires and cables shall be coordinated with structural, mechanical architectural and other disciplines for the purposes of providing adequate space, clearances and structural support, and to ensure non-interference with other trades during construction. It shall take into account the ease of maintainability of the electrical equipment installed. Maintenance operations include inspection, adjustments, cleaning, trouble shooting, servicing, repairs and replacement of electrical equipment. The equipment selected should be subject to minimal system component failure.

13.17.1 Space

Sufficient working space and adequate access shall be provided for the maintenance and replacement of electrical equipment. Adequate space around electrical equipment shall be provided and maintained to allow for heat dissipation and cooling. This requirement shall include adequate space for movement of equipment during initial installation, and during subsequent unscheduled maintenance involving removal and replacement of failed equipment.

13.17.2 Accessibility

All electrical system switching and over current protection devices shall be accessible to authorized persons only. Access to cables or conduits installed in return air plenums under station platforms shall be provided through manhole covers at appropriate locations.

Adequate means, such as lifting eyes and/or I beams with a running hoist, shall be provided for raising, lowering, shifting, removal or replacement of heavy electrical equipment. Pulling eyes shall be provided for the pulling of cables at the following locations:

- AC Switchboard Rooms
- Traction Power Substations
- Tie Breaker Stations
- Chiller Plants
- Train Control Rooms
- Communications Rooms

- Electrical Rooms
- Cable shafts
- Manholes
- Other locations where considered necessary.

13.17.3 Equipment Protection Against Water and Moisture:

Each substation building and electrical room shall be designed to preclude any entry of water. Seals shall be provided on raceway and cable penetrating a building wall, floor or ceiling at a point. No water or sewage piping shall be installed inside substation and electrical equipment rooms. No pipe or mechanical duct that could cause moisture or condensation to fall on the electrical equipment shall be located above any major electrical equipment.

13.17.4 Embedded Conduits, Conduit Sleeves and Channel Inserts:

Embedded conduits can be installed in the space available between rebar. Where a slab has to carry a large number of conduits, steps shall be taken to ensure that it will be feasible to install all the conduits without compromising the structural integrity of the concrete structure. Adequate cross sections shall be shown on the drawings to indicate how the raceways and other embedded items will be installed and cross each other where applicable. Where embedded FRE conduit emerges from a concrete slab or a wall, a FRE to galvanized rigid steel conduit adapter shall be provided, except traction power conduit.

Where conduits are not provided as raceways, channel inserts shall be installed for supporting multiple conductor cables located under platforms, and in manholes. Spare conduit and sleeves shall be provided in concrete walls, floors or ceiling slabs of the AC Switchboard Rooms, Electrical Rooms, Traction Power Substation, Tie Breaker Stations, Mechanical Rooms, ductbank and other areas as required for possible future requirements.

13.17.5 Electrical Plans, Details and Schedules:

Plans and details showing physical arrangement and elevation with dimensions shall be provided on the drawings for all major electrical and mechanical equipment, raceways, junction boxes, fixtures and other items so that the design and construction can be coordinated with mechanical, structural and other disciplines.

Schedules of all major electrical equipment including switchgear, switchboards, panelboards, transformers, disconnect switches, conduits, and cables shall be provided on the drawings. These schedules shall be complete and consistent with plans on associated electrical and mechanical drawings.

13.17.6 Lighting System

The use of incandescent lamps, whenever practical, will be avoided. Where incandescent lamps are used, they shall be of the long life type. When multiphase branch circuits are used for feeding luminaries, the luminaries shall be alternately connected on different phase and the protection devices shall be of single pole type so that a uniform illumination may be maintained in a large area when any one or two phases are de-energized.

The locations of luminaries selected shall permit easy cleaning, replacement and maintenance. Adequate illumination shall be provided on all working areas around the electrical equipment.

13.17.7 Operation and Maintenance Manual:

Operation and Maintenance Manual shall be provided for major electrical equipment. It shall include manufacturer's operation and maintenance instructions, wiring diagram, control and power elementary diagrams, list of spare parts and recommended stock quantities for one year routine maintenance and repair. A copy of approved shop drawing of equipment and other items where considered necessary shall be included.

13.18 ELECTRICAL REQUIREMENTS FOR BUS FACILITIES

13.18.1 Power Systems

13.18.1.1 Main Incoming Service:

The main incoming electrical service must be coordinated with the local Power Company having responsibility for supply. The initial discussions with the Power Company should investigate the availability of service from the medium power grid (13.8kV or 34.5 kV) which should provide a better billing rate for the facility. Electrical service guidelines and requirements must be determined prior to and followed during design of the utility interface and incoming service equipment. The preferred location for this equipment is in a separate structure situated on the site away from the main building, but within a limited distance to keep the secondary conduit and cable run to a minimum. The incoming service equipment will typically include a primary fused disconnecting switch, an incoming utility section with metering per Power Company requirements and a pad mounted transformer with primary to meet Power Company supply voltage and 277/480 volts, 3 phase, 4 wire secondary. Transformer size will be determined from load calculations performed after mechanical equipment, lighting and utility loads have been established along with a 25% factor for any future expansion considerations.

13.18.1.2 Facility Power Distribution:

The main distribution switchboard shall be 277/480 volt with a current capacity based on facility load calculations and future expansion considerations. The switchboard shall be metal enclosed dead front safety type free standing with a sufficient number of circuit breakers to meet facility design needs and adequate spare capacity to meet future growth. The switchboard fabrication and features shall include hinged front panels, hard drawn copper bus material with silver-plated contact surfaces and uniform capacity over entire length and front panel meters to display phase to phase and phase to neutral voltage and current. The circuit breakers in the switchboard shall be current limiting molded case NEMA AB 1 with 75,000 amp interrupting capacity or as necessary to meet available fault current. The switchboard shall be located in a dedicated electrical equipment room along with the main electrical distribution panelboards and transformers. This room shall be appropriately sized to accommodate equipment clearance requirements as defined by National Electric Code (NEC) latest revision, IBC, local and State codes, and as described below. Panelboard enclosures shall be NEMA PB 1 Type 1. The motor control centers shall be located in the mechanical equipment room. It is preferred that there be two separate motor control centers, one for equipment on normal power and another for equipment on emergency power. Appropriate space shall be provided in the mechanical equipment room to accommodate equipment clearance requirements as defined by National Electric Code (NEC) latest revision and as described below. Motor control center and disconnect switch enclosures shall be NEMA Type 1 or as otherwise specified to meet environmental conditions. The bus material in this equipment shall be hard drawn copper of 98% conductivity. Main distribution panels and any panelboards rated greater than 200 amps shall be located with 2'-0" clear space on both sides and any other panelboards shall have 18" clear space on both sides for ease of maintenance. Any panels mounted adjacent to each other shall have 2'-0" clear space between them and shall have 3'-0" clear space in front of panels for access, or as otherwise defined by the National Electric Code (NEC) latest revision. Any panelboards and control panels in maintenance or service areas shall be centrally located in the area covered and shall be flush mounted and/or protected by bollards or guard rails. For all panelboards, installation of conduits shall be top or bottom entry at rear of entering surface such that all available rear surface space is used prior to installing conduits on surface toward front of panelboard. Panelboards and their installation shall comply with NFPA 30A.

Space shall be provided for conduit runs at ceiling including space consideration for future conduits. All conduit and cable shall be installed as per the latest revision of the National Electric Code (NEC) and NFPA 30A with routing done overhead and drops from ceiling space and not run within slabs on grade. Conduit for power distribution shall be minimum ¾ inch size.

Exterior underground conduit shall be rigid galvanized steel encased in concrete under paved areas and rigid nonmetallic concrete encased in other areas. Interior conduit shall be rigid galvanized steel. All power wiring rated 600 volts and below shall be type THHN/THWN in raceway with a minimum No.12 AWG size. All general purpose duplex receptacles are to be rated for 20 amps, 125 volts.

13.18.1.3 Stand-By (Emergency) Power System:

The stand-by generator equipment shall be located in a structure adjacent to the incoming service equipment structure. Load calculations of the equipment and devices to be connected plus any future considerations shall determine emergency generator size. The stand-by generator shall enable the facility to maintain the most normal operations during an extended power failure. The standby generator shall meet the requirements of NFPA 110. The preferred fuel source for the generator is diesel fuel. Fuel storage for the generator shall be by an equipment mounted day tank along with a remotely mounted underground storage tank with 2000 gallon capacity. The requirements for the underground tank are described in Section 16 and Section 18.4.2.1-Underground Storage Tanks. The generator shall start automatically on occurrence of power failure. Multiple Automatic transfer switches shall be provided to transfer power load from normal power to the emergency generator. Emergency and equipment loads shall be separated on different transfer switches as required by NEC. Lighting and equipment on the stand-by system shall be marked with a red dot. The stand-by system shall provide services to the following as a minimum:

- Emergency lighting
- Exit lighting
- Fire alarm control panel
- Computer system
- Ventilation equipment in selected areas
- Security system
- Fueling system equipment and monitoring (NFPA 30A) (NFPA 497)
- The communication system

- Selected hydraulic lifts
- Selected air compressors
- Elevators
- Boiler and associated pumps
- CNG related equipment

13.18.1.4 Specialty Power Systems:

Utility power for tools, task lighting and portable equipment shall be provided at the bus maintenance and repair bays via reels suspended from overhead. Electrical cables for portable lifts shall be routed down from ceiling. Utility power receptacles with GFI protection and weatherproof enclosures shall be provided in wash areas or any other potentially wet areas and outside areas at various light poles throughout the yard area to allow for use of power tools for maintenance purposes. Explosion proof receptacles and devices shall be required in battery rooms, hazard material storage areas, maintenance pits, fuel distribution areas and any class 1 div. 1& 2 areas (NEC 500 and 511).

13.18.1.5 Grounding Systems:

The grounding system for the main pad mounted transformer shall meet the requirements of the power company and National Electric Code (NEC) latest revision, IBC, State and local codes. As a minimum, there shall be a ground loop around the transformer consisting of #4/0 awg bare stranded copper cable with ground rods (10'-0" long, ¾" diameter, copper clad steel) installed at ten foot spacing and driven 18" below grade with all connections being exothermic welded type. All metal parts of the transformer installation shall be connected to the loop using #2/0 awg bare stranded copper cable. The emergency generator shall have as a minimum a ground loop consisting of# 4/0 awg bare stranded copper cable with ground rods (10'-0"long, ¾" diameter, copper clad steel) installed at the corners of the unit and shall be connected to the transformer grounding system at least two points. All connections shall be exothermic welded type. The steel frame of the building shall be an effectively grounded system by bonding the steel frame to the foundation rebar using a minimum # 4 awg bare stranded copper cable with exothermic welded connections.

13.18.2 Lighting Systems

13.18.2.1 Exterior Lighting:

Lighting design levels for parking areas and driveways shall be determined using IES roadway illumination methods. Luminaires maintenance factor of 65% shall be assumed and luminaire selection, location and directional aim criteria shall be such as to minimize objectionable glare and interference. Luminary selection shall include features such as High-Pressure Sodium lamps, photocells, captive hardware and safety chains on components to provide for ease of maintenance.

13.18.2.2 Interior Lighting:

The lighting design for interior spaces will be based on room type and space usage. Table 13-7 shall serve as a guide for minimum illumination levels acceptable in the various operational areas within the facility. In addition to illumination levels design consideration must be given to such criteria as glare elimination, color rendition, transition eye comfort and special task lighting. Luminary selection shall take into consideration the latest in energy efficient technology.

TABLE 13.7 Illumination Levels in Bus Facilities

AREA or ROOM	FOOTCANDLES	LAMPS
Outside Parking Areas	10	Metal Halide
Access Driveways	10	Metal Halide
Outdoor Building Entrances	10	Metal Halide
Bus Service and Maintenance Bays	100 / 50*	Metal Halide
Lift and Pit areas	100 / 50*	Metal Halide
Tire Repair Bays	100 / 50*	Metal Halide
Offices and conference rooms	50	Fluorescent / LED
*The higher value is for task lighting and lower value is general level.		

13.19 ELECTRICAL REQUIREMENTS FOR ANCILLARY FACILITIES

13.19.1 Power Systems

This section identifies the requirements for installation and operation of all electrical equipment, lighting circuits, and electrical systems of Office Buildings in the Washington Metropolitan Area Rapid Rail Transit System. Specific criteria for lighting systems required for proper illumination of office buildings shall be per established national standards.

13.19.2 Scope

The following criteria cover all AC power electrical systems required to serve the lighting, electrical and mechanical equipment throughout the building. In general this includes:

- Main incoming service equipment
- Distribution equipment
- Emergency power systems
- Operational control systems
- Communications systems, including fire alarms, security alarms, CCTV monitors
- Elevators
- Lighting
- Mechanical equipment center

13.19.3 Main Incoming Service:

The main incoming electrical service must be coordinated with the local Power Company having responsibility for supply service. The preferred service voltage is 13kV or 34.5kV and shall be discussed with the Power Company as the first option. Electrical service guidelines and requirements shall be determined prior to and followed during design of the utility interface and incoming service equipment. The incoming service equipment will typically include a primary circuit breaker or fused disconnecting switch, an incoming utility section with metering per Power Company requirements with pad mounted transformer with primary to meet Power Company supply voltage and 277/480V, 3 phase, 4 wire secondary. Transformer size will be determined from load calculations performed after mechanical equipment; lighting and utility loads have been established along with a 25% factor for any future expansion considerations.

13.19.3.1 Facility Power Distribution:

The main distribution switchboard shall be 277/480V with a current capacity based on facility load calculations and future expansion considerations. The switchboard shall be metal enclosed dead front safety type free standing with a sufficient number of circuit breakers to meet facility design needs and adequate spare capacity to meet future growth. The switchboard fabrication and features shall include hinged front panels, hard drawn copper bus material with silver-plated contact surfaces and uniform capacity over entire length and front panel meters to display phase to phase and phase to neutral voltage and current. The circuit breakers in the switchboard shall be current limiting molded case NEMA AB 1 with 75,000 amp interrupting capacity or as necessary to meet available fault current. The switchboard shall be located in a dedicated electrical equipment room along with the main electrical distribution panelboards and transformers. This room shall be appropriately sized to accommodate equipment clearance requirements as defined by National Electric Code (NEC) latest revision, IBC, local and State codes, and as described below.

Panelboard enclosures shall be installed per NEMA PB-1.1. The motor control centers shall be located in the mechanical equipment room. It is preferred that there be two separate motor control centers, one for equipment on normal power and another for equipment on emergency power. Appropriate space shall be provided in the mechanical equipment room to accommodate equipment clearance requirements as defined by National Electric Code (NEC) latest revision and as described below. Motor control center and disconnect switch enclosures shall be NEMA Type 1 or as otherwise specified to meet environmental conditions. The bus material in this equipment shall be hard drawn copper of 98% conductivity. Main distribution panels and any panelboards rated greater than 200 amps shall be located with 2'-0" clear space on both sides and any other panelboards shall have 18" clear space on both sides for ease of maintenance. Any panels mounted adjacent to each other shall have 2'-0" clear space between them and shall have 3'-0" clear space in front of panels for access, or as otherwise defined by the National Electric Code (NEC) latest revision. Any panelboards and control panels in maintenance or service areas shall be centrally located in the area covered and shall be flush mounted and/or protected by bollards or guard rails. For all panelboards, installation of conduits shall be top or bottom entry at rear of entering surface such that all available rear surface space is used prior to installing conduits on surface toward front of panelboard. Panelboards and their installation shall comply with NFPA 30A.

Space shall be provided for conduit runs at ceiling including space consideration for future conduits. All conduit and cable shall be installed as per the latest revision of the National Electric Code (NEC) and NFPA 30A with routing done overhead and drops from ceiling space and not run within slabs on grade. Conduit for power distribution shall be minimum ¾ inch size.

Exterior underground conduit shall be rigid galvanized steel encased in concrete under paved areas and rigid nonmetallic concrete encased in other areas. Interior conduit shall be rigid galvanized steel. All power wiring rated 600 volts and below shall be type THHN/THWN in raceway with a minimum No.12 AWG size. All general purpose duplex receptacles are to be rated for 20A, 125V.

13.19.3.2 Stand-By (Emergency) Power System:

The stand-by generator equipment shall be located in a structure adjacent to the incoming service equipment structure. Load calculations of the equipment and devices to be connected plus any future considerations shall determine emergency generator size. The stand-by generator shall enable the facility to maintain the most normal operations during an extended power failure. The standby generator shall meet the requirements of NFPA 110. The preferred fuel source for the generator is diesel fuel. Fuel storage for the generator shall be by an equipment mounted day tank along with a remotely mounted underground storage tank with 2000 gallon capacity. The requirements for the underground tank are described in Section 16 and Section 18. The generator shall start automatically on occurrence of power failure. Multiple Automatic transfer switches shall be provided to transfer power load from normal power to the emergency generator. Emergency and equipment loads shall be separated on different transfer switches as required by NEC. Lighting and equipment on the stand-by system shall be marked with a red dot. The stand-by system shall provide services to the following as a minimum:

- Emergency lighting
- Exit lighting
- Fire alarm control panel
- Computer system
- Ventilation equipment in selected areas
- Security system
- The communication system
- Elevators
- Boiler and associated pumps

13.19.3.3 Critical Operations Power Systems (COPS):

These systems are as described by NEC, Local, State, and Federal Government to be vital infrastructure facilities that require continuous operation for reasons of public safety, emergency management, national security, or business continuity. Electrical service to these systems in the Washington Metropolitan Area Rapid Rail Transit System shall have the necessary redundancy and backup power that can provide a minimum of 72 hours at full load to the designated critical operations areas (DCOA). Storage batteries used as a source of power for critical loads shall have the capacity to maintain the total load for a minimum 90 minutes.

13.19.3.4 Grounding Systems:

The grounding system for the main pad mounted transformer shall meet the requirements of the Power Company and National Electric Code (NEC) latest revision, IBC, State and local codes. As a minimum, there shall be a ground loop around the transformer consisting of #4/0 awg bare stranded copper cable with ground rods (10'-0" long, ¾" diameter, copper clad steel) installed at ten foot spacing and driven 18" below grade with all connections being exothermic welded type. All metal parts of the transformer installation shall be connected to the loop using #2/0 awg bare stranded copper cable. The emergency generator shall have as a minimum a ground loop consisting of # 4/0 awg bare stranded copper cable with ground rods (10'-0" long, ¾" diameter, copper clad steel) installed at the corners of the unit and shall be connected to the transformer grounding system at least two points. All connections shall be exothermic welded type. The steel frame of the building shall be an effectively grounded system by bonding the steel frame to the foundation rebars using a minimum # 4 awg bare stranded copper cable with exothermic welded connections.

13.19.4 Lighting Systems:

13.19.4.1 Exterior Lighting:

Lighting design levels for parking areas and driveways shall be determined using IES roadway illumination methods. Luminaire maintenance factor of 65% shall be assumed and luminaire selection, location and directional aim criteria shall be such as to minimize objectionable glare and interference. Luminary selection shall include features such as Halide lamps, photocells, captive hardware and safety chains on components to provide for ease of maintenance.

13.19.4.2 Interior Lighting:

The lighting design for interior spaces will be based on room type and space usage. Table 13.7 shall serve as a guide for minimum illumination levels acceptable in the various operational areas within the facility. In addition to illumination levels design consideration must be given to such criteria as glare elimination, color rendition, transition eye comfort and special task lighting. Luminary selection shall take into consideration the latest in energy efficient technology.

SECTION 14 - MECHANICAL

14.1 GENERAL

These criteria cover the design of mechanical facilities for the subway, including:

Tunnel Ventilation Systems

Heating

Air Conditioning and Filtration

Drainage

Fire Protection

Gratings and Miscellaneous Metals

Emergency Access Shafts

Elevators

Escalators

Maintainability and Constructability

14.2 CODES AND REGULATIONS

Unless otherwise required herein, mechanical designs and installations shall be governed by all applicable local codes in addition to the codes, guidelines and standards listed below. In cases where national codes, local codes, and WMATA standards conflict, the most stringent code or standard shall take precedence.

14.2.1 Heating, Ventilating and Air Conditioning

All heating, ventilating and air conditioning system designs shall be based on the version of International Mechanical Code, as amended by the local jurisdiction, in effect at the time of design.

Air conditioning and refrigerating equipment shall bear the ARI stamp.

14.2.2 Sheet Metal Ductwork

All sheet metal ductwork shall be constructed in accordance with Sheet Metal and Air Conditioning Contractors National Association Inc. (SMACNA) standards.

14.2.3 Fans

All fans shall be rated in accordance with the "Standard Test Code for Air Moving Devices" and the "Test Code for Sound Rating Air moving Devices" of the Air Movement and Control Association, Inc. Fans utilized for subway smoke management purposes shall comply with the elevated temperature requirements defined in NFPA 130.

14.2.4 Plumbing

All plumbing system designs shall be based on the International Plumbing Code, as amended by the local jurisdiction, in effect at the time of design.

All plumbing installations and fixtures shall comply with the applicable requirements of the Americans with Disabilities Act Guidelines (ADAG).

14.2.5 Acoustical Materials

Acoustical materials shall be rated in accordance with the standards of the Acoustical Society of America, UL, ASTM and NFPA.

14.2.6 Noise Criteria

Noise criteria shall be as described herein and in the current handbook series published by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE).

14.2.7 Piping

Provide all pipe calculations including formulas used and assumptions made in the design.

14.2.8 Fire Protection

Fire protection system designs shall be based on National Fire Protection Association (NFPA)Standard No.130, Fixed Guideway Transit Systems, including all additional NFPA standards referenced in NFPA 130, specifically NFPA 72. All components shall be FM Global approved.

14.3 TUNNEL VENTILATION SYSTEM

14.3.1 Tunnel Ventilation System Capacity and Arrangement

Tunnel ventilation system component shall be provided and sized for emergency ventilation in accordance with current NFPA 130 requirements. The ventilation system shall be capable of preventing back layering in all tunnel segments served by that system. As verification, designer shall demonstrate that when the fire is present in any tunnel segment, the predicted air velocity in that segment exceeds the critical air velocity. The critical air velocity represents the minimum air velocity required to prevent back layering of smoke and shall be calculated on the basis of maximum grade in any tunnel segment and site specific tunnel geometric data and specific density and temperature of air in the tunnel.

14.3.1.1 The engineering analysis of the ventilation system as outlined in NFPA 130 shall include a validated subway analytical simulation program augmented as appropriate bya quantitative analysis of airflow dynamics produced in the fire scenario, such as would result from the application of a validated computational fluid dynamic (CFD). Critical air velocity shall be calculated in accordance with the Subway Environment Simulation (SES) Computer Program by using the current version of the User's Manual.

14.3.1.2 The fire magnitude shall be 69.7 million BTUH per hour. This magnitude was used previously for modeling, consult WMATA for direction.

In cases where jet fans are utilized, the system shall be sized to prevent back layering assuming failure of jet fan /fans in one niche.

Primary ventilation will be provided by the following means:

14.3.1.3 Gravity ventilation in conjunction with train piston-action induced airflows.

14.3.1.4 Mechanical ventilation provided by fans.

To facilitate ventilation by gravity and train piston action air flows, the tunnel ventilation system includes vent shafts located at each end of underground stations and if required in mid-tunnel locations. These vent shafts perform the following functions:

14.3.1.5 Provide a source of outdoor air for tunnel ventilation.

14.3.1.6 Provide a means of relieving piston action airflows.

Mechanical ventilation shall be accomplished by one of the following means:

14.3.1.7 Reversible fans housed in fan shafts.

14.3.1.8 Reversible jet fans housed in recesses in the tunnel walls.

In all cases, make-up air will enter the subway through portals and station entrances. During normal transit operations, vent shafts remain open and provide an additional source of make-up air. During emergency operation, vent shaft dampers close, thereby increasing the air flow through station entrances.

14.3.2 Purpose of Tunnel Ventilation System

The tunnel ventilation system shall provide the following capabilities:

14.3.2.1 Smoke Control - Provide the required mechanical ventilation in the event of a fire within a tunnel section.

14.3.2.2 Heat or Diesel Smoke Removal - Augment the ventilation provided by train piston action during normal operations and, when necessary, provide the primary means of limiting tunnel temperatures when train piston action induced air flows are no longer present. Allow for maintenance operations using diesel equipment.

14.3.2.3 Blast Relief - Reduce excessive air movement within stations due to piston action of trains by provision of vent shafts at each end of each station.

14.3.2.4 Access - Accommodate construction or maintenance access stairs and/or ladders within vent and fan shafts.

14.3.3 Smoke Control

The primary function of the tunnel ventilation system is provision of emergency ventilation in the event of a fire within a tunnel section per NFPA 130 requirements. Mechanical ventilation is required to control the flow of smoke in a manner which provides evacuating passengers with a smoke free exit path without back layering of smoke.

14.3.4 Heat Removal

The heat generated within the subway is attributable to five general sources:

14.3.4.1 Traction equipment - equipment which provides power to the third rail.

14.3.4.2 Train auxiliaries - equipment on the train such as brakes, motors, etc.

14.3.4.3 Wayside and station lighting and equipment

14.3.4.4 Subway passengers

14.3.4.5 Solar heat carried by train

Train piston-action, natural convection and conduction through the tunnel walls will, at most times, provide sufficient tunnel heat removal. However, when tunnel temperature conditions exceed the established limits, mechanical ventilation shall be utilized.

14.3.5 Arrangement of Fan Shaft System

In the arrangement of the tunnel ventilation system utilizing fan shafts, the following criteria shall govern design:

14 .3.5.1 The tunnel ventilation system shall utilize fan and vent shafts. Fan shafts shall house reversible fans of sufficient total capacity to account for both normal and emergency conditions. In addition by-pass dampers shall be provided at each fan shaft for the purpose of relieving piston-action induced airflow. Vent shafts shall operate in conjunction with fan shafts and shall function as either air intakes or reliefs depending on fan shaft fan operating mode.

14 .3.5.2 Certain fan and vent shafts shall be used for emergency access and egress from the subway. See "Emergency Access Shafts" Section 14.10.

14 .3.5.3 Fan and vent shaft openings at street level shall be located to avoid pedestrian and vehicle crossings and to minimize the danger of flooding the subway. Surface pavement around opening shall be sloped away from the opening. Where located in sidewalks, openings shall occupy not more than 40% of the sidewalk width and be located as far from the street curb as possible. Where possible, openings shall be located in median strips or off-street locations. Where feasible, vent and fan shaft structures shall be raised 12 inches above the adjacent level to prevent runoff water from flooding the subway and suitably screened with planting or other decorative treatment. Under no circumstances shall vent or fan shaft openings be located in roadways.

14 .3.6 Jet Fans

In the arrangement of the tunnel ventilation system utilizing jet fans, the following criteria shall govern design:

14 .3.6.1 The tunnel ventilation system in selected sections shall utilize jet fans and vent shafts with the approval of the authority. Jet fans shall be wall mounted within tunnel recesses and shall be of sufficient total capacity to account for emergency conditions.

14 .3.6.2 Jet fans shall be reversible and have the capability of moving smoke away from passengers during an emergency. Local and remote controls shall be provided to stop and reverse jet fan operating modes.

14 .3.6.3 The tunnel fans in the original 106 mile system are 50,000 cfm., New installations shall conform to the current version of NFPA 130 at the time of design. The fans shall be reversible with factory installed sound attenuations.

14 .3.6.4 Jet fans shall be secured to the tunnel walls with stainless steel hardware.
Submit calculations verifying support and fastener adequacy.

14 .3.6.5 Electrical Characteristics 460 volts, 3 phase, 60 hertz, essential power.

14 .3.6.6 Motor Control Magnetic, across-the-line start, circuit breaker disconnect, magnetically operated overload protectors. Thermal type overload will not be permitted, fans are to run until failure in an emergency. Local manual on-off automatic and forward-reverse selector switches shall be provided.

14 .3.6.7 Remote control and supervisory control from Operations Control Center
(OCC).

14 .3.6.8 Jet fans and all associated equipment shall be rated for operation at elevated temperatures as defined in latest NFPA 130.

14 .3.7 Calculation of Friction Losses

The following formula shall be applied in the calculation of friction losses for air flow in structures:

$$H_f = (F*L*v^2)/(2*D*g)$$

Where:

F = Darcy Weisbach friction factor (determined from Moody diagram).

L = Length of tunnel .

g = gravitational acceleration

v = Velocity of air

D = Hydraulic diameter = 4A/P

A = Area

P = Perimeter

The friction factor "F" shall be derived from the Moody diagram and shall be based on the relative roughness (roughness length/hydraulic diameter) of the material involved and the Reynold's number of the expected air flow. Specific Roughness ε shall be as follows:

Material Specific Roughness (ft)

Clean steel	0.00015
Smooth Concrete	0.001
Average Concrete	0.003
Rough Concrete	0.01

14 .3.8 Vent Shafts

Each vent shaft shall be designed to suit local conditions. Vent shafts shall be sized to handle ventilation volume generated by train piston action and make-up air for station exhaust systems at a velocity of not more than 350 feet per minute (f.p.m).

Where vent shaft structures are utilized for station exhaust systems (under platform and dome), separate ducts are to be provided for these systems within the vent shaft. These ducts shall have concrete or masonry walls and shall be sized in accordance with fan shaft criteria. The size of the vent shaft structure shall be increased accordingly. Intake, exhaust and reversible system openings shall be separated at grade by a distance of not less than 25 feet.

Vent shafts shall be measured as the gross face area of the grille or grating within the supporting shaft dimensions. Sudden expansions and contractions shall be avoided in the design of vent shafts, and a uniform cross section shall be maintained.

Vent shaft equipment shall include:

14 .3.8.1 Electronically or pneumatically operated dampers controlled by thermostats located near tunnel fan shafts and the supervisory control system to control dampers from Operation Command Center. Air compressor to be located as close to dampers as possible, long pneumatic piping runs to be avoided. Compressed air to be properly treated and dried (by descant dryer or other means) in order to remove moisture or contaminants from the air.

14 .3.8.2 Maintenance ladders are provided in all shafts for maintenance except where shaft bottom is within 100 feet of end of station and readily accessible.

14 .3.8.3 Drainage (See Drainage, Section 14.8).

14 .3.8.4 Fire standpipe system(s) (See Fire Protection, Section 14.13).

14 .3.8.5 Access hatchway (See Emergency Access/Egress Shafts, Section 14.10).

14 .3.8.6 Surface gratings (See Gratings, Section 14.9).

14 .3.8.7 The following electrical slots, sleeves or conduits shall be provided in each vent shaft:

14 .3.8.7.1 A.C. lighting

14 .3.8.7.2 Emergency lighting (Emergency egress shafts only)

14 .3.8.7.3 Convenience outlet

14 .3.8.7.4 Supervisory control & surveillance

14 .3.9 Fan Shafts

Each fan shaft shall be designed to suit local conditions.

Fan shafts shall be equipped with two or more fans. Each fan shall exhaust air from or direct air into both tunnels where tracks are in separate tunnels.

Fan shaft size shall be selected to meet the ventilation requirements calculated as per Section 14.3.1. Air discharge velocities from fan shafts shall fall into the following categories:

14 .3.9.1 Through sidewalks or into areas where people will be affected by the discharge of air, maximum discharge velocity - 500 fpm.

14 .3.9.2 Through medians or off-street properties where people will not be affected by the discharge of air, maximum discharge velocity - 1,000 fpm.

The maximum discharge velocity shall be based on the gross area of the grating or grille. Shafts between fan discharge and grating chamber may be designed for a maximum velocity of 1,000 fpm. Sudden expansions and contractions in the shaft cross section shall be avoided in the design of fan shafts. The minimum number of turns or elbows shall be used. Streamlining of obstructions and fan shaft passages shall be undertaken where economically warranted.

Electrically or pneumatically-operated by-pass dampers shall be provided in tunnel fan shafts. By-pass dampers shall be sized in accordance with free area established for the fan shaft but shall be no greater than 200 square feet, free area. Structural design of dampers shall meet requirements of structural design criteria.

14 .3.10 Fan shaft equipment shall include:

14 .3.10.1 Screen, inlet bell, fan, outlet transition and dampers

14 .3.10.2 By-pass dampers

14 .3.10.3 Motor control equipment controlled by the supervisory control system, thermostats, and local manual on-off controls

14 .3.10.4 Access stairs-or maintenance ladders.

14 .3.10.5 Drainage

14 .3.10.6 Acoustic treatment when required to meet the noise requirements outlined in the Environmental Section of the Design Criteria.

14 .3.10.7 Sound attenuations when required to meet the noise requirements outlined in the Environmental Section of the Design Criteria.

14 .3.10.8 Dry fire standpipe system

14 .3.10.9 Access hatchway

14 .3.10.10 Surface grating

14 .3.10.11 Steel stairs and ladders shall be provided as required.

14 .3.11 The following electrical sleeves or conduits shall be provided at each fan shaft:

14 .3.11.1 A.C. lighting

14 .3.11.2 Emergency lighting

14 .3.11.3 Convenience outlet

14 .3.11.4 Power for fans

14 .3.11.5 Supervisory control and surveillance

14 .3.11.6 Telephone or other means of communication with Control Center

14 .3.12 Tunnel Ventilation Fans (Fan Shaft System)

Primary ventilation fans shall be reversible and in accordance with the following:

14 .3.12.1 Characteristics in the exhaust direction

Volume Designed to comply with NFPA130

	control to close when tunnel temperature drops below reaches 50F
Type	Axial

14 .3.12.2 Equipment Dampers

14 .3.12.3 Motor Reversible Type

14 .3.12.4 Electrical Characteristics 460 volts, 3 phase, 60 hertz, essential power

14 .3.12.5 Motor Control Magnetic, across-the-line start, circuit breaker disconnect, magnetically operated overload protectors (thermal type will not be permitted), local manual on-off automatic and forward-reverse selector switches.

Remote control and supervisory control from Operations Control Center (OCC).

14 .3.12.6 Dampers

Dampers operate by thermostatic control, control to close when tunnel temperature drops below 50ºF, at the start of a fan, or a remote signal from Control Center. The entire damper installation shall be designed to withstand, with the blades closed, repetitive loading of 70 lb./sq. foot due to pressure transients applied to either side of the damper.

14 .3.12.7 Fans and all associated equipment shall be rated for operation at elevated temperatures as defined in NFPA 130.

14 .3.13 NOT USED

14 .3.14 Standby Equipment

Stand by ventilating equipment shall not be provided unless special circumstances indicate that it is necessary. The Authority's concurrence is required.

14 .3.15 Equipment Handling

Provisions shall be made in the form of lifting hooks and removable panels for the installation and removal of ventilating equipment.

Structural openings shall be sized so that each complete factory-built item of equipment can be installed without disassembly or special construction.

Access to vent shaft damper banks exceeding 10 feet in height shall be provided in the form of catwalks, platforms and ladders. The required arrangement shall optimize access to damper linkage, motor operators and all other serviceable damper components.

All dampers shall be located in a manner which prevents the possibility of a damper section falling on the trackway in the event of a damper failure.

14 .3.16 Control Schematics

Final designs shall include overall control air piping and/or electrical schematics. Schematics shall identify piping runs, control air origin, electrical wiring, wiring identification, major equipment items served and any other information necessary to fully describe the proposed control system, including cross reference to applicable standard drawings. This applies to Under Platform Exhaust (UPE) and Dome Fan controls as well.

Rehabilitation of legacy tunnel fan controls must include parallel capabilities for SCADA over Ethernet and the legacy DTS commands and alarms.

14 .4 SECONDARY VENTILATION SYSTEMS

14 .4.1 General

Separate secondary mechanical ventilation systems shall provide ventilation for Rapid Rail Transit System station rooms and Rail power support facilities as presented below. The ventilation and air conditioning systems shall be designed with a centralized mechanical system servicing similar areas/rooms. This is done in order to reduce the amount of mechanical equipment and required equipment maintenance.

14 .4.2 Characteristics

The characteristics of the individual ventilation systems for all areas and rooms in the Rapid Rail Transit System are described below. The following are minimum requirements:

14 .4.2.1 AC Switchboard Rooms

Rooms shall be ventilated with two fans of equal capacity operating in parallel, using a Programmable Logic Controller (PLC) in a lead lag operation with alternate duty. The first stage fan will activate when room temperature reaches 85°F and turns off when temperature reaches 80°F. The second stage fan will activate when the room temperature reaches 90°F and turns off when temperature reaches 80°F. The controller shall be capable of remote monitoring over the Ethernet using Modbus communication protocols. The PLC shall alarm a high temperature advisory when the room temp reaches 90°F and a high temperature alarm when the room temperature reaches 100°F.

Lead fan and stand-by fan shall alternate automatically after each operating cycle. Provide a H-0-A switch for each fan. During operation of any one fan, the intake damper with other fan shall be closed. Use of gravity type dampers is preferred - The fans shall be located on the supply side of the system. . Relief air shall be discharged to a point outside of the subway unless otherwise approved by the Authority.

Supply air shall be from a point outside of subway filtered through a pleated filter sized for one fan operation and discharged into the AC Switchboard Room to maintain a positive pressure of 0.1 inch of water gauge within the room with respect to adjacent space. Ventilation requirements (capacity) for the fans shall be based on the sensible heat load generated in the room:

$Q=(X)/(\rho * c_p * \Delta T)$

Where:

Q = Volume flow rate of air

I = Heat generated by equipment (switch gear equipment as well as lights, etc.) contained in the room

ρ = density of air

c_p = specific heat of air

ΔT = (Temperature Inside - Temperature Outside)

The maximum inside temperature is 104°F (max temp rating of electrical equipment) and the maximum outside temperature is to be based on the 0.4 % Cooling DB temperature listed for Washington DC Reagan AP in the ASHRAE Fundamentals Climatic Design Information Section.

If the switchgear and transformers are located in separate rooms, the air shall be distributed in proportion to the load in each room. Transfer of air from one room to the other is not allowed. Provide tight fitting, weather stripped doors with no undercuts on underground AC Switchboard Rooms.
Switchgear rooms located above grade will take into account solar gain as well as building envelope construction (i.e. wall type, ceiling type, insulation, etc) into account when calculating heat load generation and ventilation capacity.

Special consideration shall be given for control of humidity in the room.

14 .4.2.2 DC Breaker Rooms (Tie Breaker Station)

Below Grade

Supply: Ventilation shall be designed to maintain eight air changes per hour. Provide a H-0-A switch. Air shall be drawn from and discharged to a point outside of the subway unless otherwise approved by the Authority, filtered, and discharged into the breaker room so as to maintain a positive pressure not exceeding 0.1"WG within the room. Provide tight fitting, weather stripped doors with no undercuts. Fan will be operated by thermostat to maintain room temperature of 90°F.

Surface

Supply: Ventilation shall be designed to maintain eight air changes per hour. Maintain positive pressure not exceeding 0.1" WG within the room. Filtering of air not required unless special conditions exist.

14 .4.2.3 Battery Rooms

To the extent practicable ventilation design shall take advantage of passive ventilation to maintain the hydrogen concentration level below 1% and comply with applicable code requirements. Where passive ventilation is not applicable, mechanical ventilation shall be used to maintain the concentration level below 1%. Redundant ventilation shall be provided. Rooms to be mechanically ventilated at temperatures above 77°F. Provide tight fitting, weatherstripped doors with no undercuts on underground Battery Rooms.

Suspended ceilings are not allowed. Battery Rooms shall be under negative pressure not to exceed 0.1"WG. Battery rooms dependent on mechanical ventilation require remote monitoring by OCC for failure of one of the redundant fans. Local building codes may require monitoring of hydrogen levels. Hydrogen monitoring is not preferred because it requires regular sensor calibration and replacement.

14 .4.2.4 Train Control, Communications, Dispatch and Trainmen's Rooms

Provide air conditioning with 0.3 CFM of filtered, outside air per square foot of floor area to maintain 72°F during the cooling season.

Heat loads from internal electrical components and lighting in Train control rooms and Communications rooms shall be calculated based on the equipment used in those rooms. Equipment efficiency has increased but so has the amount of equipment now used in these rooms. Design should be based on actual load. Provide a basis for assumed loads. Train Control and Communications Rooms doors shall be tight fitting with no undercutting for relief air. Relief venting of these rooms shall be accomplished by means of adjustable, motorized dampers. Dampers shall be sized at 1100 feet per minute to maintain slight positive pressure in the rooms.

14 .4.2.5 Maintenance Rooms

Exhaust: Are used for storage and are uninhabited, provide louvers for natural ventilation of the room.

14 .4.2.6 Station Attendant's Kiosk

Air conditioning/heat pump and air filtration will be provided in the Kiosk to maintain 72° F. Thermostat for unit shall allow for programming of maximum heat set point for heating and minimum low set point for cooling. The maximum and minimum set points shall be lockable. Kiosk’s with AC unit located on roof, unit shall be located so that it is removable and serviceable from inside the kiosk. Preferable AC unit location is through the kiosk wall so that the unit is removable form inside or outside of the kiosk without the use of a ladder.

14 .4.2.7 Washrooms, Cleaners' Rooms, and Sewage Ejector Rooms

Exhaust: 2-1/2 CFM per square foot of floor area, exhausted to outside where possible. If not practical, exhaust to subway running tunnel remote from public areas and on same side as trains leaving the station.

14 .4.2.8 Underground Traction Power Substations

Rooms shall be ventilated with two fans of equal capacity operating in parallel, using a Programmable Logic Controller (PLC) in a lead lag operation with alternate duty. The first stage fan will activate when room temperature reaches 85°F and turns off when temperature reaches 80°F. The second stage fan will activate when the room temperature reaches 90°F and turns off when temperature reaches 80°F. The controller shall be capable of remote monitoring over the Ethernet using Modbus communication protocols. The PLC shall alarm a high temperature advisory when the room temperature reaches 90°F and a high temperature alarm when the room temperature reaches 100°F.

Lead fan and stand-by fan shall alternate automatically after each operating cycle. Provide a H-O-A switch for each fan. During operation of any one fan, the intake damper with other fan shall be closed. Use of gravity dampers is preferred. Supply air for ventilation and heat dissipation shall be drawn from ground surface area and not from tunnel, supply air to be filtered through a pleated filter. Relief air shall be discharged to a point outside of the subway unless otherwise approved by the Authority. . . .

Ventilation requirements (capacity) for the fans shall be based on the sensible heat load generated in the substation:

$$Q=(X)/(\rho * c_p * \Delta T)$$

Where:

Q = Volume flow rate of air

X = Heat generated by equipment (TPSS equipment as well as lights, etc.) contained in the substation

ρ = density of air

c_p = specific heat of air

ΔT = (Temperature Inside - Temperature Outside)

The maximum inside temperature is 104°F (max temp rating of electrical equipment) and the maximum outside temperature is to be based on the 0.4 % Cooling DB temperature listed for Washington DC Reagan AP in the ASHRAE Fundamentals Climatic Design Information Section.

The heat generation shall be based on 9MW of transformer capacity and shall include all other electrical equipment contained in the substation that generates heat.

Two fans shall be provided with each fan sized for one half of the calculated total air flow rate.

High efficiency, pleated type filters shall be provided.

Air shall be supplied to the substation, directed past the major equipment and relieved through ventilation shafts to the ground surface. Ductwork shall be minimized and shall not be run over electrical equipment. Air velocity through relief shafts shall not exceed 500 fpm. A slight positive pressure (not to exceed 0.1 inches water gage) shall be maintained within the substation to reduce infiltration of dust.

14 .4.2.9 Aboveground Traction Power Substations

Rooms shall be ventilated with one fan using a programmable logic controller to operate when room temperature exceeds 85°F and turns off when temperature reaches 80°F. The controller shall be capable of remote monitoring over the Ethernet using Modbus communication protocols.

Above ground substations are normally arranged with rectifier transformers located outside the substation building. Where substations must be located at grade with rectifier transformers within the building, they are to be treated as underground substations for ventilation requirements.

Aboveground substations shall be ventilated with outside air brought in by a single fan to operate when room temperature exceeds 85°F and turn off when temperature reaches 80°F. Manual control of fans shall be provided to permit usage when substation is occupied by maintenance personnel.
Ventilation requirements and capacity shall be calculated as outlined in Underground Traction Power Substations.

Air intakes shall be located to minimize introduction of dirt or gaseous exhaust fumes into the substation with pleated filtration provided. A slight positive pressure (not to exceed 0.1 inches water gage) shall be maintained within the substation to reduce infiltration of dust.

14 .4.2.10 Elevator and Escalator Machine/Contol Rooms-Provide HVAC to maintain an operating temperature range from 50°F to 80°F See Section 14.17.5.1.

14 .4.2.11 Operations Rooms, Police Service Rooms and Dispatcher's Rooms Provide air conditioning designed for two occupants and a lighting load of 4 watts per square foot. Provide manual on/off control. In the case of underground stations, use split system air conditioning units. Locate condensers in areas where exposure to track dust is minimized. Small capacity, package type heat pumps or self-contained air conditioning units are acceptable for use in isolated rooms above ground.

14 .4.2.12 Electric and telephone equipment rooms - no mechanical ventilation unless heat producing equipment, i.e. transformers, is to be installed in the room(s).

14 .4.2.13 Areas of Rescue Assistance and adjacent stairways - provide positive ventilation as defined in ADA and in accordance with local code. Bring supply air from outside the system to insure smoke free air.

14 .4.3 Ductwork Insulation

The following ductwork shall be insulated:

14 .4.3.1 Platform and mezzanine air conditioning supply ductwork.

14 .4.3.2 Ancillary area cooling supply and return ductwork, except ductwork in conditioned spaces.

14 .4.3.3 Ancillary area heating supply and return ductwork, except ductwork in heated spaces.

14 .4.3.4 Outside air intake ductwork.

14 .4.3.5 With the exception of Underplatform and dome exhaust fans, exhaust air ductwork between automatic damper on fan discharge and the exhaust louver.

14 .4.4 Control Sequence

Control sequences not included in the standard specifications shall be given on the contract drawings.

14 .5 HEATING

14 .5.1 General

All-heating equipment for Rapid Rail Transit System rooms and Rail power support facilities shall be electric unless specifically designated otherwise. Electric wall heaters, electric unit heaters, electric duct heaters or combination heat pump heating/cooling units may be employed as required by the application. In general, the heating system shall be designed with a centralized mechanical heat system servicing similar areas/rooms. This is done in order to reduce the amount of mechanical equipment and maintenance required. Refer to Section D, "Secondary Ventilation Systems", for volume of air to be heated.

14 .5.2 Design Temperature

Electrical heating equipment shall be provided in the following locations for total heating requirements or to supplement the heating provided in the ventilation system. In general, maintain a temperature of 68°F to 72°F in occupied rooms. In unoccupied rooms, maintain a temperature of 50°F but provide controls to allow temperature to be raised to 68°F when occupied. The temperature controls shall have the ability to automatically reset to 50°F after 1 to 8 hours.

Design dry-bulb temperatures for each room are as follows:

14 .5.2.1 AC Switchboard Rooms (Below Ground): No heat required.

14 .5.2.2 AC Switchboard Rooms (Above Ground): Provide heat to maintain 50°F.
Calculations of heating load shall include a deduction of10,000 BTU. Per hour for each 100 KVA of transformer capacity.

14 .5.2.3 D.C. Breaker Rooms / Tie Breaker Station - Below and above ground, provide heat to maintain 50°F with the ability to raise the temperature to 68°F.

14 .5.2.4 Battery Rooms Above ground, provide heat to maintain 50°F with the ability to raise the temperature to 68°F.

14 .5.2.5 Train Control and Communications Rooms-68°F.

14 .5.2.6 Dispatch, Operations, and Trainmen' s Rooms-68°F.
Deductions shall not be made for internal loads in the computation of heating load.

14 .5.2.7 Above Ground Maintenance Rooms-50°F, no heating is required in below ground maintenance rooms.

14 .5.2.8 Below Ground Traction Power Substation - no heat required provided that calculations show that electrical heat rejection is sufficient to maintain 50°F.

14 .5.2.9 Above Ground Traction Power Substation-50°F, provide thermostatically controlled, electric heat sufficient to maintain required temperature with the rectifier units inoperative.

14 .5.2.10 Station Attendant's Kiosks, 68°F. Provide electric heat as a part of package air conditioning unit.

14 .5.2.11 Washrooms, 68°F.

14 .5.2.12 Cleaner's Rooms and water service rooms, 50°F.

14 .5.2.13 Escalator wellway heating, 50°F.

14 .5.2.14 Elevator and Escalator Machine Rooms - Above ground, provide heat to maintain 50°F with the ability to raise temperature to 68°F. (See Section 14.17.5.1).

14 .5.2.15 Above Ground Electric rooms and mechanical rooms 50°F, except no heating is required in below-ground rooms.

14 .5.2.16 All ancillary rooms with employees occupancy shall be maintained at 68°F as per the International Mechanical code.

14 .5.3 Heat Loss Parameters

Underground:

14 .5.3.1 One BTU. per square foot per hour loss to ground.

14 .5.3.2 Ambient temperature assumptions: 14ºF outdoor, 30ºF in tunnels and underground station platforms.

14 .5.4 Heating Equipment - Electrical Characteristics

See Section 13.7.5 for electrical characteristics. Verify that scheduled equipment is commercially available. All heating equipment shall be thermostatically controlled with automatic set back non-user adjustable. Remote monitoring shall be the normal configuration with exceptions when approved by the Authority. Control transformers shall be provided where required.

14 .6 AIR CONDITIONING OF UNDERGROUND STATIONS

14 .6.1 General The air conditioning system shall be designed to provide localized cooling for passengers from the time of station entry until entering air conditioned trains.

Cooling will be accomplished by the following:

14 .6.1.1 Natural stratification and convection of air due to temperature differences.

14 .6.1.2 Distribution of conditioned air to cool passenger areas.

14 .6.1.3 The design and location of tunnel vent shafts, exhaust fans, and fan shafts to reduce the effect of train heat and piston action into the station. Temperature rise in stations due to heat generated in the tunnels will be reduced by the flow of air through these shafts.

14 .6.1.4 Heat transfer to the ground sink through the station walls.

14 .6.2 Design Factors

14 .6.2.1 Each station shall have 350 tons of refrigeration capacity unless otherwise directed by the Authority.

14 .6.2.2 Design temperature shall be 85ºF Dry Bulb in passenger areas when outside air temperature is 91ºF Dry Bulb and 74ºF Wet Bulb.

14 .6.2.3 Air quantities shall be maximum feasible for cooling of the platform area and mezzanine area. The total air supply for the platform air conditioning shall be not less than 50,000 CFM.

14 .6.2.4 Coils are to be selected for maximum sensible cooling.

Underground station cooling is accomplished by a spot cooling system. This system is designed to cool only the occupied portions of the platform and mezzanine. The basis of the 350 refrigeration capacity is as follows:

14 .6.2.5 Passenger heat load	1,000 BTU/hr/person
On platforms	16 sq. ft. per person
On mezzanine and in ticketing areas	1,000 BTU/hr./person

14 .6.2.6 Lighting and miscellaneous power load **-** 3 watts per sq. ft. of pedestrian floor area plus motor load of escalators from mezzanines to platform. Motor heat is dissipated to mezzanine.

14 .6.2.7 Estimated heat gain due to entrainment of warm air to distribution air, 20% of loads 14.6.2.5 and 14.6.2.6.

14 .6.2.8 Estimated heat gain due loss into tunnels and station track areas, 20% of loads 14.6.2.5 and 14.6.2.6.

14 .6.3 Distribution of Conditioned Air

Air conditioning units shall supply conditioned air via supply air registers or pylons for localized cooling of the passenger areas. Supply air register size, locations, mounting height, throw, discharge velocity, and return grille locations shall be such as to provide proper air distribution. At side platform stations, supply air registers shall be located to discharge air horizontally at 9'0" above the finished floor and with sufficient throw to reach the edges of the platform and mezzanine. The supply grille face bars shall be horizontal.

In center platform stations, unless otherwise specifically indicated, distribution shall be provided by means of standardized air conditioning pylons 9'-0" in height, and ducts in escalator well ways. The maximum capacity of each pylon shall be 3,000 CFM. Mezzanines in center platform stations shall utilize either pylons or supply air registers.

Return air from platform areas shall be carried through the tunnels under platforms from return grilles which are incorporated into platform benches, escalator well ways or located on the station end walls. For side platform stations, return air will be picked up at the back edge of the platforms. This method requires openings in platform parapet walls.

Ductwork serving elevator machine rooms within return air plenum spaces shall be fireproofed.

Intake air for mezzanine air conditioning units shall be taken from entrance passageways and shall be considered outside air.

14 .6.4 Air Conditioning units

There shall be four air conditioning units (A.C.U.) per station for side platform stations and two units per station for center platform station. There shall be one additional air conditioning unit for each mezzanine.

The mezzanine units shall be sized to handle 100% outside air. The units shall consist of filters, chilled water coils and a fan section. The air conditioning unit components shall comply with the following:

14 .6.4.1 Filters shall be of the high efficiency, pleated type.

14 .6.4.2 Water Coils shall have a maximum face velocity of 550 fpm. Where water velocities less than 2 fps are encountered, a method of tribulation shall be provided. Cooling coils shall be designed for water inlet temperatures of 43°F and outlet temperature of 55°F.

14 .6.4.3 Power Supply In addition to air conditioning units, provide power for all associated controls and control devices.

14 .6.5 Underplatform Exhaust and Ceiling (Dome) Exhaust Fans

There shall be two fans, each with a capacity of 60,000 cfm, configured to exhaust air from the trackway through ducts located under the platforms of each underground station. These fans, designated "underplatform exhaust fans," shall be reversible, of the axial type, and capable of delivering 70% of the forward (i.e. exhaust) air volume in the reverse direction.

There shall be two additional fans, each with a capacity of 25,000 cfm, configured to exhaust air from the top of the station arch through a shaft terminating in the street. These fans, designated "dome exhaust fans," shall be reversible, of the vane axial type, and capable of delivering 70% of the forward (i.e. exhaust) air volume in the reverse direction.

Rehabilitation of legacy tunnel fan controls must include parallel capabilities for SCADA over Ethernet and the legacy DTS commands and alarms.

14 .6.6 Duct System

Duct sizes shall be selected on the basis of a maximum constant air pressure drop of 0.15 inches of water per 100' and a maximum air velocity of 2,400 fpm.

High pressure ductwork shall be provided regardless of air velocity, for systems with a static pressure in ducts above six inches water gauge pressure loss.

Medium pressure ductwork shall be provided on all air supply ducts for the station platform and mezzanine areas, regardless of air velocity, where the duct static pressure is more than two inches and does not exceed six inches water gauge pressure loss.

Low pressure ductwork (SMACNA Duct Construction Standards) shall be provided on all air supply and return ducts, regardless of air velocity, where the duct static pressure does not exceed two inches water gauge pressure loss. Supply air ductwork encased in concrete shall be constructed of materials which meet structural requirements and shall be adequately braced. See Standard Specifications. Return and exhaust air passages may be constructed as for supply air or of smooth concrete or masonry.

Asbestos cement pipe shall not be used for ductwork.

14 .6.7 Chilled Water Plants - for Two 350 Ton Water Cooled Chillers

Chilled water plants shall have 3600 sq. ft. of space; 2025 sq. ft. of indoor space to house 2 water chillers, 2 condenser pumps (1 per chiller), 1 primary chilled water pump, 1 reserve chilled water pump, 1 motor control center, 6 VFDs for pumps and cooling tower fans, water treatment, piping, additional control panels and equipment, and as well as equipment clearances; 1575 sq.ft.of outdoor space to house cooling towers and clearances. Chilled water plants shall supply a minimum of one passenger station. Locations of this shall be selected by the designer with the approval of the authority. As required by ASHRAE - 15- 2013, chilled water plants shall be provided with refrigerant leak detection and ventilation systems. The Designer shall identify the heat sources located within the chilled water plant and provide cooling to maintain 76°F. The chiller plant shall be treated as unoccupied space during winter months maintain 50°F with ability to raise temperature to 68°F.

A mop service basin sink shall be included in the chiller plant indoor space for washing equipment and general clean-up. The sink shall include a heavy duty service faucet with a top reinforcing bar and pail hook on the spout.

Chillers shall be operated in series with cross pipe connectivity to allow one chiller to operate if work is required on the other. A centralized remote monitoring system for all equipment is required for all chilled water plants.

Each plant shall include the following basic components.

14 .6.7.1 Water Chillers

Water chillers shall be of the oil free centrifugal type with motor compressor, evaporator, condenser, electronic control panel including sensors, safety devices, limit control and accessories. Capacity calculations and performance specification of chillers shall be approved by the Authority. Water chillers shall comply with the following:

Maximum pump motor speed	1750 rpm
Full Load Efficiency for Station Chiller	0.47 kW/ton
Integrated Part Load Value For variable load situations	0.38

Units shall be factory packaged, charged and tested. Chilled water shall be cooled from 55°F in, to 42°F out, with condenser water temperatures of 85°F in, to 95°F out.

A minimum clearance of 1/2 the length of the chiller shall be maintained on one side of the condenser and evaporator tube openings for tube cleaning and 1 full chiller length on the opposite side for tube removal. See Section 14.18.2.5 for marking clearance zones.

14 .6.7.2 Chilled Water and Condenser Water Pumps

Chilled water and condenser water pumps shall be of the centrifugal, split case, flexible coupling, mechanical seal and base-mounted type. Pumps shall comply with the following:

Maximum pump motor speed 1750 rpm

Motor selection Inverter-Duty Type

Pumps shall be a minimum of 3' apart from one another, 3' away from the walls and/or control panels, and have a minimum of 4' of clearance in front of pump for maintenance. See Section 14.18.2.5 for marking clearance zones.

Chilled water and condenser water shall be chemically treated to maintain water quality in order to minimize corrosion, scale build-up, and biological growth and therefore.

A stand-by chilled water pump shall be provided. A condenser water pump shall be provided for each cooling tower with cross connected piping.

14 .6.7.3 Cooling Tower

Cooling towers shall be induced-flow design with vertical air discharge. The following shall be the basis of selection.

Ambient air wet-bulb temperature	79°F
Entering water temperature	95°F
Leaving water temperature	85°F
Water flow rate	3 GPM per ton

Make up water rate 1.5% of total condenser water flow.

Bleed off rate 0.3% of total condenser water flow design safety factor 10 percent of tower load
Typical design consists of 2 cooling towers, one per chiller. Platforms around the cooling towers shall be included for servicing the fan and water distribution piping. Additionally, a jib crane mounted at the top of the cooling towers shall be included for fan removal.

The make-up water and bleed off lines shall be designed to meet the sewer charge exemption requirements of the local authorities having jurisdiction. The Designer shall verify the requirements given below and include in his design any changes and/or additional requirements. For any deviations from such requirements, prior permission of the authorities having jurisdiction will be required.

14 .6.7.3.1Water Meters

14 .6.7.3.1.1 The make-up water line shall have a separate water meter with a valved bypass around the meter, equal to the size of the line. Make-up water line and meter shall be protected against freezing.

14 .6.7.3.1.2 All meters shall register in gallons

14 .6.7.3.1.3 All meters must be installed three feet above the floor and must be easily accessible.

14 .6.7.3.1.4 Make-up and blowdown meters shall be remotely monitored by the Chiller Plant Control Panel. The intent is to provide remote monitoring and alarm based on these inputs.

14 .6.7.3.2Flow Meters

Flow meters are to be used on each chilled water loop and each condenser loop. Flow meters shall be ultrasonic and mounted externally. Flow meters shall be sufficiently spaced away from VFDs and other electrical equipment to avoid inaccurate measurements due to harmonics and other electrical interference.

Flow meters shall be remotely monitored by the Chiller Plant Control Panel. The intent is to provide remote monitoring and alarms based on these inputs.

14 .6.7.4 Motor Control Center

If a Motor Control Center is required see electrical section, Section 13. .

14 .6.7.5 Freeze Protection

Ethylene glycol shall not be used. Other antifreeze products may be approved by the Authority on a case by case basis.

14 .6.7.6 Chilled Water Lines

Chilled water lines shall be arranged to permit convenient drainage of all, or portions of the water system. Heat tracing shall be provided for chilled and condenser water piping exposed to outside air with the exception of those portions of condenser water piping which are drained during cold weather.

Where burial of chilled water piping is required, burial depth shall be a minimum 2'-6" below grade and the pipe shall be encased in conduit with the following requirements.

14 .6.7.6.1Leakplates - To provide an effective moisture barrier, conduits shall be equipped with leakplates in building or manhole walls - but only when there is an anchor plate within 5 feet outside the wall. Leakplates shall consist of a steel plate flange 4" larger in outside diameter than the conduit, welded to the conduit only and located in the wall approximately 6" from the end of the conduit. Wall sleeves are recommended where anchor plates are not available within 5 feet.

14 .6.7.6.2Anchors - Prefabricated plate anchors shall be furnished and installed where shown on plans and shall consist of a steel plate, welded to pipe and conduit. The steel plate shall be 3/8" thick for 6-5/8" to 10-3/4" conduit, ½" thick for 12-3/4" to 22" conduit, and 3/4" thick for conduit over 22". A concrete block shall be cast over the plate and conduit shall be as shown for firm anchorage into undisturbed trench sidewalls and/or bottom. The concrete block to be at least 30" in length and extend a: minimum of 9" beyond the top and bottom of the anchor plate.

14 .6.7.6.3 End and Gland Seals - Terminal ends of conduits inside manholes, pits, or building walls shall be equipped with end seals consisting of a steel bulk head plate welded to the pipe and conduit. Where there is no anchor within twenty feet of a terminal end, conduits shall be equipped with gland seals consisting of a packed stuffing box and gland follower mounted on a steel plate welded to the end of the conduit. Gland seals shall only be used if it is not possible to install an end seal. All conduits shall be terminated 2" beyond the inside face of manhole or building walls to protect any exposed piping insulation from damp-wall condensation.

14 .6.7.6.4Aggregate

Material or structure for subgrade foundations shall be provided in accordance with the Standard Specification.

14 .6.8 Station Air Conditioning System Operation

The under-platform exhaust fan(s) will start when the platform temperature rises above 70EF DB. The under-platform exhaust fans shall be capable of being reversed manually from the Control Center, with a local override, to supply fresh air to the track area.

The platform and mezzanine air conditioning unit fans will start when the respective space temperatures rise above 80EF DB. A thermostat set at 85EF will open and close the chilled water coil control valve.

The chilled water pumps will be capable of being started locally. The chilled water aquastat will start the chiller and, through interlocks, will start the condenser water pump. The chiller, by means of flow switches, will be prevented from operating if chilled and condenser water flow have not been established. When chiller is started, the chilled water aquastat maintains chilled water temperature. When the condenser water pumps is operating, a condenser water aquastat will modulate the variable speed cooling tower fans to maintain condenser water temperature. A temperature sensor located in the subway near tunnel exhaust fan shafts will be monitored by a controller and open vent shaft, fan shaft by-pass dampers and fan shaft dampers when temperature rises above 50^{o}F.

Tunnel exhaust fans, jet fans and their corresponding vent shaft dampers can be controlled remotely from Operations Control Center (OCC) to clear smoke from the tunnels. The modes available during smoke control are "emergency on" and "emergency off". During the "emergency on" mode, the tunnel ventilation fans may operate in either the forward or reverse mode with the vent shaft dampers closed. The forward and reverse modes of fans in adjacent fan shafts or adjoining tunnels can be used in combination to achieve controlled air movement.

"Emergency off" turns the fans off. The fail-safe mode for the vent shaft dampers is closed and for fan shaft dampers is open.

Local control panels shall be provided for all tunnel ventilation fans and shall be equipped with selector switches for "automatic" and "emergency-exhaust (forward in the case of jet fans)" and "emergency- supply (reverse in the case of jet fans)". The latter two modes override the Supervisory Control Console at OCC. Actual fan operations shall be monitored by pressure sensors at fan outlets and shall be annunciated at OCC.

System control shall be provided by a pneumatic system in legacy systems and electronically in new or rehabilitated systems. In addition to pneumatic controls, the tunnel ventilation fans shall be provided with redundant electric control to permit, in the event of control air failure, control locally or from OCC. Compressed air for individual passenger stations, subway ventilation and chilled water plant shall be provided by a duplex compressor at each chilled water plant. A desiccant dryer shall be provided to lower the main compressed air dew point below minus 10^{o}F at 80 psi. Compressed air shall be supplied through a filter and reducing stations to maintain 20 psig. main air pressure at controls. Each station air conditioning control system, exclusive of the chiller plant, requires one cfm of air when measured at standard atmospheric pressure. When a train station is more than 500 feet from the chiller plant compressor, the air shall be available at the first control location at a minimum of 86 psig and then reduced. Installation of a compressor closer to the point of use should be evaluated. Maintenance of compressed air lines in the roadway have limited available access for leak detection and repair.

14 .6.9 Under-platform Exhaust Supply/Air System

Portions of the heat generated by the car braking resistor-grids beneath cars shall be removed, as hot air, from the station before it can enter the station environment. The hot air shall be exhausted to grade through an interconnected under-platform duct, fan system and fan shaft at each end of the station. The fan shaft and gratings shall conform to "Fan Shaft" criteria. The air passages beneath the platform shall be constructed of smooth concrete. The under-platform exhaust fan shall be reversible so that the fan can be operated in either a supply or exhaust mode, with exhaust mode being normal. Local control panel shall be provided for under-platform exhaust fans which shall have selector switches for "automatic," "emergency exhaust," and "emergency supply."

The under-platform exhaust air passages beneath the platform shall have minimum dimensions of 5'-0"wide by 3'-6"deep unless approved otherwise by the Authority. There shall be 80 standard exhaust ports under the platform. Each port shall be provided with air balancing dampers.

14 .6.10 Ductwork Insulation

Indicate on design drawings by means of symbols and/or notes, all ductwork to be insulated. If simpler and more clear, ductwork not to be insulated may be indicated instead. Following ductwork to be insulated:

14 .6.10.1 Outside air intake ductwork

14 .6.10.2 Supply air ductwork for platform and mezzanine air conditioning system

Ductwork for under-platform and dome ventilation systems is not to be insulated.

14 .6.11 Ceiling (Dome) Smoke Exhaust Fans

In addition to the underplatform exhaust system, two ceiling (dome) smoke exhaust fans shall be provided and equipped with reversible motors capable of being controlled from the Operations Control Center, with a local override. The exhaust shafts shall follow the same air discharge and equipment criteria as "Fans Shafts". The normal mode for these fans shall be exhaust. Fan intakes shall be located at nominal 1/4 and 3/4 points of station platform unless approved otherwise by the Authority. Fans and other related equipment shall have characteristics as listed below:

b. Volume	25,000 CFM in exhaust mode with delivery between 16,000 and 18,500 CFM in supply mode.
c. Type	Axial
d. Equipment	Dampers
e. Motor	Reversible type
f. Electrical characteristics	460 volts, 3 phase, 60 hertz. Essential power

g. Motor Control	Magnetic, across-the-line start, circuit breaker disconnect, magnetically operated overload protectors (thermal type will not be permitted), local manual on-off automatic selector switches. Remote control and indication and supervisory control from operations Control Center (OCC).
g. Dampers	Dampers open by thermostatic control, start of fan, or a remote signal from Operations Control Center. Assume fresh air for under-platform and dome exhaust systems make-up is brought into the station from the vent shafts. Disregard the entrance ways as sources of make-up air.

14 .6.12 Control Panel Location

Local control panels for under platform and dome exhaust fans shall be located adjacent to a mezzanine-level fire equipment cabinet.

14 .7 AIR CONDITIONING OF ANCILLARY SPACES

14 .7.1 General

Refer to "Secondary Ventilation Systems" for air conditioning requirements in the ancillary spaces.

In general, air conditioning shall be provided in rooms where personnel are stationed for extended periods of time or where equipment operation requires lower temperatures than can be provided by mechanical ventilation. Variation from this criteria must be approved by the Authority.

14 .7.2 Design Conditions

The following conditions shall be used in the selection of equipment and design of air conditioning systems.

Ambient summer design conditions:

Dry Bulb 91°F

Wet Bulb 77°F

Design room conditions at peak load:

Dry Bulb 72EF

14 .7.3 Air Conditioning Equipment

Air conditioning equipment for ancillary spaces may be self-contained or split system type. For electrical characteristics, see Section 13.7.5. Thermostatic control shall be provided. Control voltage shall not exceed 120 volts.

14 .7.4 Air Filtration

Air filters shall be of the following types:

Under 5,000 cfm - Replaceable media

5,000 cfm and over - Primary - pleated type, 80-85% efficiency;

Replaceable media Prefilter

14 .8 DRAINAGE

Typical details for the drainage system are shown on the Mechanical Design Drawings.

14 .8.1 General Requirements

Invert elevations and locating of drainage piping a teach end of a contract shall be coordinated with related Designers. Elevations or locations of drainage facilities shall be determined by the Designer with approval of the Authority.

As far as practical, drainage shall be by gravity flow. Where sections are such that gravity outfalls cannot be provided, pumping stations shall be installed.

Surface drainage except for tunnel portals, decks, entrances, ventilation shafts, fan shafts and similar openings shall not be-collected in subway drainage systems except with specific approval of the Authority.

No sanitary drainage shall be permitted to enter the track drainage system. Surface ventilation openings, where feasible shall be located at a higher elevation than adjacent pavement and if that is not permitted adjacent pavement shall be sloped away from the openings to prevent flooding.

14 .8.2 Location of Drains

In train tunnel sections, manholes or drainage slot inlets shall be provided at maximum 350 foot centers.

In station sections manholes or drainage slot inlets shall be provided at maximum 120 foot centers. Manholes shall be located at the high ends of stations 15 feet before start of platform. The last manholes shall have a minimum distance of 15 feet from lower end of station platforms.

Drainage from the low point in each escalator pit and the spaces under the platforms including depressed areas under escalator and elevator pits shall be provided. Elevator and escalator pits shall be provided with high water alarm reporting to kiosk. The High Water Alarm for all Sump Pumps in the Elevator and Escalator Pits shall also be directly monitored by the BAS systems. Where walls divide the space under the platform, sleeves to allow drainage to escape to other inlets may be provided.

Provide floor drains for the following rooms: Mechanical Room, AC Switchgear Room, DC Tie Breaker Room, Traction Power Substation, Cleaners Room, Sewage Ejector Room, and Water Service Room, Water can infiltrate these rooms either by the equipment located in the room or infiltration through wall/ceiling cracks, conduits, etc. Floor drains will allow for any water which infiltrates the room to drain and eliminate the potential for standing water in these rooms and the safety issues that this creates. If required equipment in these rooms will have containment curbs or other means of ensuring harmful fluid i.e oil, acid, etxc leaks or spills are contained and not allowed to end into the drainage system.

Provide floor drain at the Station Attendant's kiosk, for drainage of condensate from kiosk air conditioning unit.

Cleanouts are required for each 90^{o} bend and for each two 45^{o}bends. In stations where low points cannot be drained by gravity, pumping shall be provided with the pumps located so as to be readily accessible. Drain more than one depression to a single sump where feasible.

14 .8.3 Drainage Fittings

The following fittings shall be used for drainage purposes

Description	Use
Manhole frame and Cover	Access to main track drain. Drainage inlet
Drain Inlet	Drainage inlet - connection to main track drain required.
Scupper Drain	Drain inlet from fan shafts, vent shafts, and

Clean-Out	Access to drainage piping for clean-out purposes only

14 .8.4 Drainage Piping

The drainage piping for open track sections shall be concrete pipe selected in accordance with the flow requirements and depth of burial.

The drainage piping for subway sections shall be selected from the following:

Diameter (Inches)	Material	Use
4 and over	Service weight cast iron in soil pipe	Drain connection structural walls and floors
4 and over	Extra heavy cast iron soil pipe	Drain connections under floor slabs
6 and over	Polyvinylchloride (PVC), Polyethylene (PE), (Corrugated)	Branch in structural and underground
8 and over	Polyvinylchloride (PVC), Polyethylene (PE), (Corrugated)	Main track drain

14 .8.5 Drainage Volumes

The volumes of water to be handled by each drainage system shall be calculated as follows:

14 .8.5.1 Drainage for open areas other than decks, entrances, tunnel portals, ventilation shafts, fan shafts and similar openings draining into the subway drainage system shall be calculated by means of the formula:

$Q = c*I*A$

Where:

Q = Volume in cubic feet per second

c = coefficient of runoff

I = Intensity for 50 year frequency, from duration rainfall curves established by local jurisdiction

A = Drainage area in acres

14 .8.5.2 Drainage for tunnels, tunnel portals, decks, entrances, ventilation shafts, fan shafts, and similar openings shall be calculated as follows:

14 .8.5.2.1 Underground Sections in Earth

Drainage for underground section in earth designed to exclude groundwater shall be based on the formula:

$$Q = (a/14) + (L/500)$$

Where:

Q = Volume, in gallons per minute

a = Horizontal projected area of all subway openings in square ft, i.e. station entrances, fan shafts, etc.

L = Linear feet of structure in the drainage system.

14 .8.5.2.2 Underground Sections in Rock

Drainage for underground sections in rock designed to collect groundwater in order to relieve hydrostatic pressure shall be based on the formula:

$$Q = (a/14) + (L/50)$$

14 .8.6 Flow Formulas

Flow and velocity in drainage piping shall be calculated using Manning's formula.

$$V=k/n*R^{2/3}*\sqrt{S}$$

Where V = Cross section average velocity (ft/s)

k = conversion constant 1.486

n = Manning coefficient (see below)

R = Hydraulic radius (ft)

S = Slope of water surface or linear hydraulic head loss (ft/ft)

In the use of this formula, the following factors for "n" shall be

used:

n = 0.015 for concrete pipe 24" diameter and less

n = 0.013 for concrete pipe over 24" in diameter

n = 0.016 for polyethylene corrugated pipe, 8" diameter or less

n = 0.017 for polyethylene corrugated pipe, over 8" diameter.

14 .8.7 Grades

The following minimum grades shall apply:

Pipe Diameter (Inches)	Minimum Grade
4	2.0% or ¼" per foot
6	1.0% or 1/8" per foot
8	0.65%

9For the design of main drains, the Designer should consider the economics of increasing the size of the drain to permit as close a correlation between drain profile and T/R profile as possible. Main drains should be designed in such a manner that the grades produce a minimum velocity of 2.5 feet per second with the pipe flowing 50% and 100% full.

14 .8.8 Plastic (PVC and PE) Piping

Plastic piping shall not be exposed in its installed position because it gives off toxic gases when it burns and is a source of fuel for a fire. The last two feet of drain pipe at exposed termination points shall be concrete, cast iron, vitrified clay pipe. Suitable adaptor fittings are to be provided for connections between different pipe materials.

Designer shall provide separate flow calculations for PE corrugated piping and shall clearly indicate on design drawings where larger size corrugated pipe (over PVC pipe) is required to meet design flows.

14 .8.9 Pumping Stations

Pumping stations shall be of the wet well/dry well with pump type.

The pumping stations shall be selected on the following basis:

Minimum Number of Pumps:	3

Pump Rating:	Each pump 100% of "Drainage Volume." 500 GPM minimum for pumps at low point. 150 GPM minimum pumps above low point (interceptor pumps) in dr system.
Pump Head:	To suit static and friction heads of each installation. Friction head calculated with two pumps operating
Pump Type:	Non clog submersible sewage type.

for drainage

Minimum Number of Pumps:	3
Check Valves:	Swing "non slamming" type with weighted outside arms.
Motor Selection:	Pumps to be operated with Variable Frequency Drives (VFDs) See Electrical Design Criteria
Meter:	All discharge to be metered

Calculations for pump discharge piping pressure losses shall include an allowance for future deterioration of the interior surface of the piping, i.e., C=100 (Hazen Williams Formula) or equivalent. Pressure calculations to include a factor of 10% to account for unforeseen losses.

Provide fire alarm and intrusion alarm detectors. See Section 27.2.3.7.

In determining pump head, an investigation of existing sewers shall be made. If the sewer is liable to be overcharged, the pump discharge head shall be increased to exceed the overcharge head.

Pumping stations shall discharge into sanitary or combined sanitary/storm sewers only upon specific approval by the Authority. The designer shall design a system to treat pump discharge to meet federal, state and local regulations. The discharge water will likely contain the following requirements; PH range 6.0-

8.5, total suspended solids 30mg/liter, oil and grease 30mg/liter. For the specific requirement, the designer shall consult with the respective regulatory authorities. In addition to the basic criteria for package units, the station utilizing submersibles shall conform to the following:

14 .8.9.1 The pumping station shall consist of a wet and dry well, with the submersible pumps housed in the dry well. The wet well shall be sized such that volume allows the pumps to operate without short cycling; short cycling is defined as pumps operating more than three cycles (on and off) per hour. Pumping system to be designed so that pumps still operate if the drywell is flooded with water. Piping to have valves so that pumps can be isolated for service without taking the pumping station off line.
On stations where no dry well exists, pumps are to be located in the wet well on stainless steel guide rail connection assemblies which allow pumps to be installed and removed without entering the wet well.

Provide an enclosed pump room heated as required to maintain a minimum room temperature of 50ºF and ventilated to provide 10 air changes per hour when room temperatures exceeds 90ºF. Walls and doors must be able to withstand reversing transient air pressures to 70 psf where required by structural design criteria. Access is to be provided from the tunnel section. For stations of 1000 GPM or more, access will be provided from the surface if the station is not located with or adjacent to another means of access. . Dry wells and wet wells where no dry well exists shall be provided with ladder access and covered with grating. Grating to be corrosion resistant and in sections to allow for one or two person removal. Float tree, sonar mounting, etc to be stainless and accomplished above pit in order to eliminate confined space requirements.

14 .8.9.2 Pumps are to be supported independent of discharge piping. Pumps to be located on concrete pads or stainless steel support frames secured with stainless steel fasteners.

14 .8.9.3 Discharge line to be fixed, ductile iron with quick-connection coupling to pumps.

14 .8.9.4 Pumps to discharge to a redundant piping system (dual pipes) to discharge. Existing pumping stations where single discharge pipes are inaccessible/embedded does not apply.

14 .8.9.5 Provide permanent provisions for removal and installation of pumps, including overhead hoisting system. Lifting/hoisting provisions to be clearly marked and identified with rated lifting capacity.

14 .8.9.6 Pump motors to be controlled with VFDs in order to allow the pumps to operate at lower more economical speeds and eliminate short run times which can be detrimental to the pump and electrical system. The VFDs shall be programmed to provide a flushing velocity at the start of each pumping cycle. Pump controls to be PLC type with ultrasonic level monitor to provide start/stop control with automatic alternation of pumps through an alternate duty assist algorithm after each pumping cycle. The control interface is to be through a Human Machine Interface (HMI) with Ethernet communication for remote monitoring and e-mail server for alarm notification The controller shall record the number of pump starts, pump run time, volume discharged and pump efficiency. It shall also be capable of performing the following functions:

1. Fluid level monitor
2. Space available monitor
3. Differential level monitor
4. Volume totalizer

14 .8.9.7 Electrical equipment to be in NEMA 4 dust-tight enclosures and installed at least 18 inches above the pump room floor.

Where a great difference exists between estimated normal drainage flow and that expected under 50-year storm conditions, the Designer should augment the pumps sized for normal conditions, with additional pumps as required to meet maximum emergency predicted conditions. Designer to submit his recommendation, with back-up calculations, to the Authority for approval prior to proceeding with the pump station design.

14 .9 GRATINGS

The following grating types shall be adopted as standards for use in this project.

14 .9.1 Light Loading

14 .9.1.1 For general use below grade

Design loading	250 p.s.f uniform loading.
Maximum allowable deflection	1/200 span
Maximum spacing of bearing bars	1 3/16" centers
Type bearing bars	serrated, rectangular

14 .9.1.2 For walkways, shaft opening, etc.at surface subject to pedestrian traffic but not vehicular traffic.

Design loading	250 p.s.f. uniform loading
Maximum allowable deflection	1/300 span
Maximum spacing of bearing bars	1 3/16" centers

Type bearing bars	plain, rectangular

14 .9.2 Heavy Loading

14 .9.2.1 For gratings subject to vehicular traffic

Design loading	AASHTO HS20-44
Maximum allowable deflection	1/300 span
Maximum spacing of bearing bars	1 3/16" centers
Type bearing bars	plain, rectangular

Gratings located in accessible areas shall be placed so that the long dimension is perpendicular to the dominant direction of travel and openings shall be no greater than ½ inch in the direction of dominant travel.

The Designer shall ensure that emergency egress hatches are not located in areas subject to vehicular traffic. Where it is not possible to avoid this, bollards or other means of preventing a vehicle from driving over a hatch shall be provided.

14 .10 EMERGENCY ACCESS/EGRESS SHAFTS

14 .10.1 General

Access shall be provided to the subway at maximum 2500 foot centers so that no point in the subway system shall be over 1250 feet from a point of access or egress and in compliance with NFPA 130 Standards.

Where stations are over 2500 feet apart, intermediate emergency access shafts shall be provided.

Access shaft stairways shall be in accordance with NFPA 130 and IBC Standards:

Provide rise and tread widths as required by local code 48" overall width (two exit units)

Hatches for access shafts shall be in accordance with mechanical standard drawings. Hatch loadings (250 PSF) shall be indicated on drawings. Exit hatches shall be equipped with hardware and latches of readily opened from side of exit.

Hatches shall be readily opened from the outside by authorized personnel. Continuous handrails shall be provided in access shaft passageways as well as on stairways. Where locks are required, they shall be provided with panic hardware.

Enclose the top flight of stairs leading to the surface hatch and provide a partition, complete with door, across the landing at the foot of this flight of stairs.

The enclosure and partition are to be of noncombustible material and may be of openwork material, subject to its rejecting a 2-inch steel ball. The door is to be solid and equipped with a lock operated by a key on the outside and by panic hardware on the inside. If openwork material is used for the partition, provisions shall be made to assure that the panic hardware cannot be operated from the outside through the openings in the material.

14 .11 ESCALATORS

14 .11.1 General

Escalators shall be supplied and installed, complete with exterior balustrade lighting, heaters, maintenance lighting and 110-120 VAC duplex GFCI receptacles within the envelope of the escalator. The Designer shall design the space, structural supports, electric service and conduits for the installation of the escalators. Escalators shall be designed with the following parameters***:***

14 .11.1.1 The vertical rise for an escalator shall not exceed 30'-0" unless directed by WMATA.

14 .11.1.2 A vertical escalator rise over 30'-0" shall be designed with multiple escalator runs connected by landings between them.

14 .11.1.3 Landings between escalator runs shall have a minimum queuing distance of 40'-0" measured from the balustrades.

14.11.1.4 Each escalator wellway shall have at least one stair/ship ladder for maintenance access to the wellway. The stair/ship ladder shall be provided with handrails for safety.

14 .11.2 Codes and Regulations

Escalators shall as a minimum conform with requirements of the latest edition and any or supplements of the "American Standard Safety Code for Elevators, Dumbwaiters, Escalators, and Moving Walks A17.1" (ASME), Americans with Disabilities Act (ADA), National Electrical Code (NEC), NFPA 70 & 13 , International Building Code (IBC) and local related codes or shall exceed code requirements as defined in the WMATA Technical Provisions for Heavy Duty Escalators. Escalators shall be of the heavy-duty type, specifically designed to withstand the extreme patron traffic loads, environment, and potential for abuse associated with rapid transit installations. Heavy-duty escalators shall substantially exceed the operating (load carrying and braking) capacity and durability of commercial type escalators. Escalators shall have keyed operating controls (start and stop) at both landings and skirt deflectors on both sides of the moving steps.

14 .11.3 Number of Escalators

The number of escalators installed at each location shall be as ***required*** by the Authority. If the mezzanine is located at a different level from the street, there shall be a minimum of two escalators and a stair shall be provided at the entrance. A minimum of two escalators and stair shall be provide from each mezzanine to the platform.

14 .11.4 Width

All escalators shall be nominal 48" width units between balustrades as defined in the ANSIA17.1 Code. The width of the finished opening shall be as shown on the Design Drawings. This width shall include the machine room and pit, where required.

14 .11.5 Rise

Escalators and escalator wellways shall be divided into the following classes based on vertical rise between working points:

h. Class A1 - Rise of 20'-0" or less

A2 - Rise of over 20'-0" to 24'-0"

i. Class B1 - Rise of over 24'-0" to 30'-0"

B2 - Rise of over 30'-0" to 40'-0" B3 - Rise of

over 40'-0" to 60'-0"

These classifications are based on an arbitrarydefinition purelyforthe Authority’s convenience.

14 .11.6 Speeds

Escalator speeds for all escalators shall be 100 fpm. All escalators shall be equipped for inching during maintenance, inspection and a single maintenance speed adjustable between 0 and 120 fpm.

14 .11.7 Direction of Travel

10 All escalators shall be reversible.

14 .11.8 Angle of Inclination

Escalators shall be constructed at the standard 30E angle of inclination to horizontal in accordance with ASME A17.1. "Working points" (upper and lower) are intersections of this line with the finish floor elevations of the two levels.

14 .11.9 Flat Steps

The following minimum number of flat steps at the top and bottom of each escalator shall be provided:

Class A1 (Rise of 20'-0" or less) - 3 steps

Class A2 (Rise of over 20'-0" to 24'-0") - 3 steps

Class B1 (Rise of over 24'-0" to 30'-0") - 4 steps

Class B2 (Rise of over 30'-0" to 40'-0") - 4 steps

Class B3 (Rise of over 40'-0" to 60'-0") - 4 steps

14 .11.10 Dimensions

Design Drawings show the controlling structural dimensions for the installation of escalators. Escalators shall have a minimum headroom of 9'-0". The pit areas shall have a minimum clearance (work area) of 36" from the step to the end of the truss. If the drive system or any other equipment are located in the upper pit area, the clearance of 36" shall be maintained from the equipment to the end of the truss.

14 .11.11 Motors and Drive Mechanisms

The motors and drive mechanisms shall be installed within the truss or directly below and aligned with the respective units. Drive motors shall be high efficiency, total enclosed, fan cooled units with lubrication fittings installed. Drive motor controls shall be AC variable voltage, variable frequency electronic drives that run the motor during both normal and maintenance operation. Sufficient control room and equipment room spaces shall be provided for equipment placement to meet all applicable codes.

14 .11.12 Supports

There shall be no obstruction within the machine rooms or machine pits, such as supporting posts for the upper support beam, partitions, or piping. This area is reserved for the installation of controllers of various sizes and placements. Intermediate supports shall be provided for all escalators with over18'vertical rise as shown on Design Drawings.

14 .11.13 Vertical and Horizontal Reactions

Escalator support structures shall be designed to develop the reactions given on Design Drawings. The entire reaction at a support shall be assumed uniformly distributed over a distance equal to the width of the escalator truss. Reactions given include an impact load of approximately 33% of the total live and dead loads, including escalator cladding. Reactions are based on equally-spaced supports. Where supports cannot be equally spaced, modified reactions may be calculated by the Design Engineer using a method approved by the Authority. In all cases, the number of supports for a given rise shall remain the same. Reactions for rises not given maybe determined by linear interpolation. With the drive located inside the escalator truss, the chain pull "P" does not act on the supporting structure. The drive weight has been accounted for in the reactions. Prior to escalator installation, the escalator contractor shall furnish the Designer with actual reactions and shall check the support designs and certify that the supports are adequate.

14 .11.14 Structural Safety Factor

In the design of structural supports, a safety factor of five (5) shall be used to determine the allowable stresses in a structural material as a function of the ultimate strength of the material. This is in conformance with the requirement of the ASME A17.1 for trusses and all structural members.

14 .11.15 Electrical Supply

For electrical service to escalator pits, See Section 13.7.14.

14 .11.16 Controls

Non-proprietary micro-processor/PLC controllers and a non-proprietary application software shall be used. Provide Ethernet communication between the escalator control room and WMATA's communication room. The controller shall provide two data ports for communicating with WMATA's Remote Monitoring System (See Section 14.15). All escalators shall be equipped with a "fault display" to automatically register the operation of the escalator and activation of each safety device. The fault display shall be located inside the controller cabinet and visible through the controller cabinet door. The electronic controls shall operate in ambient temperatures from +32° F to + 140°F and relative humidity between 35% to 50%.

All application programs included in the escalatorshall be the propertyofWMATA and shall not be considered proprietary to OEM.

14 .11.17 Controller Location and Pit Access

The escalator controller shall be located in a locked walk-in control room at floor level under the escalator incline for easy access and suitable operating environment. See Section 14.4.2.10 for HVAC requirements.

The escalator contractor shall furnish and install an access floor plate or removable panel in the upper and lower landing plates of each escalator. If a removable panel is furnished, it shall be of a size and weight that permits removal by one person without special lifting tools.

14 .11.18 Electrical Interlock

An interlock switch shall be provided on each entrance gate at the mezzanine or passageway level of entrance escalators to prevent the escalators from operating if the entrance gates are not fully open. The interlock switches shall be wired in series and shall be open when the switch contacts for the entrance gate are not fully open. The wiring for the switches shall terminate in a junction box inside the escalator control room. The escalator installation shall connect the escalator controls so as to stop the escalator when the contacts open.

14 .11.19 Weatherproofing

All escalators which extend to street level and are exposed to the weather shall have weatherproof features including but not limited to:

14 .11.19.1 Nonferrous or stainless steel exposed parts.

14 .11.19.2 Protective covers over electrical equipment.

14 .11.19.3 Snow-melting heaters along the length of the escalator units and escalator machinery rooms.

14 .11.19.4 Waterproof construction of electrical equipment.

14 .11.19.5 Balustrade skirt edges sealed against moisture.

14 .11.19.6 Canopycovers for exterior escalators in accordance with ANSIA17.1 shall be provided in the station contract. A construction sequence shall be provided to allow for escalator installation without obstruction from the cover.

14 .11.19.7 Weatherproof escalator truss, truss support beams and truss mounting angles

14 .11.19.8 Corrosion protection for escalator truss support beams and truss mounting angles.

14 .12 VIBRATION ISOLATION

14 .12.1 Vibration Isolation

Equipment producing vibrations shall be isolated from the structure by spring or rubber-in-shear vibration isolators. All pipe and ducts connected to equipment mounted on vibration isolators shall contain flexible connections or provisions made for vibration isolating type supports. Identify on drawings where vibration isolators are to be provided.

14 .12.2 Equipment Mountings

Equipment to be mounted on the floor shall be placed on reinforced concrete housekeeping pads. Minimum pad height shall be six inches, all equipment to be suspended from ceiling shall be provided with suspension type hangers consisting of combination of spring and neoprene in series.

14 .13 FIRE PROTECTION

14 .13.1 Fire Alarm System

Fire Alarm Systems shall be designed as per this section and communication Section 27.2.3.7.

14 .13.2 Smoke and Fire Detection System

Detectors will be of the optical sensing type, combined rate of rise/fixed temperature type. Detectors will be designed to detect abnormal smoke densities, products of combustion or heat in station ancillary rooms, ducts of air conditioning systems, elevator machine rooms, and escalator pits. The detection system will be equipped with contacts which can perform the following functions:

14 .13.2.1 With the exception of underplatform exhaust fans, ceiling (dome) exhaust fans and tunnel ventilation fans, stop all air conditioning fan units and ventilation fans having a capacity in excess of 2000 cfm and battery room fans that serve or are located in the zone protected by activated detector.

Terminal boxes shall be located in mechanical equipment rooms and control wiring shall be run to nearest terminal box. Equipment schedules shall identify the units served by each terminal box.

14 .13.2.2 Stop all street entrance escalators moving contrary to the direction of exit travel when any fire detection or fire protection system in the station is activated. The Designer shall include conduit, embedded where necessary, from escalator control panel to nearest kiosk.

14 .13.3 Fire Department Standpipe System

The standpipe system is to be designed as a Class I system per the latest release of NFPA 14, NFPA 130 and amendments or as required by the adopted codes and regulations of the jurisdictional authorities except as modified herein, design drawings to identify release.

The fire department connection and fire pipe line mains shall be not less than 4 inches in diameter.

Underground piping shall be cement lined ductile iron minimum thickness class 52 and lined with cement mortar of twice standard thickness.

Above ground piping embedded or otherwise inaccessible shall be galvanized steel, schedule 80, exposed or otherwise accessible shall be galvanized steel, schedule 40.

14 .13.4 Fire Department Standpipe System in Subway (below ground) Stations

All underground stations are to have a wet standpipe system serving fire equipment cabinets and platforms, and the system shall be connected to the municipal water system. A 2-1/2 inch angle hose valve shall be provided in each fire equipment cabinet and at 200-foot intervals under the platforms with a valve within 100 feet of each end of the platforms). Access to angle hose valves under the platforms) shall be through manholes marked "Standpipe." These manholes shall not open up into underplatform exhaust plenums. Provide fire water line valve at interface of building water service and fire line piping. Locate these valves so as to be readily accessible to fire department personnel and are to be clearly identified. Valve shall be OS&Y type supervised in the open position so that a change in the normal position of the valve will generate a supervisory signal at the supervising station. Where a fire alarm system is provided, a signal shall also be transmitted to the control unit.

Coordinate with local jurisdiction as to whether fire service (wet) is to be metered.

A fire department connection shall be located near each station entrance and within 100 feet of a vehicular access. The fire line piping between the fire department connection and the wet standpipe shall normally be kept dry by use of a check valve with ball drip valve. Fire line piping shall not be embedded or encased in concrete and shall be located so as to be readily removed and replaced. In multi-platform level (cross-over) stations, each level is to be considered as a separate station insofar as standpipe systems are concerned, but the systems shall be interconnected with not less than 4-inch diameter line. . Pressure calculations to include a factor of 10% to account for unforeseen losses. Piping shall be pitched to allow for draining after use or testing.

If fire department connection is more than 15 feet above the ball drip check valve, a manual drain is also required on the upstream side of the check valve.

14 .13.5 Fire Department Standpipe System in Surface Stations

All surface stations to have a dry standpipe system serving fire equipment cabinets and station platforms..

A 2-1/2 inch angle hose valve shall be located at 200-foot intervals under the platforms with a valve within 100 feet of each end of the platforms. Access to these valves shall be through manholes marked "Standpipe".

A fire department connection shall be provided near each station entrance and within 100 feet of a vehicular access. If there is multi-level access to the station, provide additional fire department connections as required by fire authority having jurisdiction. These connections should be located such that fire hose between hydrant and the connection will not be subject to rail traffic. If necessary, extend connection across tracks. Pressure calculations to include a factor of 10% to account for unforeseen losses. Piping to be pitched to allow for draining after use or testing.

Neither thermal insulation nor heating tracers shall be used on fire department lines, valves, fittings, etc.

Provide high-capacity, automatic air release valves on main fire lines at end(s) of system opposite from fire department connections

Fire line piping shall not be embedded or encased in concrete and shall be located so as to be readily removed and replaced.

14 .13.6Fire Department Standpipe System in Vent Shafts, Fan Shafts and Rail Tunnel Areas.

All fan and vent shafts shall contain a dry standpipe system. This system shall consist of a fire department connection at the surface; a fire pipe line down the shaft; and fire pipe lines branching horizontally into the tunnel(s) in both directions to a point within 200 feet of the end of adjacent standpipe system(s). .. Pressure calculations to include a factor of 10% to account for unforeseen losses. When straight vertical runs of piping of 50 feet or more are required, special attention shall be given to the piping supports and or anchors at the base of these runs to assure the support is adequate for the piping under both static and flowing conditions. First horizontal support beyond the base of the vertical run is to be located as required by the loading but in no case more than five feet from the vertical run for six-inch pipe or six feet for four-inch pipe. To assure against possible violation of the maximum train car dynamic outline, the design shall include typical cross sections of each type of tunnel within the limits of the design contract. These cross sections shall reflect, as a minimum, the maximum dynamic outline of the car and the minimum clearance between this outline and the closest point of the standpipe system (refer to Section 8, Design Policies).

Fan/vent shafts terminating at the surface in an area where vehicular traffic is possible shall have the fire department connection located near a shaft wall just beneath the shaft grating so as to be readily accessible for connecting of fire hoses from outside the shaft. A plate identifying connection location is to be installed on the hatch leading to the connection. Fan/vent shafts terminating in areas not subject to pedestrian or vehicular traffic shall have the fire department connection extended above finish grade/grating to a height of between 18 and 36 inches. The design shall indicate sidewalk widths and location of tree space or boxes in the immediate vicinity of the fire department Siamese connection.

Fan/vent shafts terminating in an area subject to pedestrian traffic only shall have the fire department connection extended above finish grade unless the connection obstructs pedestrian traffic. Otherwise locate connection below grade as for an area subject to vehicular traffic.

A 2-1/2 inch angle hose valve shall be provided at the base of each shaft at track level and at not more than 200-foot intervals along the horizontal fire lines in the tunnels.

Fire lines are to be routed so that a clear head room of at least 6'-8" is provided along all paths of egress. Fire lines are not to encroach on stairways, ladders, etc., unless there is no practical alternative.

A control valve shall be provided within the fan or vent shaft or in the cross over for each horizontal branch fire line extending into the tunnel(s) more than 200 feet. A valve is not required where only a single horizontal fire line is required. These valves shall be located so that they are accessible without entering the train tunnels (i.e. not on tunnel side of dampers or fans).

Automatic ball drip valves in addition to manual drain valves are to be provided at all low points in the system. Automatic air release valves are to be provided at the ends of each branch line, sized as follows:

All mechanical pipe joints shall be electrically bonded for stray current control (see Standard Drawings ST-E-301, ST-E-302, ST-E-303 and ST-E-304.).

14 .13.7 Fire Equipment Cabinets

Fire equipment cabinets shall be provided on the station mezzanine level and both platform ends of subway stations and on the station mezzanine level and one platform end of surface stations.

Each fire equipment cabinet shall be sized for:

14 .13.7.1 One 2-1/2 inch angle hose valve.

14 .13.7.2 Two portable fire extinguishers, Type 10A

14 .13.7.3 One portable fire extinguisher, type 40B: C.

14 .13.7.4 Monitor Fire Equipment Cabinet from Fire Alarm Control Panel which is centrally monitored.

14 .13.8 Fire Protection for Escalators (Underground Stations)

All escalators shall be provided with a fire suppression system per NFPA 130 the system shall be provided within the truss space of exterior entrance escalators. The system is to discharge shall be designed in accordance with NFPA 13 in each escalator wellway and will be furnished and installed by the contractor, including fire line control. Fire lines shall be galvanized steel sch. 40.

14 .13.9 Fire Extinguishers

Portable fire extinguishers shall be of the dry powder, stored pressure type, Type 4A:40B:C, suitable for use on Class A, B, and C fires; or alternate type consistent with the degree of hazard, except as follows:

Train Control, and selected Communications Rooms-- Carbon dioxide or Clean Agent (CF_3CHFCF_3), 10B: C.

Fire extinguishers in traction power substations and A.C. switchboard rooms are to be located such that the maximum travel distance to any extinguisher will not exceed 50 feet.

14 .13.10 Fire Hydrants

A fire hydrant shall be located within 100 feet of fire department Siamese connection. Location shall not necessitate running fire hoses across a major or heavily-trafficked thoroughfare. Coordinate hydrant location with the local jurisdiction. Fire hydrants located in public right-of-way will be provided by the local jurisdiction. Water line of adequate size will be extended to the WMATA property line by the responsible jurisdiction.

14 .13.11 Fire Walls

The integrity of all fire walls shall be maintained at all penetrations of whatever sort, as for piping, conduits, ductwork, air intake, air exhaust or air relief openings, etc. Walls or floors that separate ancillary rooms from public areas or train tunnels shall be treated as fire rated; additionally, certain other walls may be designated fire wall in order to comply with applicable codes.

Fire dampers complying with the SMACNA Fire Damper Guide and all other applicable codes and standards shall be installed at all duct penetrations and at all other openings provided for the passage of air in fire walls except in the ductwork serving under platform exhaust system. The location of fire dampers shall be indicated on the contract drawings. Where fire dampers are installed in ducts, access panels will be provided to permit inspection and resetting of the fire dampers.

Where pipes or conduits penetrate a fire wall, the space between the sleeve and pipe or conduit shall be tightly packed with an approved noncombustible material of a rating equivalent to the wall or better. In all cases, there shall be full closure of the penetration in a manner as to preserve the fire rating of the fire wall.

14 .13.12 Fire Protection for Cleaner's Rooms, Toilet Rooms and All Ancillary Rooms Used for Operational/Office Areas

These rooms shall be provided with a sprinkler system for materials storage, NFPA ordinary hazard, Group 1. Sprinkler pipes are to be galvanized steel sch. 40. Use one ½" sprinkler head for floor area of 130 square feet or less and two or more sprinkler heads for greater area.

Sprinkler heads shall be uniformly located within the space, midway of the width of the room in cases where a single sprinkler head is required, and equally spaced where two or more sprinkler heads are required.

Sprinkler heads are to be of the fusible link type with temperature rating of 165 ^{0}F. An unmonitored OS&Y shut-off valve, a swing check valve and a flow detector switch are to be provided in the branch line to the sprinkler heads. OS&Y valve shall be easily accessible, be readily viewed from the room door, and sealed in the open position. A flow detector shall be located between the OS&Y valve and check valve. A ½" bronze angle hose valve is to be installed at the end of the sprinkler pipe. The flow switch is to be connected into the fire alarm circuit for the fire zone in which the room is located.

14 .13.13 Clean Agent Suppression Systems

Where fire suppression systems in rooms with mission critical electrical equipment are required by the local jurisdiction or in rooms where the value of the asset warrants, Clean Agent (FM-200 / CF_3CHFCF_3) systems shall be provided in accordance with NFPA 2001 Standards and as follows:

14 .13.13.1 Reserve supplies shall not be provided unless required by local jurisdiction.

14 .13.13.2 Clean Agent (FM-200 / CF_3CHFCF_3) storage shall be located near the protected room (storage may be in protected room if conditions make it
necessary).

14 .13.13.3 Each system shall be cross zoned for activation.

14 .13.13.4 Clean Agent System panel shall activate audible alarm, close dampers and shut off fan if either zone signal is received.

14 .13.13.5 When the second zone signal is received, Clean Agent System panel shall:

14 .13.13.5.1 Activate audible alarm.

14 .13.13.5.2 Start timer (O to 60 sec.).

14 .13.13.5.3 Discharge Clean Agent when timer times out.

14 .13.13.5.4 Activate "Clean Agent" visual alarm outside of each entrance to the room when Clean Agent is discharged.

14 .13.13.6 A manual by-pass fan switch shall be provided outside the protected room (for Fire Department use).

14 .13.13.7 Provide a manual Clean Agent release switch for the fire department use only.

14 .13.13.8 Provide backup battery power for the Clean Agent panel. Batteries shall be equipped with a trickle charger in accordance with NFPA 72.

14 .13.13.9 A remote reset switch shall be provided at a station supervising the system.

14 .13.13.10 Protected room doors shall swing out.

14 .13.13.11 Panic hardware shall be provided for protected room door latches.

14 .13.13.12 A standby clean agent storage tank connected to the system shall be provided where required by the local jurisdiction.

14 .13.13.13 In rooms where the equipment does not warrant a clean agent suppression system and a sprinkler system is not used due to the potential of leaks or faulty activation ruining equipment, a fire detection system shall be installed which is connected to a centrally monitored fire alarm control panel.

14 .14 PLUMBING

14 .14.1 Pipe and Fittings

14 .14.1.1 Soil pipe within the structure shall be pitched at 1/4" per foot, except soil pipe in invert running the length of the station shall be pitched at 1/8" per foot with one pipe size larger pipe.

14 .14.1.2 Domestic hot and cold water piping in the structure shall be copper tubing.

14 .14.1.3 Drainage pipe (for track drains and seepage drains) shall be perforated or unperforated as required.

14 .14.1.4 Force mains shall be mechanical joint, ductile iron pipe.

14 .14.1.5 Pipe for water service entrance shall be ductile iron, mechanical joint.

14 .14.1.6 Floor drains in Mechanical Equipment rooms may be connected to the track drains without venting.

14 .14.1.7 Minimum waste pipe size underground or in structural slab shall be 2".

14 .14.1.8 Electrolytic separation shall be provided for dissimilar metals.

14 .14.1.9 Cathodic protection for buried pipe shall be provided as required.

14 .14.1.10 Unless otherwise approved by the Authority, water, sewer and drainage pipes shall not be run through electrical equipment spaces.

14 .14.2 Roughing-in

Sleeves shall be provided in the structure to accommodate plumbing installations. Sleeves shall be provided in structural walls for the extension of the force main from the sewage ejector. Piping shall be run as directly as possible. All piping shall be run parallel to and at right angles to walls and partitions. Multiple pipes shall be grouped in parallel lines.

14 .14.3 Water Service

14 .14.3.1 At least four (4) inch diameter water service connection shall be provided to each passenger station, except where the fire protection standpipe system, including fire equipment cabinet connections, is completely dry. In this case, size for domestic service requirements with a minimum service connection of two inches. Each domestic service shall have a main shut-off valve immediately inside the structure wall.

14 .14.3.2

Fixture demand in GPM can be estimated from data in The International Plumbing Code, Washington Suburban Sanitary Commission Plumbing Code, or International Building Code (IBC), whichever is applicable.

The demand for outlets, (hose connections, cooling tower, make-up, etc.) which are likely to impose continuous demand, shall be estimated separately and added to the fixture demand GPM to determine the total demand.

14 .14.4 Hot Water Service

Hot water shall be supplied to all toilet and cleaner's rooms. Hot water shall be supplied by electric heaters. Heaters shall be installed at least six inches above floor. See Section 13.7.5 for electrical characteristics. Heater capacity shall be based on 100EF recovery and shall be sized in conformance with the fixtures installed which are to be served by the heater.

Provide relief valves in accordance with code requirements. Relief valve shall be piped to indirect waste.

Provide a reticulation system if supply piping is more than 100 feet long.

14 .14.5 Insulation and Freeze Protection

The following shall be insulated:

Water piping.

Portions of all water piping subject to freezing. Condenser water piping exposed to freezing temperatures shall be drained after the cooling season. Any remaining exposed sections which are not drained shall be heat traced to prevent freezing.

Portions of drainage and cold water piping subject to sweating. Hot

water heater, if not factory insulated.

Where freeze protection is required, use electric heating cable.

14 .14.6 Plumbing Fixtures

Provide number and types of fixtures as required by the applicable local plumbing code. One set of fixtures and accessories in each men's and women's washrooms shall be suitable for use by the physically handicapped and in compliance with local codes and ADA.

Mop service basins shall be of the floor-mounted type.

Provide one electric water cooler per station in heated area such as ancillary space. Electric water coolers shall be wall-mounted and hand-operated and ADA compliant.

Water supplied to lavatories and flush valve fixtures shall have water shock absorbing provisions.

Vacuum breakers shall be installed on all outlets with hose bib connections and submerged inlets.

In addition to the features listed above, plumbing fixtures shall also meet the following requirements:

Lavatories:	Self closing outlet devices 0.5 GPM Outlet temperature, 110 EF maximum Maximum hot water, 0.25 gallon/actuation
Showers:	3 GPM per shower head

All water supplies to fixtures shall have key operated service valves. Each connection shall carry the pressure recommended by the fixture manufacturer but not less than 15 psi for flush valves and 8 psi for other fixtures.

PLUMBING FIXTURE SCHEDULE

Symbol	Fixture	Soil/Waste	Trap	Vent	HW	CW	Remarks
WC	Water Closet	4”	Integral	2”	No	Yes	Wall Hung
UR	Urinal	2”	Integral	1 ½”	No	Yes	Wall Hung
LAV	Lavatory	1 ½”	1 ¼” x 1 ½ ”	1 ½”	Yes	Yes	Wall Hung
MSB	Mop Sink Basin	3”	3”	1 ½”	Yes	Yes	Set on Floor Slab
EW/ES	Eye Wash /Emergency Shower	1 ½”	*	*	Yes	Yes	Wall Hung
EWC	Electric Water cooler	1 ½”	1 ½”	1 ½”	No	Yes	Wall Hung

* Required only where connected to sanitary sewer.

Minimum Fixture Supply Pipe Sizes

Flush Valve Water Closet	1"
Flush Valve Urinal	3/4"
Lavatory	3/8"
Mop Service Basin	½"
Hose Bib	3/4"
Eye Wash Fountain and Body Spray	½"
Electric Water Cooler	½"

Where city water pressure is above 60 psi at water service room, provide reducing valve assemblies consisting of reducing valve, three-valve bypass, and strainer.

Emergency eye wash and body spray facilities shall be provided in chilled water plants, battery rooms, traction power substations, tie breaker stations, train wash buildings, and in any other areas where corrosive materials are handled or stored. Permanent fixture or facilities shall be stainless steel or galvanized. Portable eye wash and body spray facilities will be furnished and installed by the Authority; however, their locations are to be designated and a clear wall space of not less than 30" wide and 6'-0" high provided. Shields will be provided at both permanent and portable facility locations as required to protect electrical equipment from water spray. A minimum of 20 psi water flow pressure is to be provided to the permanent eye wash fountain and body wash facilities.

14 .14.7 Sewage Ejector Stations

Sewage Ejector stations shall utilize either sewage pumps or pneumatically operated pots.

14 .14.7.1 Pumping System

Sewage ejector pumping stations shall be of the duplex type and utilize vertical dry pit sewage pumps. Each pump shall have a capacity of 100 percent of the design load, minimum capacity of 50 gpm, and a total dynamic head (TDH) to suit the location. A sump pit and pump shall be provided in the dry pit and shall discharge to the wet well. Wet wells shall be sealed and vented per local codes. Wet well access shall be through a gas tight manhole. Sewage ejector pumping stations shall be controlled by a PLC with ModBus protocol, interfaced through a Human Machine Interface (HMI) with Ethernet communication for remote monitoring and e-mail server for alarm notification. Level detection shall be performed by ultrasonic level sensor with float switch backup. The pumps are to be cycled through an alternate duty assist algorithm. The controller shall record the number of pump starts, pump run time, volume discharge, and pump efficiency.

14 .14.7.2 Pneumatic System

Sewage ejectors pneumatic pumping stations shall consist of two stainless steel vessels/pots minimum 50 gallon capacity located in a dry pit. The vessels will be pneumatically operated to discharge sewage at a minimum of 50 gpm to the nearest sewer line with a total dynamic head (TDH) to suit the location. The system shall operate using two air compressors, an ASME air tank 200 gallon min., and a three way control valve. The dry pit shall contain a sump pit with a sump pump, pump to discharge into the incoming line on the vessel.

Pneumatic Sewage ejector stations shall be controlled by a PLC with ModBus protocol, interfaced through a Human Machine Interface (HMI) with Ethernet communication for remote monitoring and e-mail server for alarm notification. Level detection shall be performed by dual conductivity probes or sonar. The system shall operate by upon reaching a high level set point, the PLC will signal the three-way control valve to close off the tank vent and allow the stored air to fill the sewage receiver/pot and empty the contents. Receivers shall be regulated by a self-contained pressure reducing valve. When the level reaches the lower level set point the three-way control valve shall close off the air supply and open the vent. The PLC shall allow only one receiver to be pressurized and discharged thereby allowing the other receiver to receive sewage from the system.

14 .14.7.3 Dry Pits

Dry pits shall be provided with ladder access and covered with grating. Grating to be in sections to allow for one or two person removal. Ceiling mounted hoisting apparatus such as hook, beam, etc to be provided for sewage equipment removal and installation, hoisting apparatus capacity to be clearly identified. Float tree, sonar mounting, etc to be accomplished above pit in order to eliminate confined space requirements.

Electrical	
Characteristics	See Section 13.7
Ejector Discharge	Ejector discharge to the nearest sanitary or combined sewer shall be minimum four-(4) inch cast iron pressure pipe mechanical joint. Discharge velocity shall be 2.5 feet per second minimum, 7 feet per second maximum.

14 .15 AUTOMATED ENERGY MANAGEMENT SYSTEM

14 .15.1 General

The Automated Energy Management System (AEMS) utilizes Remote Terminal Units installed for transmission of data between field supervised and controlled facilities and a central location. Interface cabinets will connect field AEMS installation with Central Control Center thru RTU. Interface cabinets, accessories, sensors, transmitters, power supplies, instruments, piping and all interconnection wiring from each status, control and analog telemetry point to the AEMS interface cabinet shall be installed under station and line contracts. AEMS Interface panels shall be located in a manner which consolidates the greatest number of functions per cabinet and minimizes the total number of cabinets required.

AEMS status, control and analog telemetry points shall be in addition to the central control points identified as Data Transmission System (DTS) except for points associated with the Chiller Plant, which shall be connected only to the AEMS interface cabinet located in the Chiller Plant.

14 .15.2 Scope Station and Tunnel Sections

The AEMS shall provide the following functions in station and tunnel sections:

14 .15.2.1 ANALOG POINTS (4-20mA):

ACU Chilled Water Supply Temperature	DEG F
ACU Chilled Water Return Temperature	DEG F
ACU Chilled Water Flow	GPM
ACU Supply Air Temperature	DEG F
ACU Return Air Temperature	DEG F
Station Ambient Temperature	DEG F

14 .15.2.2 EQUIPMENT STATUS POINTS (Contact Closure):

ACU Fans	ON/OFF
Under Platform Exhaust Fans	ON/OFF
Dome Exhaust Fans	ON/OFF
Tunnel Ventilation Fans	ON/OFF
Unit Heaters, (larger than 10 kW)	ON/OFF
ACU Air Pressure Drop Across Filter	NORMAL/ABNORMAL
ACU Air Pressure Drop Across Coil	NORMAL/ABNORMAL

14 .15.2.3 HOA SWITCH STATUS POINTS (Contact Closure)

ACU Fans	AUTO/HAND
Unit Heaters (larger than 10 kW)	AUTO/HAND

14 .15.2.4 CONTROL POINTS (Contact Closure):

ACU Fans	ON/OFF
Unit Heaters (larger than 10 kW)	ON/OFF

14 .15.3 Scope Chilled Water Plants

The AEMS shall provide the following functions in chilled water plants:

14 .15.3.1 ANALOG POINTS (4-20mA):

Chiller Oil Temperature	DEG F
Chiller Chilled Water Supply Temperature	DEG F
Chiller Chilled Water Return Temperature	DEG F
Chiller Condenser Water Return Temperature	DEG F
Chiller Condenser Water Supply Temperature	DEG F
Chiller Chilled Water Flow	GPM
Chiller Refrigerant Purge Air Pressure	PSI
Chiller Condenser Refrigerant Pressure	PSI
Chiller Evaporator Refrigerant Pressure	PSI
Chiller Condenser Water Flow Diff. Pressure	PSI
Chiller Oil Pressure	PSI

Outdoor Temperature	DEG F
Outdoor Humidity	0-100%
Chiller kW Demand	KW
Chiller Plant Space Temperature	DEG F
Chiller Voltage	V

14 .15.3.2 STATUS POINTS (Contact Closure):

Chiller Motor	ON/OFF
Condenser Water Pump	ON/OFF
Chilled Water Pump	ON/OFF
Cooling Tower Fan	ON/OFF
Chiller Refrigerant Purge Air Pump	ON/OFF
Chiller	NORMAL/ABNORMAL
Chiller Condenser Water Flow	NORMAL/ABNORMAL
Control Air Pressure	NORMAL/ABNORMAL
Chiller Plant Space Temperature	NORMAL/ABNORMAL
Condenser Water Pumps HOA Selector Switch	HAND/AUTO
Chilled Water Pumps HOA Selector Switch	HAND/AUTO
Cooling Tower Fans HOA Selector Switch	HAND /AUTO

14 .15.3.3 CONTROL POINTS (Contact Closure):

Chiller Motor	ON/OFF
Condenser Water Pumps	ON/OFF
Chilled Water Pumps	ON/OFF
Cooling Tower Fans	ON/OFF

14 .15.3.4 ANALOG CONTROL POINTS (4-20mA):

Chiller Demand Limiting	0 – 100%
Chiller Chilled Water Temperature	DEG F

14 .15.3.5 PULSE ACCUMULATOR POINTS (Contact Closure):

Chiller Digital Power Meter	kWH

14 .16 SUPERVISORY CONTROL

14 .16.1 General

The Mechanical Supervisory Control System utilizes the Data Transmission System (DTS) installed by the Contractor / Train Control Sub Contractor for transmission of all data between field supervised and controlled facilities and the Command Center Room. The Central Supervisory Display and Control Console is also designed and installed under the Train Control stage contract. The design of the mechanical and train control systems must be closely coordinated, particularly with respect to interface details and locations.

14 .16.2 Scope

The mechanical systems shall be provided with remote surveillance and remote control capability. These systems shall be provided by the Contractor/Mechanical Sub Contractor with the specific items of electro mechanical equipment, as specified. The Contractor will furnish and install terminal strips in each AC Switchboard Room of every station, at each chilled water plant; and, if more than 300 feet from station limits including ancillary rooms, at each sewage ejector, at each drainage pumping station, at each tunnel fan shaft, and at each vent shaft if remote from the station, and jet fans in the tunnel sections. This terminal strip shall interface the mechanical work with the DTS. The Contractor/ Mechanical Sub Contractor shall provide connections from one side of the terminal strip to the equipment under surveillance or control and provide the necessary items including sensors, contactors, relays, analog to digital converters, external sinks, water level indicators and wiring to perform the indicated functions. The DTS functions shall be replicated and Ethernet communication be made available to the RTU for current and future transition to an Ethernet based system.

The contacts of the items connected to the DTS System shall be of the dry contact type which meets the requirements included in the Train Control and Mechanical Specifications.

The conditions which are measured and values transmitted shall be processed through analog-to-digital converters which shall transmit an updated seven-bit binary code signal to the appropriate terminals on signal from DTS for transmission to the control center.

The Remote Surveillance and Control Systems shall provide the following functions:

14 .16.2.1 The following items shall be remotely controlled from OCC:

Tunnel ventilation fans

Vent shaft dampers

Underplatform exhaust fans

Ceiling (dome) exhaust fans

Jet fans

14 .16.2.2 The following items shall be supervised and abnormal conditions shall be alarmed:

Tunnel ventilation fans and dampers, and jet fans

Underplatform exhaust fans

Ceiling (dome) exhaust fans

Platform and mezzanine air conditioning unit filters

Vent shaft dampers

Track drainage pump wet wells

Sump pumps in operationally critical locations

Fire water shut-off valve

Battery Room exhaust fan

Fire water flow

Sprinkler water flow

Station temperature (high limit only)

Tunnel temperature (high and low limit)

14 .16.3 Standards

The supervisory control equipment for mechanical functions shall embody modern designs which provide the highest degree of safety and reliability. Wherever applicable, design of equipment for these functions shall be in accordance with ANSI, NEMA and IEEE Standards and Specifications. The principles of these criteria shall be maintained where new devices or techniques are developed, even though the technicalities of the specifications do not envision these new devices and techniques.

14 .16.4 Equipment and System Interfaces

14 .16.4.1 Control Center Console:

The Operations Control Center located in the Operations Control Center Building will contain a Control Console which will give immediate alarm and visual indication of status changes or other abnormal conditions associated with the mechanical systems. This Control Console will be further equipped to provide the operating attendant with the capability of control. The specific mechanical systems indicate the scope of these criteria.

(Note: Additional functions of the Control Console are described in other sections of these-criteria.)

14 .16.4.2 Remote Terminals and Interface to DTS - Mechanical Facilities:

The Mechanical Sub Contractor shall be required to route and connect all supervisory control cabling from the devices to the interface terminal cabinets. The interface terminal cabinets will be located where indicated in the scope of this section of criteria.

14 .17 ELEVATORS

14 .17.1 General

Dual street elevator access and dual center platform elevators shall be provided - a minimum of two elevators per mezzanine shall be provided.

All are similar in appearance, but the doors vary to meet the different relationships that exist between surface, mezzanine, and platform. The cab shall have center opening door meeting ADA requirements.

Elevators will be furnished and installed by contractor. The Contractor will be responsible for the complete installation including the car, machinery, hoistway and car appurtenances including hoistway door framing and door, landing controls and indicators, buffers, hydraulic jacks and lines, car and counter weight, guide rails, rail brackets, car control and signal systems, car lighting and communications, car ventilation, provisions for fire/smoke sensor in car and intrusion alarm sensors on surface entrance hoistway doors.

The Designer shall design the ancillary spaces, hoistway (including pits and overhead structures), structural supports, machine rooms, electric services, and conduits for installation of the elevators.

There are several elevator types used in the system. The following classification of elevators are in use:

Hydraulic (Types I-IV)

Vertical rise shall not exceed 36 feet for the In-ground (Holed) elevators and shall have sufficient capacity to lift the rated load at 150 feet per minute.

Machine room can be remote from elevator if necessary

- Electronic soft-start shall be used on the pump motor.

Traction (Types VI-VIII)

Vertical rise over 36'-0"

Machine room must be overhead or adjacent to elevator

Traction elevators shall use closed-loop, AC variable voltage, variable frequency drive .

All are similar in appearance, but the doors vary to meet the different relationships that exist between surface, mezzanine, and platform. The cab shall have center opening door meeting ADA requirements.

Elevators will be furnished and installed by contractor. The Contractor will be responsible for the complete installation including the car, machinery, hoistway and car appurtenances including hoistway door framing and door, landing controls and indicators, buffers, hydraulic jacks and lines, car and counter weight, guide rails, rail brackets, car control and signal systems, car lighting and communications, car ventilation, provisions for fire/smoke sensor in car and intrusion alarm sensors on surface entrance hoistway doors.

The Designer shall design the ancillary spaces, hoistway (including pits and overhead structures), structural supports, machine rooms, electric services, and conduits for installation of the elevators.

14 .17.2 Codes and Regulations

See Section 14.11.2 Codes and Regulations.

14 .17.3 Number of Elevators

The number and types of elevators at each location will be as per Design Criteria and the project specification requirement provided by the authority.

14 .17.4 Location and Access

Generally, elevator entrances at the surface shall be located so that patrons will have direct access from public spaces.

Elevator landings at mezzanines and platform levels shall be located to permit as direct access as possible to entrance passageways, mezzanines or train platforms. Connecting corridors between elevator landings and passageways, mezzanines, or train platforms are to be avoided if possible. Where possible, elevator landings shall be designed so that patrons will be required to pass through the normal fare collection facility between the free area and paid area at the mezzanine level when entering or leaving the station. Direction signs and barrier free access paths leading to and from the elevators shall be provided in all cases.

14 .17.5 Elevator Environment

14 .17.5.1 Machine Room

Machine room entrances shall be sufficiently wide enough to allow installation and removal of the equipment.

Machine Room for the single elevator shall be 224 sq.ft minimum.

Clearance around equipment in each machine room shall comply with provisions of all applicable codes. Clear distance for the maintenance purposes shall be at least 18" between equipments. In no case shall this clearance supersede minimum Code requirements.

Machine rooms must be air conditioned and heated to maintain an ambient temperature of 50 F to 80 degrees F and a relative humidity between 35% to 50%. The heating system for the machine room is also a built in system. A forced removal should be done by moving the air from the room to the outside of the building to another part of the building to keep an air exchange through the equipment room. Intake and exhaust vent should not be located close to each other.

Minimum head room clearance of 7'-0" shall be provided under the HVAC equipment and ductwork. Where possible, the supply and exhaust ventilation for the HVAC system for the machine room shall be free of obstructions except for necessary grilles, screens or dampers. Fire dampers shall be provided at pierce points (openings) in the machine room walls, floor or ceilings. No water piping shall be allowed to run in any elevator machine rooms. Only equipment used directly in connection with the elevator shall be permitted in elevator machine room and hoistway. Where possible avoid locating elevator machine room under the platform.

14 .17.5.2 Car

The cabs shall be stainless steel, and the interior surfaces mar-resistant.

Cab floor cover shall be resistant to urine absorption and deterioration.
An exhaust fan will be provided to operate continuously when the elevator is in an operational mode.

Forced ventilation shall be provided on observation elevators with glass walls exposed to direct sunlight. There shall be a minimum air handling capacity to provide one air change per minute based on net inside car volume. An auxiliary power source capable of providing the minimum air handling capacity for a continuous period of at least 1 hour shall be provided on each elevator car.

A ventilation fan rated at 350 CFM will be provided by the Elevator Contractor in the car ceiling to provide car ventilation. Connect continuous ventilation fan to emergency power. Sixty (60) minute backup battery power for fan shall be provided.

14 .17.5.3 Hoistway

Hoistway in underground stations, from surface to mezzanine and/or Platform, shall be provided with mechanical ventilation intake and exhaust air vents where practical (one at the top and one at the bottom) with a minimum of three (3) square feet of free area for ventilation of hoistway to the outdoors.

Glass or metal solid panel as part of the hoistway enclosure shall be allowed. The front side of the hoistway shall be stainless steel cladding. In order to minimize particles entering to the hoistway, and protect the elevator from natural weather effect, metal mesh without solid panel shall not be used between terminal landings.

Metal parts visible to the public shall be stainless steel, or Hot-dipped galvanized

All interior elevator glass and stainless steel hoistway designs will maintain a minimum dimension of 7'8" from the finish paver tile to the underside of the horizontal structural steel tubing above the door header.

All exterior elevator hoistway designs shall maintain a minimum of 7'0" to the underside of the roof overhang and 7'2" to the underside of the horizontal structural steel tubing above the door header from the finished granite surface.

Concrete hoistways within stations will maintain "alcove" ceiling heights of horizontal structural members above the doorheaderat7'8"minimum from the finished paver tile as noted. For this hoistway configuration, all door surrounds and all structural supports will be provided by the contractor/ elevator sub-contractor. The contractor shall be instructed to affix temporary safety closure full width and height of hoistway opening until the time elevator installation start.

All paver tile and granite floor finishes will be completed by the contractor. The contractor will caulk the completed sides of the hoistway.

The Designer shall ensure that any structural projections on the hoistway interior are shown to be finished with appropriate angled projections per ASME A17.1 requirements.

The contractor will provide elevator pit and head house lights and receptacles and the pit ladder.

For parking garages or observation elevators where the hoistwayare enclosed by glass and stainless steel cladding, exposed to direct sunlight, a forced ventilation system with an exhaust fan and an air intake louver shall be provided to maintain one air change per minute based on net inside car volume . An auxiliary power source capable of providing the minimum air handling capacity for a continuous period of at least 1 hour shall be provided on each elevator car (see ASME A17.1, paragraph 2.14.2.3.3). The fan shall be controlled by a thermostat located in the hoistway.

14 .17.6 Weatherproofing

Elevators shall be designed to operate while exposed to the natural elements of weather, including sunlight, rain, snow, slush, salt; all condition of relative humidity, de-icing chemicals, debris, airborne dust, and corrosive elements. The elevators shall have a special winter operation and operate in the event the outside temperature falls below a pre-established minimum value.

All elevator installations and/or components exposed to the elements shall be provided with weather protective features such as:

Waterproof construction

Wind and rain screening

Rust resistant properties or coatings

Non-slip paving surfaces

Weatherproof electric wiring

14 .17.7 Duty

Elevators will be designed for continuous duty with a 4,500 pounds capacity.

Hydraulic elevator operating speed will be one hundred fifty (150) feet per minute. Electric elevator operating speed will be three hundred (300) feet per minute, minimum. The rated load for the car will be determined from the inside net platform areas shown by the Contract Drawings and the application of National Standard Code formula rules.

In addition, the mezzanine-to-platform elevators will be designed to support a 1260 pound cart, with the load distributed on four (4) wheels.

14 .17.8 Space and Physical Requirements

14 .17.8.1 Space -Space provisions and dimensions for elevator penthouses, hoistways, hoistway enclosures, and machinery rooms shall be as shown on Design Drawings. Queuing areas, building set-backs, foyers, and corridors (where necessary) serving the elevators shall be as shown on architectural drawings and as required by local jurisdictions. See Section 9.5.19.

14 .17.8.2 Hoistways - All hoistways shall be vertical unless specifically approved otherwise. Hoistways and hoistway pits shall be designed to accommodate elevator appurtenances (*ladders*, overhead beams, hoistway doors, car guide rails and rail brackets, buffers, hydraulic cylinder installations, pit ladders, sump pump, etc.) and to provide sufficient support for the various static and impact loads which may occur.

14 .17.8.3 Machine rooms - machine rooms for electric type elevators shall be located above the elevator hoistway or immediately adjacent to the top of the hoistway unless this location is not feasible in which case the machine room may be adjacent to the bottom of the hoistway. Elevator machine rooms may be located immediately adjacent to and near the bottom or top of the hoistway. Approval of the Authority shall be obtained for any machine room. Machine rooms for hydraulic type elevators shall be located as close as practicable to the hoistway Machine rooms for electric and hydraulic elevators may be built to accommodate the machinery for more than one elevator. In all cases, access means shall be provided to machine rooms for maintenance services and for equipment installation. Machine room doors shall open outward and shall be hollow metal, 1-1/2 hour fire rated doors with a Class B label, self-closing and self-locking. Locks are to be always operable from the inside without a key.

14 .17.8.4 Hydraulic lines - In all cases, design means for passage (embedded conduit, sleeves, trenches, etc.) of rigid hydraulic pipe lines from the elevator machine room to the hoistway pit shall incorporate features which will permit the initial installation of the hydraulic pipe line by the

Elevator Contractor, also allowing for periodic piping inspections as well as the subsequent removal and replacement of the entire line or any portion thereof without a removal of any components or affecting the structures. Design shall provide that the hydraulic line not run exposed in public areas, train rooms, or train tunnels.

14 .17.8.5 Structures - For structural design and construction of elevators and related structures such as hoistways, pits, and machine rooms, etc., see Section 15.15 - Structural, of this Manual and Structural Design Drawings.

14 .17.8.6 Travel - In general, Hydraulic elevators will be used in cases where the elevator travel is thirty-six 36) feet or less. Electric elevators will be used where the travel of the elevator exceeds a nominal thirty-six 36) feet. Electric elevators, unless otherwise noted, shall be overhead traction types with 1:1 roping.

14 .17.9 Car Control and Operation

14 .17.9.1 Elevator Controls - Non-proprietary micro-processor/PLC controllers shall be used. Door control features will include automatic door opening and closing with nudging operation, adjustable door hold-open time, car door electric contacts, and hoistway - unit system hoistway-door interlock. All devices or controls for use by patrons at landing and inside shall be in accordance with ADA requirements. These will be clearly marked and designed so that their function can be identified by all patrons including those with sight impairment. An emergency stop key switch will be provided inside the car for use by authorized personnel only. Code-compliant car-top inspection operation shall be provided. Elevators shall be equipped with a fault display to automatically show the operation of the elevator and the activation of each safety device. The fault display shall be visible through the controller cabinet door, without opening the door.
The elevator controller shall be capable to operate in ambient temperatures from +32° F to 140° F and relative humidity of up to 90%. However the air conditioner on controller cabinet shall maintain the operating temperature in range of 50º F to 80˚F. The controller shall be mounted in a NEMA 4X stainless steel cabinet within the controller machine room.

14 .17.9.2 Elevator Operation

The elevator will be equipped with a selective collective type automatic control system. The car will remain at the last landing served until summoned for service by the next patron. Two-stop elevators shall have an automatic dispatching operation include “Step-in-and-Go”. The calls for the opposite landing is set when the elevator opens its doors for a hall call. The door to the elevator will normally be closed until the elevator is summoned. All doors will be power operated and controlled by a closed loop, electronic operator with door speed and torque independently adjustable. Doors will be single-speed, center opening except when limited by dimensions. Two-speed, offset doors may then be used. The automatic dispatch system shall be provided, if a group of elevators are serving the same landings. At least one elevator shall be at each landing when there is no call registered. The group of elevators shall then be at the designated parking floor after a specified time.

14 .17.9.3 Elevator Car and Hall Station Fixtures

Elevator Car Control Panel and Hall Station Control Panel fixtures shall meet all current national fire service codes including ASME A17.1, ASME A117.1, and ADA requirements. Fixtures shall be vandal-resistant with illuminating LEDs on the buttons and hall lanterns. Floor indicator push buttons in Cars and Hall Station call buttons shall be metallic, impact- and pry-resistant with a center illuminating light and a finish that contrasts with the surrounding control panel finish. Car operating stations shall contain Braille plates adjacent to each call button.

Hall Station: Provide the extended/vertical hall call station, single push button fixture at each terminal landing and button fixture having push buttons with UP and DOWN legends at intermediate landings. The Push Buttons shall be flush, round, have a Metalized Halo and center jewel. The metalized halo shall be from different color. Braille Indicator Plate shall be provided. The arrow design shall meet the criteria laid out in WMATA's Manual of Graphic Standards.
An arrow indication included in the floor identification plate adjacent to the call button, as shown in FIGURE 14.1. Use manufacturer's standard symbols.

Car Control Panels:

The Car Control Panel shall be a vertical type with stainless steel finish, layout inside the cab shall be designed as required by the ASME A17.1 Code and ADAAG and logically configured so that the floor indicator push buttons are arranged in a vertical fashion or in columns for elevators traveling to multiple floors. Upper floor buttons shall be mounted above lower floor buttons. Buttons for DOOR-OPEN, DOOR-CLOSE, ALARM, EMERGENCY PHONE call functions as well as "Hands-free" ADA compliant telephone/intercom for emergency communication shall be incorporated.

Car Operation Station shall have a locked service cabinet for keyed switches of the car light; exhaust fan, independent operation, GFI duplex outlet and other "Non Public" key switches.

See FIGURE 14.1.

Hall station panels:

Hall station panels with "Up" and "Down" call buttons shall also be arranged with the "Up" button on the top and the "Down" button below it. Call buttons shall be grouped together on the panel separate from other fixtures on the panel and closest to the door opening if applicable. The vertical arrangement hall station shall be provided. Hall stations shall contain

Braille plates adjacent to each call button.

14 .17.10 Kiosk Control, Indications and Operations

Controls will be provided by the Elevator Contractor at the designated Major Elevator Kiosk to enable placing each elevator out of service; holding each elevator at any given landing opening and holding the doors of the elevator at any given landing; and car override control. Each of the above controls will normally take effect with the same priority as the landing and car controls. If the override control is actuated, the elevator will respond only to the kiosk controls and the override key switch located at every hall call station. The override control will not preempt the elevator safety controls. The station Major Elevator Kiosk will be equipped by the Elevator Contractor with an elevator status system which will provide a visual display of elevator car status. The functions shown will be landing stopped at, direction of travel, landing being approached, indication of "Out of Service" due to a malfunction, and "Car Stopped" due to activation of "Stop" control button bar car patron. In addition, the kiosk will be equipped with those display indications specified under Paragraph 12, Detection System.

14 .17.11 Communications

An intercom station will be provided by the Elevator Contractor in each car, at each outside entrance landing and at each platform landing to permit two-way voice communication between the station occupants and the kiosk attendant. Depressing a momentary contact push button a teach intercom station will activate both audible and visual indicators in the kiosk. By depressing a pushbutton in the kiosk, a two-way voice communication link shall be established. Communication in the cab must rollover to a 24-hour manned site if the kiosk does not respond to a call. In case the two way communication drops, the system shall include the means allowing the central office to establish the two way communication to the car.

Conduit shall be provided in surface elevator hoistways to permit the future installation of surveillance CCTV equipment.

The two way communications means within the car shall include a means to verify operability of the telephone line. Verification of the line shall be automatically performed at least on a daily basis and shall not require activation of the two way communication link.

14 .17.12 Detection Systems

14 .17.12.1 Smoke and Fire

The elevator hoistway and machine room will be equipped with smoke and fire detectors. The Elevator Contractor will connect the smoke and fire detector in the elevator car to an interface terminal panel installed in the elevator machine room. Connections between the interface panel and the Station Fire Detection System will also be connected by the Station

Contractor. The elevator hoistway and machine room that contain combustible hydraulic fluids shall be equipped with automatic sprinklers. The station kiosk attendant will receive a visual display and audible alarm if any temperature or ionization detector is actuated. Simultaneously, an alarm signal that a fire or smoke condition exists at the station will be transmitted via the data transmission system to the Command Center. See Section 14.13 , Fire Protection. Machine room and elevator lobby alarm signals shall be provided to the elevator controller to allow Code Compliant Fire Service operation.

14 .17.12.2 Intrusion

The elevator hoistway door at the surface and the elevator machine room door will be equipped with intrusion alarm sensors to detect unauthorized entry. In the event any intrusion alarm sensor is actuated, the kiosk attendant will receive a visual display and audible alarm and an "Intrusion Alarm Signal" will be transmitted to the Command Center via the data transmission system. The intrusion alarm sensor on the hoistway door will be by the Elevator Contractor while the sensor on the machine room door will be installed by the Communications Contractor. The sensors will be connected by the respective contractor to an interface panel installed in the machine room by the communications Contractor. Connections between the interface panel and the Station Intrusion Detection System will be by the Communications Contractor.

14 .17.13 Safety

14 .17.13.1 Fire Resistant Materials

Fire resistant noncombustible materials and fire resistant construction methods shall be utilized and in all cases shall conform to governing code requirements and recognized standards, except for glass materials.

14 .17.13.2 Car Safeties

Car safeties will be provided in accordance with the requirements of governing codes and standards.

14 .17.13.3 Materials and Construction Properties

The physical properties and related design allowances for all materials and construction of all elements of the elevator installation shall meet or exceed those specified in governing codes and recognized standards.

14 .17.14 Electrical services

See Section 13.7.16, Electrical Services Requirements for Elevators.

14 .17.15 CLEARANCE TO INSTALLATIONS

A minimum of two inches is required between any fixed installations (e.g. pipes, pipe hangers, pipe supports, signals, luminaries, etc.) and the design vehicle dynamic outline. This is defined by the clearance envelop (refer to Section 8, Design Policies). However, installations shall be so dimensioned and located that maximal distances are obtained between these and clearance envelope along tangent and curved alignments.

14 .18 MAINTAINABILITY AND CONSTRUCTABILITY

The design of mechanical systems and equipment installations shall be coordinated with structural, electrical, architectural and other disciplines for the purpose of insuring adequate space, clearances, structural support, and non-interference with other trades during construction. Designs shall incorporate access to mechanical equipment for maintenance. Maintenance operations will include inspection, adjustments, cleaning, trouble shooting, servicing, repairs and replacement of mechanical equipment. A minimum clearance of 18 inches shall be maintained between equipment that requires access for maintenance and inspection. The selected equipment shall be subject to minimal system component failure.

All mechanical equipment shall be located and mounted to provide proper access and clearance requirements as identified by code and manufacture in order to perform routine maintenance and servicing of equipment. Required clearances shall be maintained to allow for equipment install and removal and shall be marked on the floor to ensure clearances are maintained.

14 .18.1 Space and Accessibility

Sufficient working space and adequate access shall be provided for the maintenance and replacement of all mechanical equipment. Ensure clearances identified by code or manufacturer are maintained. This requirement shall include adequate space for movement of equipment during initial installation, and during subsequent maintenance involving removal and replacement of failed equipment. Required clearances shall be marked on the floor with paint and stripping to ensure clearances are maintained.

Equipment mounted above floor or suspended from ceiling shall have a clear area below equipment to provide direct access to equipment. No ductwork, piping, conduit, etc shall be located below the equipment thus preventing or hindering access. In addition, the floor area below the equipment shall be clear of other equipment, housekeeping pads, etc to allow for proper access.

14 .18.2 Specific Requirements

Mechanical system designs shall be in accordance with the following requirements:

14 .18.2.1 Mechanical equipment such as large fans, vent and fan shaft dampers, etc. mounted 8 feet or more above the finish floor shall be provided with work platforms. Fixed ladders shall be provided to all work platforms. The mechanical equipment in this category shall include any items which require frequent servicing or contain large components or require large replacement parts.

14 .18.2.2 When an elevator drive machine is located inside of the hoistway, a direct access to the machine area shall be provided from the outside of the hoistway and shall be indicated on the contract drawings.

14 .18.2.3 Chain operators shall be provided for chilled and condenser water valves mounted 8 feet or more above the finish floor.

14 .18.2.4 Chiller tube pull spaces shall be indicated on the contract drawings and shall be marked on the floor with paint and stripping to ensure clearance is maintained.

14 .18.2.5 Filter, coil, fan motor assemblies, etc. pull spaces shall be indicated on the contract drawings and shall be marked on the floor with paint and stripping to ensure clearance is maintained.

14 .18.2.6 Special requirements (e.g. cooling tower drive shaft pull space) shall be considered and called out on the contract drawings as required.

14 .18.2.7 Equipment shall not be suspended over floor mounted equipment or pits in a manner which prevents access to the suspended unit.

14 .18.2.8 Locations where mechanical equipment is placed on the roof of a facility and require routine maintenance shall have roof access via stairs and a door onto the roof. This allows maintenance personnel to safely access the roof with their required tools and mechanical equipment parts such as filters, motors, belts, etc. Facilities where roofs are located at various heights shall have permanent stairs to access different levels.

A non-freeze hydrant(s) shall be provided on the roof at locations where mechanical equipment such as coils, etc require periodic cleaning. A Non-freeze hydrant shall be provided within 75 ft of all mechanical equipment requiring periodic cleaning.

14 .19 MECHANICAL REQUIREMENTS FOR BUS FACILITIES (Moved to Section 6.26)

14 .20 LEGACY DTS CONTROL FUNCTIONS (TO BE REPLACED BY SCADA CONTROLS IN SECTION 28)

TABLE II, ELECTRICAL AND SUPPORT EQUIPMENT CONTROLS

GROUP	NO.	FUNCTION NAME
Traction Pwr.	1A	AC INC LINE BRK (No.) CLOSED
Traction Pwr.	1B	AC INC LINE BRK (No.) TRIP
Traction Pwr.	1C	AC RECT TRANS FDR BRK (No.) CLOSED
Traction Pwr.	1D	AC RECT TRANS FDR BRK (No.) TRIP
Traction Pwr.	1E	DC FDR TIE BRK (No.) CLOSED
Traction Pwr.	1F	DC FDR TIE BRK (No.) TRIP
Ventilation	2A	FANS (No.) EMERGENCY OFF
Ventilation	2B	FANS (No.) EMERGENCY ON
Ventilation	2C	FANS (No.) AUTOMATIC ON
Ventilation	2D	FANS (No.) SUPPLY
Ventilation	2E	FANS (No.) EXHAUST

TABLE IV, ELECTRICAL AND SUPPORT EQUIPMENT INDICATIONS (2 BITS)

Group	No.	Function Name
Traction Power	1Ai	AC INC LINE BRK (No.) CLOSED
Traction Power	1Aii	AC INC LINE BRK (No.) TRIP
Traction Power	1Bi	AC SEC TIE BRK (No.) CLOSED
Traction Power	1Bii	AC SEC TIE BRK (No.) TRIP
Traction Power	1Ci	AC RECT TRANS FDR BRK (No.) CLOSED
Traction Power	1Cii	AC RECT TRANS FDR BRK (No.) TRIP
Traction Power	1Di	AC FDR BRK, AUX PWR TRANS (No.) CLOSED
Traction Power	1Dii	AC FDR BRK, AUX PWR TRANS (No.) TRIP
Traction Power	1Ei	DC RECT BRK (No.) CLOSED
Traction Power	1Eii	DC RECT BRK (No.) TRIP
Traction Power	1Fi	DC FDR TIE BRK (No.) CLOSED
Traction Power	1Fii	DC FDR TIE BRK (No.) TRIP
Traction Power	1Gi	TRANS OVER TEMP (No.) NOR/OFF
Traction Power	1Gii	TRANS OVER TEMP (No.) ABN/ON
Traction Power	1Hi	RECT OVER TEMP (No.) NOR/OFF
Traction Power	1Hii	RECT OVER TEMP (No.) ABN/ON
Traction Power	1Ii	RECT TRAINS LOCKOUT (No.) NOR/OFF
Traction Power	1Iii	RECT TRAINS LOCKOUT (No.) ABN/ON
Traction Power	1Ji	AC INC LINE VOLTS (No.) NOR/OFF
Traction Power	1Jii	AC INC LINE VOLTS (No.) ABN/ON
Traction Power	1Ki	AC SUPPLY (No.) TO SWGR FAIL NOR/OFF
Traction Power	1Kii	AC SUPPLY (No.) TO SWGR FAIL

ABN/ON

TABLE IV, ELECTRICAL AND SUPPORT EQUIPMENT INDICATIONS (2 BITS)

Group	No.	Function Name
Traction Power	1Li	AUX PWR TRANSFER SW (No.) NOR/OFF
Traction Power	1Lii	AUX PWR TRANSFER SW (No.) ABN/ON
Traction Power	1Mi	BAT CHARGE RLY (No.) NOR/OFF
Traction Power	1Mii	BAT CHARGE RLY (No.) ABN/ON
Traction Power	1Ni	AC FDR BRK, AUX PWR TRANS TEMP NOR/OFF
Traction Power	1Nii	AC FDR BRK, AUX PWR TRANS TEMP ABN/ON
Traction Power	1Oi	AC GROUP NOR/OFF
Traction Power	1Oii	AC GROUP ABN/ON
Traction Power	1Pi	RECT GROUP NOR/OFF
Traction Power	1Pii	RECT GROUP ABN/ON
Traction Power	1Qi	BATTERY CHARGE GROUP (No.) NOR/OFF
Traction Power	1Qii	BATTERY CHARGE GROUP (No.) ABN/OFF
AC Svc. Room	2Ai	AC INC LINE BRK (No.) CLOSED
AC Svc. Room	2Aii	AC INC LINE BRK (No.) TRIP
AC Svc. Room	2Bi	AC SEC MAIN BRK (No.) CLOSED
AC Svc. Room	2Bii	AC SEC MAIN BRK (No.) TRIP
AC Svc. Room	2Ci	AC SEC TIE BRK (No.) CLOSED
AC Svc. Room	2Cii	AC SEC TIE BRK (No.) TRIP
AC Svc. Room	2Di	AC TRANS OVER TEMP (No.) NOR/OFF
AC Svc. Room	2Dii	AC TRANS OVER TEMP (No.) ABN/ON
AC Svc. Room	2Ei	BATTERY ROOM EXHAUST FAN (No.) NOR/OFF
AC Svc. Room	2Eii	BATTERY ROOM EXHAUST FAN (No.) ABN/ON

TABLE IV, ELECTRICAL AND SUPPORT EQUIPMENT INDICATIONS (2 BITS)

Group	No.	Function Name
AC Svc. Room	2Fi	AC EMERG TRANSFER SW (No.) NOR/OFF
AC Svc. Room	2Fii	AC EMERG TRANSFER SW (No.) ABN/ON
AC Svc. Room	2Gi	AC BAT CHARGE RELAY (No.) NOR/OFF
AC Svc. Room	2Gii	AC BAT CHARGE RELAY (No.) ABN/ON
Misc.	3Ai	INVERTER OUTPUT (No.) NOR/OFF
Misc.	3Aii	INVERTER OUTPUT (No.) ABN/ON
Misc.	3Bi	FANS (No.) EMERGENCY OFF
Misc.	3Bii	FANS (No.) EMERGENCY ON
Misc.	3Di	THIRD RAIL HEATER (No.) ON
Misc.	3Dii	THIRD RAIL HEATER (No.) OFF

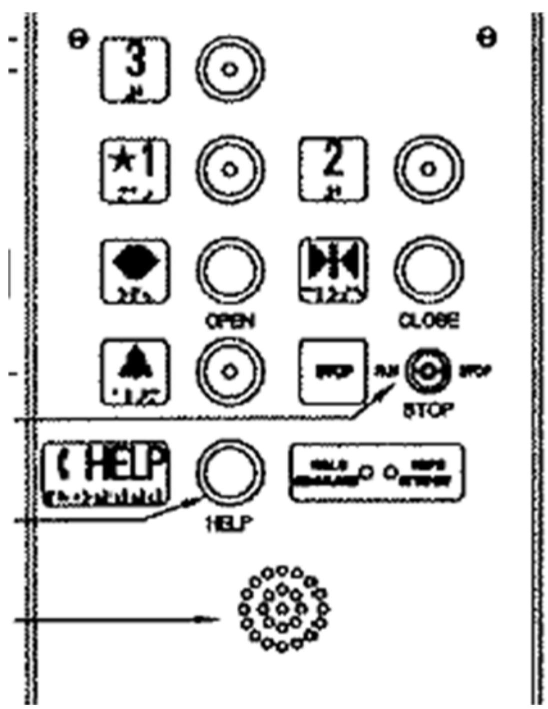
TABLE V ELECTRICAL AND SUPPORT EQUIPMENT - INDICATIONS (1 BIT)

Group	No.	Function Name
Tunnel	1A	FANS (No.) SUPPLY
Tunnel	1B	FAN SHAFT DAMPER (No.) ABN/ON
Tunnel	1C	VENT SHAFT DAMPER (No.) ABN/ON
Tunnel	1D	FANS (No.) OPERATION ABN/ON
Tunnel	1E	FANS (No.) REMOTE CONTROL ABN/ON
Tunnel	1F	TUNNEL TEMP. (No.) HIGH ABN/ON
Tunnel	1G	TUNNEL TEMP. (No.) LOW ABN/ON

Station2A STATION AMBIENT TEMPERATURE ABN/ON

Station	2B	ACU FAN (No.) ABN/ON
Station	2C	FRESH AIR AHU FAN (No.) ABN/ON
Misc.	4A	SUBWAY DPS (No.) ABN/ON
Misc.	4B	SEWAGE PUMP (No.) AIR ABN/ON
Misc.	4C	FVD WARNING ACTIVE/ON
Misc.	4D	FVD ALARM ACTIVE/ON
Misc.	4E	FIRE ALARM (No.) ACTIVE/ON
Misc.	4F	UNAUTHORIZED ENTRANCE (No.) ACTIVE/ON
Misc.	4G	BLDG AMBIENT TEMP. ABN/ON
Misc.	4H	SUMP PUMP (No.) ABN/ON
Misc.	4I	GARAGE EXHAUST FAN (No.) ABN/ON

FIGURE 14.1



SECTION 15 - STRUCTURAL

15.1 GENERAL

These criteria shall govern the analysis and design of all structures which are part of the Washington Metropolitan Area Transit Authority (WMATA) system, including structures which are auxiliary to the system or support the system.

15.1.1 DESIGN LIFE - It is the intent of the Authority that all structures provide a minimum design life of 100 years. Prestressed Parking Garage Structures shall have a minimum design life of 50 years. All structural details shall be prepared with these durability requirements. Prediction of life of concrete structures may be performed using the guidelines of American Concrete Institute (ACI) 365.

15.1.2 INSPECTION AND MAINTENANCE - Structural configuration and details shall permit reasonable access and a fall protection system required for inspection and maintenance consistent with the requirements of the structure in question. Fall protection design shall be in compliance with OSHA requirements.

15.1.3 DESIGN RESPONSIBILITIES - Design responsibilities shall be as defined in the contract documents. In this section, whenever Section Designer/Design Engineer is mentioned it will also mean the Engineer of Record of the design/build contractor team.

15.1.4 OCCUPANCY (RISK) CATEGORY OF BUILDING AND OTHER STRUCTURES - All buildings and other structures in WMATA system including auxiliary or supporting structures shall be classified as Occupancy (Risk) category III for Flood, Wind, Snow, Earthquake, and Ice loads per IBC (ASCE 7).

15.2 DESIGN CODES, MANUALS AND SPECIFICATIONS

In addition to the requirements stipulated in this “Manual of Design Criteria”, structural design shall also be governed by the ***Applicable*** Edition of the following codes, manuals or specifications. Unless noted otherwise, most stringent criteria as delineated in the “Manual of Design Criteria” or in the applicable code(s) shall be used. ***Applicable Edition*** of a code shall mean the most current edition published at the time of initiation of design, edition of code per jurisdictional requirement, edition of code required per contract documents, edition of code negotiated with WMATA representative, or edition of code used for design of an existing structure.

15.2.1 Design Codes

15.2.1.1 "Manual for Railway Engineering" (published by American Railway Engineering and Maintenance-of-Way Association (AREMA)), hereinafter referred to as the AREMA Manual.

15.2.1.2 American Association of State Highway and Transportation Officials (AASHTO) Specifications including the Standard Specifications for Highway Bridges 17th Edition, hereinafter referred to as the AASHTO Code, and other pertinent AASHTO codes and specifications.

15.2.1.3 "International Building Code" (published by the International Code Council) with Local Jurisdictional Amendments - hereinafter referred to as IBC or IBC Code.

15.2.1.4 "Manual of Concrete Practice" published by the American Concrete Institute, hereinafter referred to as ACI, including the "Building Code Requirements for Structural Concrete (ACI-318) and Commentary (ACI 318R)" hereinafter referred to as the ACI 318 Code.

15.2.1.4.1 For above ground concrete structures (plain concrete, reinforced concrete, precast concrete, and prestressed concrete), other than bridges or structures subject to railroad, highway or Metro loading, the latest edition of the ACI "Building Code Requirements for Reinforced Concrete(ACI 318)" shall be used.

15.2.1.4.2 For all underground concrete structures or earth retaining structures, ACI 318-99 containing the "Alternate Design Method" shall be used. The proposed design method shall be coordinated with the Authority before starting the design.

15.2.1.5 "Manual of Steel Construction - Allowable Stress Design" by American Institute of Steel Construction, Inc., hereinafter referred to as the AISC Code.

15.2.1.5.1 For structural steel structures, other than bridges or any structures subjected to railroad or highway loading, the current edition of the "Manual of Steel Construction Allowable Stress Design" of the American Institute of Steel Construction, hereinafter referred to as the AISC Code.

15.2.1.5.2 For parking structures, composite structural steel and concrete construction shall not be used. Stay in place steel form construction shall not be used as a structural element. See Sections 15.9.3.2.3 and 15.21for parking structures.

15.2.1.6 The current edition of the "American Society of Civil Engineers Minimum Design Loads for Building and Other Structures", hereinafter referred to as the ASCE 7.

15.2.1.7 In addition to the above, "The latest Building Codes of the local jurisdiction, supplemented by any WMATA requirements, shall apply."

15.2.1.8 "National Design Specification for Wood Construction" of the National Forest Products Association shall apply for timber structures, other than railroad or highway bridge.

15.2.1.9 Cast Iron – For cast iron structures, the current edition of "The Gray Iron Castings Handbook" of the Gray Iron Founders' Society.

15.2.1.10 American Welding Society (AWS) Structural Welding Codes D 1.1, D 1.4 and D 1.5.

15.2.1.11 Any design methods or special applicable requirements or codes, not listed above or in WMATA Design Criteria shall require prior WMATA approval. The independent professional engineer shall at no expense to WMATA, review all components of structures, materials specifications, design concept, calculations, and construction procedures, for compliance with WMATA criteria. If the independent professional engineer finds the alternate method/code meets WMATA criteria and submits a formal evaluation report, the proposed method/code maybe considered. The report shall include two as-built documents (drawings, calculations and specifications) on transit rail system projects.

15.2.2 Other Design Criteria - For designs not covered by the design codes in 15.2.1 above, the following shall be used:

15.2.2.1 Railroad Bridges - For bridges, which support railroad loading, the design requirements of the applicable railroads. In the absence of such requirements, the current edition of the AREMA Manual, per Section 15.2.1.1.

15.2.2.2 Highway Bridges - For bridges, which support highway loading, the design requirements of the applicable jurisdiction. In the absence of such requirements, the current edition of the AASHTO Code, per Section 15.2.1.2.

15.2.2.3 Earth Embankments - For earth structures, the AREMA Manual.

15.2.2.4 Concrete - For above ground concrete structures (plain concrete, reinforced concrete, precast concrete, and prestressed concrete), other than bridges or structures subject to railroad, highway or Metro loading, the latest edition of the ACI "Building Code Requirements for Reinforced Concrete(ACI 318)" shall be used. For all underground concrete structures and earth retaining structures, ACI 318-99 containing the "Alternate Design Method" shall be used. The proposed design method shall be coordinated with the Authority before starting the design.

15.2.2.4.1 The minimum concrete cover for reinforcement in the platform slab (cast-in-place, precast or prestressed concrete) shall not be less than 1½ inches in any cases.

15.2.2.5 Structural Steel

15.2.2.5.1 For structural steel structures, other than bridges subjected to railroad or highway loading, AISC Code (see Section 15.2.1.5).

15.2.2.5.2 For parking structures, composite structural steel and concrete construction shall not be used. Stay in place steel form construction shall not be used. See Sections 15.9.3.2.3 and 5.21 for parking structures.

15.2.2.6 Timber-For timber structures, other than bridges subjected to railroad or highway loading, the current edition of the "National Design Specification for Wood Construction" of the National Forest Products Association

15.2.2.7 Cast Iron - For cast iron structures, the current edition of "The Gray Iron Castings Handbook" of the Gray Iron Founders' Society.

15.2.2.8 Concrete Crash Wall Design - For highway bridge piers located adjacent to WMATA tracks or for WMATA bridge piers located adjacent to railroad tracks, refer to AREMA Manual, Section 2.1.5. Collision force used shall be as specified in AASHTO LRFD Article 3.6.5.1.

15.2.2.9 All piers and abutments located within a distance of30 feet to the edge of roadway shall be protected as specified in AASHTO LRFD Article 3.6.5.1.

15.2.2.10 Unless otherwise instructed, precast concrete construction for station and facilities, except parking garage, shall not be used.

15.2.2.11 For Pedestrian Bridges, LRFD Guide Specifications for the Design of Pedestrian Bridges. See section 15.3.2.4 for live load.

15.3 LOADS AND FORCES - The rapid transit structures shall be proportioned for the following loads and forces when they exist:

15.3.1 Dead Load (DL)

15.3.1.1 Structures Constructed by Cut and Cover Methods:

15.3.1.1.1 The dead load for structures constructed by cut and cover methods shall consist of the weight of the basic structures, the weight of secondary elements permanently supported by the structure, and the weight of the earth cover supported by the top of the structure and acting as a simple gravity load.

15.3.1.1.2 The design shall consider the application of the dead load to represent all the construction sequence and stages. For example, removal of the earth cover from a prestressed concrete span at some future date may create a serious upward deflection problem and should be analyzed as a separate loading case.

15.3.1.1.3 The design unit weight of earth, both above and below the groundwater table, shall not be less than 130 pcf. In making calculations with regard to dead weight resisting flotation of the structure, the actual unit weight of backfill placed over the structure shall be used. In those cases where full hydrostatic pressure below the groundwater table is used as a design load, a submerged design unit weight of not less than 68 pcf shall be used for earth below the groundwater table.

15.3.1.2 Earth and Mixed Face Tunneled Structures - The loads for earth tunnels, mixed face tunnels, and cut and cover structures shall be as given in the Designer's Geotechnical Design Report (GDR) approved by WMATA. For construction and short term loading cases with lesser lateral loads, refer to the GDR and Figure 15.17, whichever governs. The overburden should include any weight of existing structures or other elements, permanently supported by tunneled structure. Also, the unit weight of earth shall not be less than 130 pcf, except the actual weight of earth should be used for buoyancy check.

15.3.1.3 Rock Tunnel Structures - For construction and long term loading cases, refer to the Geotechnical information and the Designer's (GDR)approved by WMATA and Figure 15.4 thru Figure15.8 and Table 15.1 whichever governs .

15.3.1.4 Minimum Earth Cover for Design

15.3.1.4.1 All underground structures other than cut and cover arch roof sections shall be designed for the actual cover depth but not less than 8'-0".

15.3.1.4.2 Cut and cover arch roof sections shall be designed for actual cover depth. When the actual cover depth is less than 4'-0"at the crown, the arch roof shall be designed for (a) an assumed minimum cover depth of 4'-0" at the crown and (b) a minimum average depth of 8'-0" over the entire cross-section.

15.3.1.4.3 Unless otherwise instructed, structures under private properties shall also conform to these criteria.

15.3.1.4.4 All footings shall have a minimum of two feet earth cover from the finished grade to the top of footing.

15.3.1.5 Loads from Adjacent Building Foundations or Other Structures

15.3.1.5.1 As noted in Section 15.7.3.2., the Contractor shall determine the need for permanent underpinning of all buildings or structures not in

Zone A.

15.3.1.5.2 Designs of all underground structures shall be based on the assumption that Zone B structures will not be underpinned.

15.3.1.5.3 Considerations shall be given to the maximum and minimum loads which can be transferred to the designed structure and design loads shall be assumed to be as those for which the adjacent structure was designed. In the absence of specific information, provisions in the applicable building code or the actual weights and the heaviest occupancy for which the building is suitable shall be used.

15.3.1.5.4 Horizontal and vertical distribution of loads from foundations of existing buildings shall be determined in consultation with the Designer's geotechnical consultant.

15.3.1.6 Above Ground Structures - The dead load for aboveground structures shall consist of the weight of the basic structure and the weight of secondary elements permanently supported by the structure.

15.3.1.7 Miscellaneous Loads - Consideration shall be given to any system or facility which will apply a permanent load or force to the design structure.

15.3.1.8 Design Weights of Materials - The design weights of materials shall be as listed in IBC. For those not listed the best available technical information shall be used and its source or reference shown or provided in calculations.

15.3.2 Live Load (LL) - Live load, excluding impact (for impact see Section 15.3.3) shall consist of any non-permanent gravity load placed on the structure:

15.3.2.1 Rapid Transit Loading - See Figure 15.1 for car dimensions and weights. Any combination of train lengths and loadings which produces the critical design loading shall be used for structural design.

15.3.2.2 Crane Car Loading - See Figure 15.2 for car dimensions and weights.

15.3.2.3 Highway Loading for WMATA Structures

15.3.2.3.1 Highway Loading On WMATA Highway Bridge Structures shall be in accordance with the requirements of the AASHTO. Loading HS 25 for all bridges with spans 35 feet and over. Loading HS 27 for all bridges with simple spans less than 35 feet in length as shown in Figure 15.18. If the bridge is connecting two different jurisdictions, the more conservative requirements shall apply.

15.3.2.3.2 Highway Loading on Underground Rapid Transit Structures: the roadway live loads on underground rapid transit structures shall be based on the HS25 loading shown in Figure 15.18. HS 25 Wheel loads shall be distributed in accordance with the AASHTO Specifications to a maximum depth of four feet. Between 4 feet and 8 feet a graduated uniform live load of 550 psf to 300 psf shall be used. The depth is to be measured to the top of the underground structure's roof slab. Unless otherwise instructed, structures constructed under private properties shall conform to this criterion. The more severe of the following two conditions shall govern (see Section 15.3.1.4. "Minimum Earth Cover for Design").

15.3.2.3.2.1 The actual depth of cover plus super imposed HS25 wheel load distributed in accordance with the above requirement.

15.3.2.3.2.2 An assumed future cover of 8' plus a uniform live load of 300 psf.

15.3.2.4 Pedestrian Areas including Station platforms, Stairways, Pedestrian Bridge, Pedestrian ramps, mezzanines, and other pedestrian areas shall be designed for a uniform live load of 150 psf (no area reduction factor allowed). Stairs shall also be checked for a minimum concentrated load of 300 lbs (on area of 4 square inches) on stair treads. In the District of Columbia, stair treads only shall be designed for a uniform load of 100 psf plus a concentrated load of 300 pounds.

15.3.2.5 Storage Space and Machinery Rooms - Electrical equipment rooms, pump rooms, service rooms, storage space and machinery rooms shall be designed for a uniform load of 250 psf, to be increased if storage or machinery loads dictate.

The loads for which such rooms are designed shall be stated on the structural drawings.

15.3.2.6 Escalators and Passenger Conveyors

15.3.2.6.1 Structures supporting escalators or passenger conveyors shall be designed for the maximum reactions imposed by the equipment installed. The reactions are provided in the WMATA Manual of Design Criteria Facilities, Section 14.

15.3.2.6.2 The design of the structural supporting elements shall be as stipulated in the WMATA Manual of Design Criteria Facilities, Section 14.

15.3.2.7 Parapets and Railings

15.3.2.7.1 Concrete parapets in station platform and mezzanines shall be designed for a horizontal load of 150 plf and vertical load of 100 plf at their top. Railings and guardrails in station platform, mezzanines and on enclosed pedestrian bridges shall be designed to resist a load of atleast200 pounds applied in any direction at any point of the top rails or a vertical and horizontal load of 50 pounds per linear foot applied at the top rails, whichever produces the worst condition.

15.3.2.7.2 Railings in other places of public assembly shall be designed in accordance with local codes. Railings in equipment rooms and working areas shall be designed for a 200 pound load applied in any direction at any point except for removable railings in ancillary spaces, which shall be excluded from 200 pound uplift.

15.3.2.8 Gratings -Ventilation shaft gratings should not be located in roadways, whenever possible. Where unavoidable, vent gratings located in a street or in sidewalk shall be designed to carry HS 25 loading in accordance with AASHTO Specifications. Gratings protected from vehicular traffic shall be designed for a uniform load of 250 psf. Gratings which might be subjected to loading from out-of-control vehicles shall be designed for HS 25 loading.

15.3.2.9 Curbs - A horizontal force of 500 plf shall be applied at the top of curbs on permanent structures.

15.3.2.10 Safety walks - Safety walks shall be designed for a uniform load of 85 psf of walkway area.

15.3.2.11 Live Load on Parking Structures - See Section 15.21.1.1.

15.3.2.12 Other Structures - Structures not listed in Section 15.3.2 shall use IBC live loadings.

15.3.2.13 Roof Live Load - The minimum roof live load shall be 30 Pound per Square Foot (psf), applied to the horizontal projection of the roof.

15.3.2.14 Wind Load - The minimum basic (nominal) wind speed shall be 105 mph (3-Second Gust, Vasd=105 mph).Loads and pressures (MWFRS or C/C) determined by wind tunnel testing shall be limited to not less than those calculated by other (analytical/envelope) procedures in ASCE 7. The most unfavorable loads/pressures from either ASCE 7 or wind tunnel testing shall be considered. Using regional climate data in lieu of the basic wind speed given here is not acceptable to WMATA.

15.3.2.14.1 Exposure "C" for the wind exposure category shall be used.

15.3.2.14.2 Drifts (lateral deflections) in service ability checking from the effects of wind - Drift limits for buildings/structures shall be limited to a maximum of 1/400 of the building/structure overall height using ASD load combinations in ASCE 7. However, serviceability limits for a specific building/structure will be determined by WMATA in conjunction with all functional requirements of the building/structure.

15.3.2.15 Live Load Reduction

The live loads shall not be reduced. No exceptions will be taken.

15.3.3 Impact (I) - Impact loads are statically equivalent dynamic loads resulting from vertical acceleration of the live loads:

15.3.3.1 Impact considerations for aerial structures supporting rapid transit loading are covered under "Design of Rapid Transit Aerial Structures" in this section.

15.3.3.2 Design for the top slab of underground rapid transit structures supporting roadway loading shall conform to the following:

15.3.3.2.1 0'-0" to 1'-0" earth cover I = 30% LL

15.3.3.2.2 1'-1" to 2'-0" earth cover I = 20% LL

15.3.3.2.3 2'-1" to 3'-0" earth cover I = 10% LL

15.3.3.2.4 Greater than 3'-0" earth cover I = 0% LL

15.3.3.2.5 The depth of cover shall be measured from the top of ground or paving to the top of the underground structure.

15.3.3.3 Structures supporting special vehicles, equipment, or other dynamic loadings which cause significant impact shall conform to the Building Code of the locality or, if not covered by Code, shall be considered individually using the best technical information available.

15.3.3.4 Impact shall not be considered for stairways, mezzanines, station platforms, or other pedestrian areas.

15.3.4 Centrifugal Force (CF) - On curves a percentage of the rapid transit loading per track equal to .0012 x speed^2 (MPH) x degree of curvature (degree) shall be applied horizontally 5 feet above the top of low rail, on all tracks. The degree of curvature is the angle in degrees, subtended by a 100 foot arc.

15.3.5 Rolling Force (RF) - A force equal to 10% of the rapid transit loading per track shall be applied downwards on one rail and upwards on the other, on all tracks.

15.3.6 Longitudinal Braking and Traction Force (LF)-A force equal to 15% of the rapid transit loading per track shall be applied 5 feet above the top of rail on all tracks. Consideration is to be given to combinations of acceleration and deceleration forces where more than one track occurs.

15.3.6.1 For double track structures, three longitudinal loading cases shall be considered:

15.3.6.1.1 Single track loaded. Train Accelerating or decelerating.

15.3.6.1.2 Both tracks loaded. One train accelerating, one decelerating. Longitudinal forces from both trains acting in the same direction.

15.3.6.1.3 Both tracks loaded. Both trains accelerating or decelerating. Longitudinal forces acting in opposite directions.

15.3.7 Horizontal Earth Pressure (E) - Structures which retain earth shall be designed for side pressure due to earth abutting against the structure, load surcharges resting on abutting earth, and hydrostatic pressure below the groundwater table.

15.3.7.1 Rapid transit loading shall be assumed as a uniform surcharge equal to three additional feet of earth. Such surcharge shall be extended uniformly to the face of the retaining wall (between stem walls).

15.3.7.2 Live and dead loads from adjacent foundations shall be considered in computing horizontal pressures.

15.3.7.3 Where railroad loading occurs, the surcharges shall be determined by the AREMA Manual, Chapter 8, Part 5.

15.3.7.4 Hydrostatic pressure shall be computed at 62.5 pounds per square foot per foot of depth below groundwater table. Site groundwater elevation to be established based on field measurements. Groundwater elevation to be used for design to include an additional height to reflect variation likely to occur within the design life of the structure but not less than five feet, subject to Authority review and approval. Regardless of the presence of sub-drainage systems, structures shall be waterproofed and designed to resist full hydrostatic pressure.

15.3.7.5 The rock pressure to be used in design shall be established by the designer and approved by WMATA. For loading conditions see Figure 15.4 to Figure 15.8 and Table 15.1.

15.3.7.6 Lateral earth pressures shall be calculated using At-Rest lateral earth pressure coefficient (a minimum of Ko = 0.5).

15.3.8 Buoyancy (B) - Buoyancy shall be considered as it affects the design and construction of any structure. During construction and backfill operations the elevation of groundwater shall be observed and controlled so that the calculated total weight of structure and backfill shall always exceed the calculated uplift due to buoyancy by at least 10 percent.

15.3.9 Flood (FL) - Floods may add loads to subaqueous structures or structures in the flood plain. Anticipated flood elecation shall be determined by a study of official flood records. Design of the structures should make allowance for this loading as required by the particular type of structure and the conditions affecting each location.

15.3.10 Other Loads and Forces - Other loads and forces to be considered, including wind loads, shrinkage and thermal forces, friction, seismic and rail/structure interaction loads are covered under Section 15.5 "Design of Rapid Transit Aerial Structures."

15.3.10.1 Wind Loading of Open-Air Station Roof/Ceilings - The wind loading on open air ceilings shall be in accordance with the IBC. The elements required to resist the wind uplift load shall be anchored to the foundation. A maximum of two-thirds of the dead load shall be considered in determining the resistance to the uplift load. Uplift in excess of the total reduced loads shall be resisted by foundation anchorage.

15.3.11 Thermal Forces - See Section 15.5.1.2.6.

15.4 DESIGN OF EARTH RETAINING STRUCTURES

15.4.1 Earth pressures and other soil constants shall be determined in consultation with the Designer's geotechnical consultant and approved by WMATA. . Unless established by site specific testing and verified with laboratory data, the soil parameters shall not exceed the limits given by the local building code, as applicable, and Section 15.5.1.7 which ever governs.(See Section 15.6 for Soil & Geological Criteria)

15.4.2 All earth retaining structures shall be classified in one of the categories, along with their design requirements, listed below.

15.4.2.1 Reinforced Concrete Box and Arch Station - These structures retain earth but are not free to yield significantly. As a minimum, three basic loading cases shall be investigated at working stress levels. Additional permanent, temporary and construction loading cases shall be investigated as required by the particular circumstances.

15.4.2.1.1 Case I - Full vertical and long-term horizontal load, as recommended by the Designer's geotechnical consultant, and as shown in Figure 15.20 whichever governs.

15.4.2.1.2 Case II - Full vertical load, long-term horizontal load on one side and short term horizontal load on the other side, as recommended by the Designer's geotechnical consultant, and as shown in Figure 15.20 whichever governs.

15.4.2.1.2.1 In underground concrete box structures which could be subjected to unequal lateral pressures, the structural analysis shall consider the top slab as both restrained and unrestrained against horizontal translation in arriving at maximum shears, thrusts, and moments.

15.4.2.1.3 Case III - Full vertical load with short-term horizontal load neglecting groundwater pressure on both sides, as recommended by the Designer's geotechnical consultant, and as shown in Figure 15.20 whichever governs.

15.4.2.1.3.1 For stress analysis, variations in the elastic support of the subgrade shall be considered for the different loading cases as appropriate.

15.4.2.1.3.2 For design, the horizontal earth pressure distribution diagram may be rectangular, giving a total load on the sides of the structure equivalent to the load produced by an assumed trapezoidal pressure diagram.

15.4.2.1.3.3 Compression forces shall not be considered in shear design of the top and bottom slabs in box section.

15.4.2.1.4 Use of precast shallow cut-and-cover box tunnel require prior WMATA approval. The following additional requirements shall be satisfied:

15.4.2.1.4.1 Invert must be designed as cast in place reinforced concrete and fully cured Precast reinforced concrete walls and roof must be match-cast and the segments post-tensioned into minimum 300 feet long units with a minimum uniform pre-compression of 300 psi before permanent connection to the invert.

15.4.2.1.4.2 Connection to the invert must be tightly grouted and designed to withstand vibrations, uplift and air pressure from running trains (see Section 15.5.1.7).

15.4.2.1.4.3 All joints must be sealed and entire box must be waterproofed all around with an Authority approved waterproofing membrane.

15.4.2.1.4.4 In arch sections, compression forces may be considered both in invert and arch.

15.4.2.1.5 The design of station arch sections shall be directed toward obtaining maximum economy, considering the costs of both the permanent structure elements and the Contractor's proposed method of construction.

15.4.2.1.6 The Contractor shall be given the option of selecting the arch construction method in his bid. Support of excavation is to be designed by the Contractor to accommodate the arch construction option selected. Arch construction options are shown on Figure 15.3.

15.4.2.1.7 In Option A, the lower section of the arch is loaded as a cantilever prior to the construction of the upper section. Considerations shall include:

15.4.2.1.7.1 allowable increase in stresses due to the temporary nature of the loading

15.4.2.1.7.2 creep in the concrete

15.4.2.1.7.3 effect of soil arching

15.4.2.1.7.4 arch flexibility

15.4.2.1.8 Option B maybe implemented by use of tie back support of excavation or, after placement of the slab or grade, by removing struts as necessary to clear the arch, on by strutting the lower section of the arch. The construction specification shall stipulate that if the Contractor proposes strutting of the lower section of the arch, the working drawings he submits for approval must reflect proper consideration of such aspects as magnitude of reload in replacement struts, thermal or stress-induced strain in the struts, crushing of packing, and induced stress and deflection of the permanent structure. The Contractor's proposal shall detail the proposed instrumentation and monitoring to ensure the permanent structure will not be over-stressed or otherwise damaged.

15.4.2.1.8.1 The Contractor shall submit, working drawings for the option selected for approval. The working drawings shall include supporting computations for all governing loading cases during construction and the order of procedure proposed. In all cases, the specifications for support of excavation must reflect any limitations inherent in the design of the permanent structure. The Designer shall show on the General Notes sheet/sketch, similar to those shown on Figure 15.3. illustrating construction basis for the design.

15.4.2.2 Reinforced Concrete Rigid Earth Tunnel Sections

15.4.2.2.1 The method of driving these tunnels is proposed to be full shield for the circular section. Temporary tunnel support will be provided by precast concrete lining and permanent support by cast-in-place concrete lining.

15.4.2.2.2 These sections shall be designed as rigid structures using working stress design methods, per Section 15.2.2.4. Horizontal earth pressure shall be calculated using an earth pressure factor established in consultation with the Designer’s geotechnical consultant and approved by WMATA.

15.4.2.2.3 The structural design shall be checked by ultimate strength design methods using a load factor of one. The maximum concrete stress, considering rectangular stress distribution, shall not exceed 85% of the required 28-day concrete strength. Two horizontal earth pressure factors, 0.45 and 1.00, shall be used in these check analyses.

15.4.2.3 Flexible Earth Tunnel Sections - See Section 15.10.2 ., One Pass System Circular Earth Tunnels

15.4.2.4 Permanent Retaining Walls

15.4.2.4.1 Reinforced Concrete Retaining Walls - Retaining walls shall be designed on the basis of specific soils information relating to the backfill material and in accordance with the procedures outlined in the AREMA Manual, Chapter 8, Part 5. The retaining walls shall be designed using working stress design methods, per Section 15.2.2.4.

15.4.2.4.1.1 Retaining wall shall be designed with shear key and water stops at expansion, construction and contraction joints.

15.4.2.4.1.2 Lateral earth pressures - See Section 15.3.7.6.

15.4.2.4.1.3 The minimum stem wall thickness shall be 12 inches.

15.4.2.4.2 External Stability of Wall System

15.4.2.4.2.1 Stability of the retention system as a whole must satisfy three conditions: The factors of safety against sliding and overturning must be adequate; the soil pressure beneath the toe of the foundation must not exceed the allowable soil pressure; and differential settlements of the foundation must not be excessive.

15.4.2.4.2.2 Safety Against Sliding

15.4.2.4.2.2.1 Sliding of a retaining wall is resisted by the friction between the soil and base and by the passive earth pressure of the soil in contact with the outer face of the foundation.

15.4.2.4.2.2.2 The factor of safety against sliding is equal to horizontal resisting forces divided by the horizontal component of the backfill pressures, which should be at least 1.5. The friction between the base and clean sand or silty sand is equal to the effective normal pressure on the base times the tangent of the friction angle ø between soil and base. The value of ø may be taken as 30° for a coarse-grained soil containing no slit or clay, and as 24° for a coarse-grained soil containing silt. The value of ø between sand and under laying clay can be assumed as 20°. The passive resistance in front of the wall shall be disregarded unless approved otherwise by the Authority.

15.4.2.4.2.2.3 Safety Against Overturning - The factor of safety against overturning is determined by dividing the sum of moments of forces tending to resist rotation of the wall about the center of rotation of the wall/footing by the sum of moments of forces tending to produce the overturning. A factor of safety of at least 1.5 is required. If walls rest on a highly compressible or cohesive soils, based on the information and the Designer's Geotechnical Design Report, a minimum factor of safety of 2 shall be provided.

15.4.2.4.2.2.4 Allowable Soil Pressure and Settlement-The maximum base pressure at the toe of the wall will be limited by the allowable bearing capacity of the soil. The foundation/footing should be designed such that the point of application of the resultant force is within the middle third. The allowable bearing capacity shall have a minimum factor of safety of 3.0.

15.4.2.4.2.2.5 Overall Stability -where retaining walls are underlain by weak soils (ø<25º), the overall stability of the mass containing the retaining wall shall be checked with respect to the most critical surface of sliding. A minimum factor of safety of 3 is required.

15.4.2.4.3 Reinforced Earth/Mechanically Stabilized Earth: This system may be used only after prior approval of the Authority.

15.4.2.4.3.1 Reinforced Earth (RE) and Mechanically Stabilized Earth (MSE) walls shall be designed in accordance with the current requirements of the AASHTO Standard Specifications for Highway Bridges and as supplemented by the criteria and requirements below.

15.4.2.4.3.2 Design Life of walls shall be minimum 100 years; with minimum 5-year warranty period on wall system, during which annual inspections shall be performed by the engineer of record or authorized agent.

15.4.2.4.3.3 RE/MSE wall supplier shall be the engineer of record for the RE/MSE wall design, and shall be responsible for internal, external and global stability design including allowable bearing capacity. Supplier shall certify that wall installation conforms to approved design.

15.4.2.4.3.4 RE/MSE wall supplier shall provide the following for WMATA approval:

15.4.2.4.3.4.1 With Proposal package:

Complete specifications identifying

Design parameters (including minimum required soil bearing capacity)

Materials and design properties Installation methods

Catalog cuts

Equipment list

Sample calculations for tallest wall section (including internal, external and global stability calculations, and settlement calculations for which design/builder will be fully responsible)

QC Plan and QC Staff

Cost Loaded Bar Chart Schedule showing planned start and finish dates of activities and associated costs

Identification of limit of work and access through site.

Method of controlling differential settlement along the wall based on the available soil boring information. (To include at least the minimum requirements in Section 15.4.2.4.6.6 below.)

Monitoring program to monitor potential settlements and other wall movements.

Schematic design of drainage system to control, collect and discharge water from behind the wall.

Design for corrosion protection of steel elements.

15.4.2.4.3.4.2 Prior to Construction :

15.4.2.4.3.4.2.1 Final calculations with P.E. stamp (including internal, external and global stability calculations, and settlement calculations).

15.4.2.4.3.4.2.2 Shop Drawings

15.4.2.4.3.4.2.3 Details of drainage system to control, collect and discharge water from behind the wall.

15.4.2.4.3.5 RE/MSE wall design/constructor must demonstrate the groundwater and soil corrosive properties at the site, including pH, will not affect the performance and service life of the wall.

15.4.2.4.3.6 Backfill:

15.4.2.4.3.6.1 Backfill for undercut shall be Virginia DOT Stone No. 57 as specified in the latest edition of Virginia Department of Transportation Specifications, Road and Bridge Specifications, or equivalent.

15.4.2.4.3.6.2 Backfill for reinforced earth volume: VDOT Stone No. 57 or Select Granular Backfill Material as specified below.

15.4.2.4.3.6.3 Select Granular Backfill Material shall be free from organic and other deleterious material and conform to the following gradation limits:

% by Weight of Material

U.S. Sieve Size	Passing Sieve
1½ in	100
½ in	25 - 60
No. 40	15 - 30
No. 200	0 - 5

15.4.2.4.3.6.4 Plasticity Index (PI) for Select Granular Backfill Material shall not exceed 6.

15.4.2.4.3.6.5 Random backfill beyond the limits of the reinforced earth volume shall meet the requirements for backfill in Standard Specification Section 2320, Section 2.01.A. The pH for Random Backfill shall be between 5.0 and 8.0.

15.4.2.4.3.7 Subgrade Preparation: To control differential settlement along the length of wall, undercut within limits described below, place Tensar Geogrid BX1100 or WMATA approved equal on excavated surface, overlay geogrid with layer of geotextile fabric and fill with VDOT Stone No. 57.

15.4.2.4.3.8 Limits of undercut:

15.4.2.4.3.8.1 Length: The entire length of the wall.

15.4.2.4.3.8.2 Width: Equal to or greater than the length of the reinforcing elements behind the wall, and in front of the wall to a distance from the edge of the leveling pad equal to or greater than the depth of undercut.

15.4.2.4.3.8.3 Depth: Minimum 3 feet, but shall be increased in areas of weak soil if shown in soil boring reports, so that differential settlement is eliminated or reduced to a negligible amount. If unstable or poor soil conditions are encountered during excavation, the engineer of record shall propose a solution; any resulting additional work and material, such as undercut, rip rap, fabric and, fill will be paid as a unit price item.

15.4.2.4.4 RE/MSE wall supplier shall provide the following minimum factors of safety (FOS):

External Stability	Minimum FOS
Sliding	2.0
Overturning	2.7
Global Stability (Overall depth/Deep seated slope stability)	1.7
Bearing Capacity	2.5
Pullout Resistance	2.0

15.4.2.4.5 Wall face:

15.4.2.4.5.1 Reinforced Concrete Panels are preferred.

15.4.2.4.5.2 Minimum concrete strength at installation shall be4000 psi.

15.4.2.4.5.3 Alignment of panels and construction of wall face shall provide a true vertical plane with uniform surface after deflection. Precast tolerances and erection tolerances shall be coordinated.

15.4.2.4.5.4 A minimum of 2 layers of steel reinforcing per panel with maximum vertical spacing of 30" on centers shall be provided. Panels shall be adequately reinforced for flexure.

15.4.2.4.5.5 All panels shall be keyed to each other (shear connection).

15.4.2.4.6 Concrete Modular Block Wall with effective anchoring (each block shall have an individual anchorand the anchor's length shall be equal to the height of the wall) may be used as an alternate, with WMATA approval.

15.4.2.4.6.1 Minimum strength of concrete modular block at installation shall be 4000 psi.

15.4.2.4.6.2 Alignment of blocks and construction of wall face shall provide a true vertical plane with uniform surface after deflection. Precast tolerances and erection tolerances shall be coordinated.

15.4.2.4.6.3 The steel reinforcing shall be designed to provide the full structural support, neglecting any contribution from the geotextile or geogrid, which shall be assumed to provide the facial stability only.

15.4.2.4.6.4 Inextensible Reinforcements: RE/MSE walls to be retained with inextensible reinforcement.

15.4.2.4.6.4.1 Reinforcement Material: Steel, hot-dipped Galvanized after fabrication.

15.4.2.4.6.4.2 Minimum length > 1.0 x H (wall height)

15.4.2.4.6.5 Settlement:

15.4.2.4.6.5.1 No settlement 3 months after completion of the wall. Surcharge wall as needed to accelerate settlement.

15.4.2.4.6.5.2 Allowable during construction, as long as an approved monitoring and remediation program can be implemented without compromising the project schedule.

15.4.2.4.6.5.3 Design/Construction documents shall include provisions such as subgrade preparation to limit settlement. See Subgrade Preparation Section

15.4.2.4.3.7 above.

15.4.2.4.6.6 RE/MSE wall shall be designed to support a traffic barrier and moment slab withstanding AASHTO loading and deflection due to fire truck (WB-50). Traffic barrier shall be capable of accommodating future site lighting pole shown on plans.

15.4.2.4.6.7 Provide effective permanent drainage including necessary drainage blankets in back of and behind the reinforced zone, and other internal drainage elements, to eliminate seepage from behind the wall. Drainage from behind the wall shall be controlled, collected and discharged from common point(s).

15.4.2.4.6.8 Detailed design for corrosion protection (100 year minimum) of any steel elements in the system including consideration of stray current, aggressive elements infiltrating from surface flows and groundwater flows. All steel elements in the system must be hot dipped galvanized.

15.4.2.4.6.9 Design/Construction shall accommodate installation of planned subsurface utilities, such as ballast drains, cable trenches, ductbanks, light pole foundations and storm drain pipes; without decreasing wall performance/service

15.4.2.4.6.10 RE/MSE wall supplier shall provide a full time inspector during wall construction. Inspector shall provide daily reports through the

Contractor. Reports shall include, but not be limited to, preplacement, placement, and post-placement inspection records of precast panels.

15.4.2.5 Linings for Structures Tunneled in Rock

15.4.2.5.1 For each rock tunnel construction contract, the Designer shall prepare a Geotechnical Design Report, based on current subsurface information, describing the basis of the design, estimated loads on the lining and lining construction specifications.

15.4.2.5.1.1 The design shall consider pressure mobilized by the resistance of the rock mass to the outward deflection of the lining. The recommended average properties of the rock elastic modulus are 100,000 psi in compression and 50,000 psi in shear. Crown grouting will be required to fill voids between the rock and the permanent lining. For horseshoe tunnels, crossovers and station structures, satisfactory drainage shall be provided behind the lining and hydrostatic pressures shall be assumed to be relieved. However, in cases where exploratory information indicates complete drainage may be impracticable, the design loading shall include an allowance for exterior hydrostatic pressures or alternatively, grouting will be required to reduce the permeability and expected inflow, and provide drainage. For horseshoe tunnels, crossovers and stations waterproofing shall be provided in the crown and side walls. In A hydrostatic pressure relief system will not be required for circular tunnels. However, full water proofing must be designed in all cases.

15.4.2.5.2 Where exploratory information indicates drainage is necessary and practical to relieve hydrostatic pressure on the lining, provide drainage, spaced longitudinally as required. At each such location there should be four drains installed to a predetermined pattern. Also, specify the installation of additional drains if required by conditions encountered during construction. Generally, the drain holes shall be 3-inch diameter and be spaced 10 feet apart.

15.4.2.5.3 The Designer shall specify tunneling method(s) and techniques to be employed based on the WMATA Tunneling Specifications.

15.4.2.5.4 Tunnel Type

15.4.2.5.4.1 Depending on size, two basic rock tunnel designs shall be considered:

15.4.2.5.4.1.1 Running tunnels, including single and double track and crossovers with track centers not exceeding 14'-0".

15.4.2.5.4.1.2 Station tunnels, including crossovers and transition sections when the crossovers and transition sections have more than 14'0" distance between tracks.

15.4.2.5.4.2 Design of Running Tunnel Linings

15.4.2.5.4.2.1 Initial support are elements provided within the contract design to systematically support the anticipated rock conditions. Local support are additional elements, of a limited extent, required beyond the designed initial support to handle localized conditions as detected in the field. The design of the local support such as rock bolts, steel sets, shotcrete, and combination thereof, shall be specified as the Contractor's responsibility. The initial support shall be installed close to the face as soon as the heading is advanced and tight blocking shall be installed without delay. Assume a degree of rock loosening prior to construction of the permanent lining. In the design of the final lining, consider all loading cases, I, II, III, IV, and V as shown on Figures 15.4, 15.5, and 15.6 apply. Design for case V and check for adequacy in the other four cases. Hydrostatic pressure shall be considered for the design of circular tunnel linings.

15.4.2.5.4.3 Design of Station Linings

15.4.2.5.4.3.1 Due to the blocky nature of rock, joint pattern, shallow cover, and the requirement for multiple drift excavation methods, the final lining for stations, transitions, and crossovers shall consist of structural steel ribs or lattice girders encased in reinforced concrete. The concrete may be placed either by cast-in-place or shotcrete methods.

15.4.2.5.4.3.2 Take into account, in the design of the initial and final lining that the support system will carry loads resulting from different rock excavation stages. For the initial and final lining design, the Designer shall determine the sizes and maximum spacing of rock bolts or steel sets and shall specify the pattern of rock bolts and installation timing to reduce rock movement and loosening.

15.4.2.5.4.3.3 The design shall specify a multiple drift method when required by anticipated conditions field conditions. The Designer shall consider restrictions imposed by the final lining on the geometry of the initial support, the restrictions imposed by the drainage system, and necessary safety features. The Designer shall design the final lining for loading cases I, II, III, IV, and V, as shown on Figures 15.7 and 15.8.

15.4.2.5.4.3.4 The Contractor will be responsible to design additional support if field conditions require initial support additional to the final lining.

15.4.2.5.4.3.5 The Designer shall design the initial support at portal sections and at other critical locations such as intersections of openings. The design shall contain provisions for suitable modifications for conditions disclosed by the excavation.

15.4.2.6 Slurry Walls

15.4.2.6.1 Slurry walls may be used for temporary or permanent retaining walls.

15.4.2.6.2 Design Loadings - Lateral earth pressures for the design of temporary cofferdam walls are shown on Figure 15.15. Lateral at-rest pressure should be used for the design of a permanent slurry wall. Horizontal pressure from surcharge loads should be added to the above loadings. Table 15.2 depicts soil properties for design. Figure 15.16 provides criteria for horizontal pressure due to surcharge loads.

15.4.2.6.3 Embedment Depth - The depth of slurry wall embedment below the bottom of the excavation is designed based on the depth required to develop adequate resistance to lateral earth and surcharge pressure, provide overall stability, minimize deflections, provide adequate bearing capacity, and limit settlement. Slurry walls can also be designed to provide containment of ground water outside of excavation. Passive resistance provided by the soil in the interior of the cofferdam is computed utilizing the conventional expressions for passive pressures, ignoring vertical wall friction forces on the cofferdam. A factor of safety of 1.5 must be applied to the computed theoretical passive pressures for temporary walls. A factor of safety of at least 2.5 shall be used for permanent slurry walls. Drawing No. DD-S-138 depicts several slurry wall types normally used, as well as typical details.

15.5 DESIGN OF RAPID TRANSIT AERIAL STRUCTURES

15.5.1 The Criteria Set Forth in this Section Shall Pertain Specifically to the Design of Aerial Structures Carrying Train Loading and Aerial Stations.

15.5.1.1 Aerial Structures supporting Stations shall be designed in accordance with ACI or AISC as applicable.

15.5.1.1.1 Aerial Structures for train loading shall be designed in accordance with AASHTO specifications and the AREMA specifications using the train car loadings and other criteria provided in this Manual of Design Criteria.

15.5.1.1.2 Structures with spans greater than 150 ft. between centerline of bearing supports will require Authority's prior approval and may require additional modifications to the subject codes.

15.5.1.2 Loads and Forces - Where applicable, loads and forces listed in Section 15.3 shall be used for the design of rapid transit aerial structures. These loads and other loads and forces to be considered include:

15.5.1.2.1 Dead Load (DL)

15.5.1.2.1.1 The dead load of aerial structures shall consist of the gravity loads of the basic supporting girders and structure.

15.5.1.2.1.2 Trackwork and appurtenances and secondary elements supported by the structure and added after construction of the basic structure shall be considered as superimposed dead load. In areas of tie and ballast construction, the weight of the ties and ballast shall also be considered as superimposed dead load.

15.5.1.2.2 Live Load (LL) & Derailment Load - Refer to Section 15.3. for live load magnitudes. Transit and crane car wheel loads shall be distributed as follows:

15.5.1.2.2.1 Non-Ballasted Aerial Structure - Where a wheel load is transmitted to a slab through rail mountings placed directly on the slab, the wheel load shall be assumed to be uniformly distributed on the slab over a 3'-0" length of rail and a 1'-2" width normal to the rail and centered at the rail. In addition, the aerial structure shall be designed to support the derailment loads of Section 15.5.1.2.13.

15.5.1.2.2.2 Ballasted Aerial Structures

15.5.1.2.2.2.1 Where an axle load is distributed to a slab through ties and ballast, the axle load shall be assumed to be uniformly distributed on the slab over an area, centered below the axle, of the following dimensions:

15.5.1.2.2.2.1.1 Width normal to rail - Tie length plus depth of ballast below tie but not greater than the width at the bottom of ballast.

15.5.1.2.2.2.1.2 Length parallel to rail 3'-0" plus depth of ballast below tie, but not greater than 6'-6".

15.5.1.2.3 Impact (I)

15.5.1.2.3.1 Impact shall be applied to the superstructure, and generally those members of the structure which extend down to the main footings. The portion above the ground line of concrete or steel piles rigidly connected to the superstructure as in rigid frame or continuous design is included. Impact shall not be considered for abutments, retaining walls, piles, foundations, footings and safety walks, except the portion of piles (pile bents) rigidly connected to the superstructure.

15.5.1.2.3.1.1 Vertical impact for aerial structure shall be considered in the design as follows:

15.5.1.2.3.1.1.1 Non-ballasted Aerial Structures

15.5.1.2.3.1.1.1.1 Impact force for the design of simply supported longitudinal girders less than 150 feet long between centerline of bearing supports:

15.5.1.2.3.1.1.1.2 I = 30 percent of the total rapid transit vehicle or crane car loading.

15.5.1.2.3.1.1.2 For structures with longitudinal girders continuous over supports, including cantilever systems:

15.5.1.2.3.1.1.2.1 I = 40 percent of the total rapid transit vehicle or crane car loading for the girders in regions of negative bending and for the supports where the girders are continuous.

15.5.1.2.3.1.1.2.2 I = 30 percent of the above loading for continuous girders in regions of positive bending and for the supports where the girders are discontinuous.

15.5.1.2.3.1.2 Ballasted Aerial Structures - Vertical impact for ballasted rapid transit longitudinal girders shall be equal to 30 percent of the total rapid transit vehicle or crane car loading for both positive and negative moment areas. The vertical impact forces shall be applied as concentrated vertical loads at the axle locations.

15.5.1.2.4 Stream Flow Pressure (SF)

15.5.1.2.4.1 Anticipated flood elevations shall be determined by a study of official flood records. Stream flow pressures shall be included in the design of aerial structures where applicable.

15.5.1.2.4.2 All piers and other portions of structures which are subject to flood forces shall be designed in accordance with sound engineering practice. The requirements outlined in the AASHTO Specification shall be used as a guide, as a minimum.

15.5.1.2.5 Shrinkage and Creep Forces (S)

15.5.1.2.5.1 These forces are described under "Reinforced and Prestressed Concrete Design" Section 15.5.1. 5..

15.5.1.2.6 Thermal Forces (T)

15.5.1.2.6.1 The largest combination of TRF, DT and FF forces shall be included in load combinations as the loading "T".

15.5.1.2.6.2 (TRF) Temperature changes which are uniform throughout the structure and which cause stresses in the structure due to restraint of a uniform tendency for thermal expansion or contraction: Provision shall be made for stresses and deformations resulting from uniform temperature changes as follows:

15.5.1.2.6.2.1 Concrete

15.5.1.2.6.2.1.1 Temperature Rise 50º deg. F

15.5.1.2.6.2.1.2 Temperature Fall 50º deg. F

15.5.1.2.6.2.1.3 Coefficient of Expansion 0.0000060 inch/inch/deg. F

15.5.1.2.6.2.2 Steel

15.5.1.2.6.2.2.1 Temperature Rise 60 deg. F

15.5.1.2.6.2.2.2 Temperature Fall 60 deg. F

15.5.1.2.6.2.2.3 Coefficient of Expansion 0.0000065 inch/inch/deg. F

15.5.1.2.6.3 (DT) Temperature gradients within the structure which are due to variations in solar and atmospheric heating and cooling at the structure's surfaces:

15.5.1.2.6.3.1 Provision shall be made for stresses and deformations resulting from the following temperature distributions:

15.5.1.2.6.3.1.1 Concrete

15.5.1.2.6.3.1.1.1 See Figure 15.14a. This is based on a simplified adaptation of ACI 435.7R. Alternately, it is permissible to follow the procedure of ACI 435.7R using U.S. Weather Service Climatological Data applicable to the site of the structure. The AASHTO Guide Specification for Thermal Effects in Concrete Structures may be used for temperature effects in statically indeterminate concrete box girders.

15.5.1.2.6.3.1.2 Steel

15.5.1.2.6.3.1.2.1 See Figure 15.14b. This variation from the treatment for concrete is due to the fact that the gradient is small in steel compared with concrete, since the thermal diffusion/conductivity of steel is almost 30 times that of concrete.

15.5.1.2.6.3.2 (FF) Frictional forces due to temperature changes shall be considered in the design of structures with bearings.

15.5.1.2.7 Wind Load on Structure (W) - Values are nominal design pressures for allowable stress design.

15.5.1.2.7.1 Wind Load on Superstructure

15.5.1.2.7.1.1 A horizontal uniform wind load shall be applied simultaneously at the centroid of all exposed areas.

15.5.1.2.7.1.2 For girders and beams: 50 psf in the traverse direction and 12 psf in the longitudinal direction, with a minimum of 300 plf, in the transverse direction and 75 plf in the longitudinal direction.

15.5.1.2.7.1.3 In addition to the horizontal wind loads, an upward load shall be applied at the windward quarter point of the transverse width of the superstructure. This vertical load shall be 25 psf on the plan area of the deck and walkway.

15.5.1.2.7.2 Wind Load on Substructure-The substructure shall be designed to withstand the preceding loads applied to the superstructure as they are transmitted to the substructure. In addition a horizontal wind load of 44 psf in any direction shall be applied simultaneously at the centroid of the exposed substructure area.

15.5.1.2.8 Wind Load on Live Load (WL)-Design shall include a transverse horizontal wind load of 400 plf and a longitudinal horizontal wind load of 100 plf for the entire length of track supported by the element being designed. The transverse load shall be applied to the train as concentrated loads at the axle locations, in plane 7 feet above the top of the low rail and normal to the track. The total load for double track shall be the same as for single track.

15.5.1.2.9 Rail/Structure Interaction Force (RS)

15.5.1.2.9.1 Non-Ballasted Aerial Structures. During the design of non-ballasted aerial structures, an analysis shall be made of the forces resulting from continuously welded rail (CWR)/structure interaction. This analysis shall be coordinated with the Authority.

15.5.1.2.9.1.1 The design of the deck, girders, bearings, frames, pier caps, piers and foundations shall include the forces resulting from the interaction between the rails and the structure when:

15.5.1.2.9.1.1.1 The superstructure expands and contracts beneath the rail,

15.5.1.2.9.1.1.2 One rail breaks,

15.5.1.2.9.1.1.3 The structure restrains the rail from displacing radially on horizontal curves,

15.5.1.2.9.1.1.4 Combination of the above.

15.5.1.2.9.1.1.5 Maximum allowable rail break gap is 3 inches.

15.5.1.2.9.1.2 The design shall include the forces imparted to the structure as the superstructure moves beneath the rail due to thermal variations.

15.5.1.2.9.1.2.1 The thermal load criteria shall be the same as Section 15.5.1.2.6., Thermal Forces. The rail shall then be considered attached to the deck at 30 inch intervals with a mechanism which mobilizes 3 kips of longitudinal force per fastener resisting the movement of the deck, girders, pier caps, and piers relative to the rail (See Figure 15.13 for range of load vs. deflection of the fasteners). The rail beyond the abutments of the structure shall be considered, if direct fixation track, to have the same restraint characteristics as the track on the deck (i.e. 30 inch spacing of fasteners, 3 kips restraint per fastener) and if ballasted track, 27 inch tie (fastener) spacing with a restraint of 1500 lbs/rail/tie (equivalent spring rate of 15000 lbs/inch per rail per tie). In general, in order to keep the structure interaction balanced, piers shall alternate between those having fixed bearings for the superstructure and those having expansion bearings. On either side of piers with the fixed bearings, the superstructure should be of approximately equal length.

15.5.1.2.9.1.2.2 The design shall include the forces mobilized in the structure to restrain a broken rail when the rail has a 100EF temperature differential from rail neutral temperature. Each mechanism which attaches the rail to the deck at 30 inch intervals mobilizes 3 kips of restraint between the broken rail and the superstructure until the thermal rail force is developed.

15.5.1.2.9.1.2.3 The design shall include the loads mobilized in the structure which provide lateral restraint to the rail when the structure is located on a horizontal curve. The analysis shall consider a 100EF temperature differential from rail neutral temperature in the rails.

15.5.1.2.9.1.3 Special Trackwork. The layout of the aerial structure shall be such that there will be a minimum relative movement due to the thermal conditions between the rails and the superstructure at switch locations in turnouts and at derails.

15.5.1.2.9.1.3.1 The force in the rail resulting from interaction shall not exceed 132 kips.

15.5.1.2.9.1.4 Ballasted Aerial Structures. No interaction loads need be considered.

15.5.1.2.10 **Prestressing Forces (PS)** - Prestressing creates forces within the structure include:

15.5.1.2.10.1 Primary forces occurring in any prestressed structure and secondary forces occurring due to restraint of deformations resulting from the primary effect of prestressing.

15.5.1.2.10.2 Forces arising during construction due to temporary restraint of post-tensioning shall be considered under Erection Loads During Construction. However a movement due to shortening during prestressing should never be obstructed.

15.5.1.2.11 **Foundation Settlement (FS)**-Aerial structures shall be analyzed for a minimum of ½ inch vertical differential settlement between adjacent pier foundations. If a greater value of differential settlement is permitted per Section 15.5.1.7, that value shall be used.

15.5.1.2.12 **Seismic Forces (EQ)** - Seismic forces for aerial structures supporting rapid transit loading shall be in accordance with the AASHTO specifications. At least 50% live loading from rapid transit shall be included in the seismic load combination.

15.5.1.2.13 **Derailment forces (DRF)**

15.5.1.2.13.1 The aerial structures shall be designed for a vertical derailment load caused by a misdirected car oriented with its longitudinal axis parallel to the track, and transversely positioned a minimum of 1.5 feet to a maximum of 3 feet from the centerline of the track.

15.5.1.2.13.2 The derailment load shall consist of standard vehicles with a modified impact factor.

15.5.1.2.13.3 A derailment impact equal to 100 percent of the axle load shall be applied to any two adjacent axles at a time, with a normal impact factor applied to the remaining axles. The 100 percent impact axles shall be selected to produce the critical loading condition for the structure.

15.5.1.2.13.4 When checking any component of a superstructure or substructure that supports two or more tracks, only one train on one track shall be considered to have derailed, with the other track being unloaded and loaded with a stationary train.

15.5.1.2.13.5 When investigating derailment loads, the percentage of basic unit stress may be increased to 150 percent. For prestressed concrete members, the steel tendon stress shall not exceed 85 percent of the ultimate tensile strength (0.85 f's) and the concrete stress shall not exceed 60 percent of the 28-day compressive strength (0.60 f'c).

15.5.1.3 Loading Combinations and Unit Stresses

15.5.1.3.1 The basic unit stresses for various materials in structures supporting the rapid transit system are defined in their respective sections. The following combinations of loadings shall be considered in design:

Allowable Percentage of Basic Unit Stress

Group I = DL + LL + I + CF + RF +E + B + SF + PS @ 100%

Group II = DL + LL + CF + LF + T +S + B + SF + PS @ 100%

Group IIa = DL + LL + I + RF + CF +T + RS + PS@100%

Group III = DL + E + B + W + SF + PS@ 125%

Group IIIa = DL + PS + E + B + SF + S + DT@ 100%

Group IV = Group 1 + 30% W + WL + FS @ 125%

Group V = Group II + 30% W + WL +RS + FS@ 125%

Group VI = Group III + EQ - W@ 133%

Group VII = DL + CF + LF + RS + DRF@ 150%

Where: DL = Dead Load

LL = Live Load

I = Impact

CF = Centrifugal Force

RF = Rolling Force

LF = Longitudinal Braking and Traction Force

E = Horizontal Earth Pressure

B = Buoyancy SF =Stream Flow Pressure

S = Shrinkage and Creep Force

T = Thermal Force, Total

DT =Forces due to Thermal Gradient

W = Wind Load on Structure

WL = Wind Load on Live Load

RS = Rail/Structure Interaction Force

PS = Post-tensioning Forces

FS = Foundation Settlement Forces

EQ = Seismic Force

DRF = Derailment Force

15.5.1.4 Special Design Considerations

15.5.1.4.1 Vibration Limitations

15.5.1.4.1.1 To limit potential dynamic interaction between aerial structure girders and rapid transit vehicle and amplification of deformations from resonance, the aerial structure shall be designed so that the unloaded natural frequency of the first mode of vibration of the longitudinal simple span girders is not less than 3.0 cycles per second.

15.5.1.4.1.2 For continuous spans girders the natural frequency of the first mode of vibration shall be not less than 3.0 cycles per second.

15.5.1.4.1.3 Concrete rail plinths and parapets shall not be considered in the cross section properties.

15.5.1.4.1.4 If straddle bent is provided for supporting longitudinal girders, the natural frequency analysis shall combine straddle bent and longitudinal girders.

15.5.1.4.2 Fatigue-Consideration shall be given to the effect of change of stress levels caused by passage of rapid transit trains over structures. Over the life of the structure, 3 million cycles of maximum stress shall be used in estimating the number of repetitive maximum stress cycles.

15.5.1.4.3 Uplift shall not be allowed for any loading combinations. However, provision shall be made for adequate attachment of the superstructure to the substructure should any loading or combination of loading, increased by 100% of the live load, produce uplift at any support

15.5.1.4.4 Friction (FF)-Frictional effects shall be considered in the structural design.

15.5.1.4.5 Track Girders shall follow WMATA Structural Design Drawings (DD Drawings) showing box girder configurations, unless a special exception is approved by WMATA .

15.5.1.4.5.1 Access to Interior of Box Girders and Future Bearing Replacement Details:

15.5.1.4.5.1.1 Provide access openings in the box girder large enough to allow personnel to enter the inside of the box girder for inspection and maintenance. The opening shall be located in an area of the span which shall make it easily accessible, and would not impair the structural adequacy of the girder. Also design sealed access openings from the box girder’s deck. Provide details and procedure for future bearing replacements. Replacements should be made possible from the inside of box girders using access from the Metro track. Opening size shall be 2'-6" x 2'-6" as shown on drawing DD-S-128.

15.5.1.4.5.1.2 Design and provide removable water tight cover.

15.5.1.4.5.1.3 An access opening shall be provided for every box girder. If the proposed access opening is provided on the top of the deck, a ladder shall be installed to access inside the box girder. The access ladder shall be made up of non-corrosive material.

15.5.1.4.5.2 If AASHTO Bulb Tee girders used in aerial structures, span length for Precast pre-stressed AASHTO Bulb Tee girders shall be limited to 100 feet maximum. Reinforcing bar arrangements in the girders shall conform to the AASHTO standard details.

15.5.1.4.6 Drainage and Water Infiltration

15.5.1.4.6.1 Superstructure should be designed such that no water leaks inside the box girder. Deck joints should be sealed and made water-tight. Runoff shall be directed to drain inlets, into drainage pipes, which are mounted on the outside face of the aerial structure and against the piers down into a proper outfall.

15.5.1.4.6.2 2" minimum diameter weep holes shall be provided at the low spots on the box girder bottom flange to ensure that box girder remains dry at all times. Weep holes should be lined with PVC pipe and firmly secured to prevent corrosion and staining of the concrete. The weep hole inlet should be covered with a suitable screen.

15.5.1.4.7 Operational and Maintenance Preferences

15.5.1.4.7.1 Provide ballasted track bridges along ballasted alignment on bridges with a total length of 600 feet (8 rail car lengths) or less.

15.5.1.4.7.2 Provide separate aerial structures for each track to enable maintenance work on one span to proceed independent to the other span.

15.5.1.4.7.3 Achieve super-elevation by rotating the cross section and adjusting rail plinth height.

15.5.1.5 Reinforced and Prestressed Concrete Design - Reinforced and prestressed concrete members for rapid transit aerial structures shall conform to the requirements of Section 15.9 except as modified below.

15.5.1.5.1 Camber and Deflections

15.5.1.5.1.1 Non-Ballasted Aerial Structures-As a guide in design, the total long term predicted camber growth shall be limited to 1/2000 of the span length for unballasted, prestressed concrete aerial structures. The short term camber growth prior to Trackwork construction shall be limited to 1/4000 of the span length. A minimum 2-month period between structure construction and trackwork installation is assumed.

15.5.1.5.1.2 Ballasted Aerial Structure

15.5.1.5.2.1.1 The Designer shall consider the stress conditions and effect of camber growth in prestressed concrete, ballasted, aerial structures for the simple dead load condition prior to placement of superimposed dead load.

Girder members shall also be checked on the assumption that superimposed dead load may be removed at any time during the life of the structure.

15.5.1.5.2.1.2 Long term deflections under dead load plus superimposed dead load conditions shall be limited to 1/3000 of the span length.

15.5.1.5.2 Live Load Deflections

15.5.1.5.2.1 Girders of simple or continuous spans shall be designed so that deflections due to live load plus impact shall not exceed 1/1000 of the span length. The deflection of cantilever arms due to live load plus impact shall be limited to 1/450 of cantilever arm.

15.5.1.5.2.2 For deflection calculations only, normal loading of the rapid transit vehicle may be considered. Live load shall be assumed as 132,000 lb. distributed equally to four axles.

15.5.1.5.3 Longitudinal Tensile Stresses in Prestressed Aerial Structure Members

15.5.1.5.3.1 Longitudinal tensile stresses shall not be permitted under any combination of loads, except in the bottom fibers where tension will be permitted as 3 rf'_c maximum for impact loading only.

15.5.1.5.3.2 Reinforcing bars shall be added to resist the tension stresses resulting from impact loads.

15.5.1.5.3.3 In no case tension stresses are allowed at the joints in precast segmental post tensioned concrete. Maintain a minimum compressive stress of 50 psi minimum, under all loads and loading combinations at the joints, at all locations, in precast segmental posttensioned concrete.

15.5.1.5.3.4 Longitudinal tensile stresses shall not be permitted under any combination of loads in post tensioned concrete.

15.5.1.5.4 Shrinkage and Creep

15.5.1.5.4.1 Model for predicting shrinkage and creep in concrete structures shall be ACI 209.

15.5.1.5.4.2 Stresses and movements resulting from concrete shrinkage and creep shall be considered in the design and included in all load combinations.

15.5.1.5.4.2.1 The shrinkage coefficient shall be assumed to be 0.0002 inches per inch for both prestressed and reinforced concrete.

15.5.1.5.4.2.2 To minimize creep problems, it is suggested that the average prestressing compression stress after losses should not exceed 1000 psi.

15.5.1.5.5 Structure Deformations and Settlements-All structure deformations, including foundation settlement, shall be considered, not only for their effect on structural behavior, but also for their effect on track work. The control of deformations through proper structural design is of paramount importance in obtaining acceptable riding quality of the rapid transit trains.

15.5.1.6 Structural Steel Design

15.5.1.6.1 Structural steel and composite steel-concrete flexural members for rapid transit aerial structures shall conform to the requirements of Section 15.8.

15.5.1.6.2 The requirement governing live load deflections and structure deformations and settlements as outlined for Reinforced and Prestressed Concrete Design shall also apply to Structural Steel Design.

15.5.1.7 FOUNDATIONS

15.5.1.7.1 Foundations for girder spans up to 150 feet in length shall not have total settlements greater than 1" nor differential settlements greater than 1/4", however, the design shall be based on a minimum ½" differential settlement. For spans over 150 feet in length, the Designer shall develop settlement values subject to Authority approval.

15.5.1.7.2 Allowable foundation bearing capacity shall be determined in consultation with the Designer's geotechnical consultant, and approved by the Authority.

15.5.1.7.3 The type of foundation shall depend on local soil conditions and are classified into three types as follows:

15.5.1.7.3.1 Spread footing shall not be permitted for aerial guideway foundation.

15.5.1.7.3.2 Pile Footings

15.5.1.7.3.2.1 Pile footings Pile foundations for aerial structures shall be designed in accordance with the requirements of AASHTO Specifications. However, uplift shall not be permitted in bearing piles or combination bearing and friction piles

15.5.1.7.3.2.2 Deleted.

15.5.1.7.3.2.3 Drilled Caissons

15 .5.1.7.3.2.3.1 The design shall keep maximum soil pressure at base of caisson below allowable soil bearing value.

15 .5.1.7.3.2.3.2 Bearing values shall be established and verified by independent testing as approved by the Authority.

15 .5.1.7.3.2.3.3 Permanent steel casing shall not be considered for both structural and geotechnical designs. Caisson Foundation for aerial structures shall be designed with multiple caissons. Single caisson foundation shall not be used. Caisson foundations for straddle bent structures shall be designed with minimum of four caissons per column.

15.5.1.7.3.3 Rammed aggregate pier foundation (or similar ground improvement) shall not be used in Metro facilities or aerial guideway structures.

15.5.1.8 Bearings

15.5.1.8.1 Pot bearings shall not be permitted.

15.5.1.8.2 Elastomeric bearings for Aerial Stations:

15.5.1.8.2.1 Criteria for the design shall be governed by AASHTO Section 14 "Elastomeric bearings". Method A or B is to be used as applicable. The compressive strain should not exceed 7%.

15.5.1.8.2.2 If at one end of girder or structure sliding bearing is used, the bearing assemblies shall be the sliding plate type bearing which allows translation by sliding of a self-lubricating surface across a smooth hard solid stainless steel mating surface.

15.5.1.8.2.2.1 The assembly is to have solid stainless steel bearing plate on the upper unit with sole plate and a preformed fabric pad with a rigidly confined PTFE bearing surface in the lower unit with masonry plate.

15.5.1.8.2.2.1.1 The preformed fabric pad shall meet AASHTO Specifications 10.3.12 “Preformed Fabric Pads” and capable of withstanding loads of 10 ksi perpendicular to the plane of lamination.

15.5.1.8.2.2.1.2 The metal bearing plate shall be fabricated from minimum of 13 gage stainless steel, and have a mirror finish with a minimum 20 micro inches RMS on the PTFE bearing side.

15.5.1.8.2.2.1.3 The coefficient of friction between the steel plate and the PTFE surface shall be no greater than .06 at 800 psi compressive loading.

15.5.1.8.3 Bearings for Aerial Line Sections

15.5.1.8.3.1 Bearing assemblies used in the line sections of the aerial structure with span lengths of 80 feet or more, shall be self-lubricating bearing assemblies to provide rotation and longitudinal movement as needed for expansion joints. The bearing assembly shall be an integral unit composed of:

15.5.1.8.3.1.1 Spherical bearings plates - A convex solid stainless steel plate with surface of woven PTFE fabric mechanically interlocked to the substrate plate, and a mating solid stainless steel concave plate with finished bearing surface. The spherical interface shall provide rotational movement in any direction.

15.5.1.8.3.1.2 Flat bearing plates - A flat plate with the PTFE material similarly fixed on the sliding surface, and a solid stainless steel concave mating plate, as described in Section 15.5.1.8.3.1.1 above with a flat finished sliding surface, to provide longitudinal translation movement. The relative movement between these two flat surfaces is to be restricted to the longitudinal direction. Such a flat bearing plate assembly is required along with Spherical bearing plate assembly only at the expansion end.

15.5.1.8.3.1.3 The PTFE fabric shall have a minimum thickness of 1/16" and is to meet the following requirements:

15.5.1.8.3.1.3.1 Hardness at 78°F per ASTM D676 - 50-65 Durometer D

15.5.1.8.3.1.3.2 Tensile strength per ASTM D638 - 2800 psi (Min. Avg.)

15.5.1.8.3.1.3.3 Elongation per ASTM D1708 - 200% (Min. Avg.)

15.5.1.8.3.1.3.4 The coefficient of friction between the steel plate and the PTFE surface shall be no greater than .06 at 800 psi compressive loading.

15.5.1.8.3.1.4 The stainless steel surfaces shall have a finish of 20 RMS.

15.5.1.8.3.2 Expansion bearings shall be sized and set at the time of construction to allow for the following:

15.5.1.8.3.2.1 The maximum temperature movement based on the mean 48 hour prior temperature.

15.5.1.8.3.2.2 The anticipated rotation and movement due to creep, shrinkage and elastic shortening from time of setting through day 400. These computed rotation and movements shall be increased by a factor of 1.3.

15.5.1.8.4 Materials and fabrication for all type bearings, shall be in accordance with AASHTO's Section 18. Division II, and with the contract specifications.

15.5.1.8.5 All types of bearing assemblies installation, shall have provisions for:

15.5.1.8.5.1 Future bearing replacement and inspection shall be indicated on the design drawing.

15.5.1.8.5.2 The reactions for the jacking forces required for removal of the bearings shall be included in the contract drawings.

15.5.1.8.5.3 Provision for Inspection and future replacements of bearings should be made possible from inside box girders.

15.5.1.8.5.4 Furthermore, design shall provide inspection and maintenance manual for the aerial structures indicating

15.5.1.8.5.4.1 All critical items and area for periodic inspections such as bearings, tie-downs, end & deviation blocks, connections, fracture critical members locations and connections, etc.

15.5.1.8.5.4.2 inspection flow charts, frequency and procedures.

15.5.1.8.6 Anchor bolts subject to tensile fatigue loading shall be torqued in accordance with AREMA Manual.

15.5.1.8.7 Bearing pads shall be non-shrink grout. Minimum 28 days compressive strength for non-shrink grout shall not be less than 7000 psi.

15.5.1.9 Precast Box Girder Segment for Aerial Structures - Casting and Erection:

15.5.1.9.1 Minimum strength prior to lifting segments or lowering forms: 2500 psi.

15.5.1.9.2 Minimum concrete strength prior to stressing vertical and transverse post-tensioning: 4000 psi

15.5.1.9.3 Minimum age of segments at time of erection: 14 days

15.5.1.9.4 Minimum concrete strength prior to stressing longitudinal posttensioning: 6000 psi

15.6 SOILS AND GEOTECHNICAL CRITERIA

15.6.1 The Authority will provide site specific Geotechnical Information (GI).

15.6.2 The Designer of Record/Design-Builder may perform additional geotechnical investigations, as he deems necessary.

15.6.3 The Design-Builder's Geotechnical Consultant shall investigate and summarize the geotechnical information provided with existing and newly obtained data, identify subsurface strata and recommend properties for design in a separate Geotechnical Design Report (GDR).

15.6.4 Soil and rock properties given in Table 15.2 (pages 1 through 5) are the allowed limits required for design. The Designer may use values for design provided in the GDR if obtained through site-specific testing and verified by laboratory results, and approved by WMATA.

15.6.5 The Designer of Record/Design-Builder will be responsible for the certification / sealing of the design and the design drawings, by a professional engineer registered in the jurisdiction of the work location.

15.6.6 Expansive Soil

15.6.6.1 Expansive soil is defined by section 1803.5.3 of the IBC 2012.

15.6.6.2 Provide piles under footings or remove and replace to a depth of 5 feet below the bottom of footing.

15.7 SUPPORT AND UNDERPINNING OF EXISTING STRUCTURES

15.7.1 **All Designs** for support and underpinning of existing structures shall be coordinated with the Authority. The economics and feasibility of various underpinning and dewatering methods for structures influenced by excavation or tunneling shall be investigated by the Design/Builder and recommendations shall be made as to the method best suited to the particular structure.

15.7.2 **Special Provisions** shall be made in the contract documents requiring the construction contractor to maintain, protect and be responsible for the safety, stability and integrity of all buildings and structures which may be affected by the work. These provisions shall be coordinated with the Authority.

15.7.3 **All Structures**, within the WMATA zone of influence shall fall into one of the following two categories:

15.7.3.1 Zone A Structures

15.7.3.1.1 Structures within Zone A (see Figure 15.19) require underpinning design, detailed drawings and specifications prepared by the Designer for Authority approval. In identifying Zone A structures the Design/Builder shall investigate all structures over or adjacent to the work Zone A shall include:

15.7.3.1.1.1 Buildings or structures which extend over transit structures to an extent requiring support during construction and permanent underpinning.

15.7.3.1.1.2 Buildings or structures immediately adjacent to the transit structures, which must be carried on underpinning braced to act as retaining elements supporting the sides of the excavation.

15.7.3.1.1.3 Underpinning walls or piers supporting buildings or structures and forming a portion of the excavation support system shall be extended to a minimum depth of 4'-0" below subgrade elevation to the underground rapid transit structure.

15.7.3.1.2 Methods used to underpin or protect these buildings or structures shall depend on local soil conditions and shall be designed to eliminate differential settlement.

15.7.3.2 Zone B Structures

15.7.3.2.1 Structures located within the WMATA zone of influence but not requiring underpinning, in accordance with Figure 15.19 and as determined by the Designer/Builder, subject to Authority approval. Such structures shall not be listed in the contract documents. The need for protection, temporary support or permanent underpinning of Zone B structures shall be the responsibility of the construction contractor, who shall be required to submit designs and computations prepared by an engineer registered in the locality of the work.

15.7.3.2.2 Zone B includes structures which may be affected by groundwater lowering.

15.7.3.2.3 All underground construction shall be designed on the assumption Zone B structures will not be underpinned.

15.8 STRUCTURAL STEEL DESIGN

15.8.1 Consideration shall be limited to the following Types of Structural

Steel. Other types may be used only with the approval of the Authority.

15.8.1.1 Structural Steel-For normal use: ASTM A36; ASTM A709, Grade 36.

15.8.1.2 High Strength Structural Steel

15.8.1.2.1 For uses requiring higher strength steels or where economically justifiable use: ASTM A242, A514, A588, A572, A709 and A992 (for structures not carrying train loading).

15.8.1.2.2 For elevators for the physically disabled, hoistway framing ASTM A500. Grade B. modified to 50,000 psi minimum yield strength if necessary. Architectural metal cladding as shown on the directive drawings.

15.8.1.3 Connections

15.8.1.3.1 Shop connections shall be welded or bolted. All welding shall be in accordance with the applicable requirements of the American Welding Society Structural Welding Code as described in Section 15.2.1.11. Design of welded aerial structures shall also comply with the applicable provisions of fracture control plan as required by the AASHTO Standard Specifications for Highway Bridges, latest edition. Special consideration shall be given to welded connections for addressing Fatigue to alleviate future cracks. Each aerial structure design shall be evaluated to determine the location of any non-redundant fracture critical member or member components that may exist and their location shall be clearly delineated on the contract plans.

15.8.1.3.2 Functionality shall be considered as well as strength in determining whether failure of a structural element is critical, and appropriate measures up to or including those for a fracture-critical member, shall be prescribed to avoid failure of such an element. In particular, it is possible that an aerial structure supporting tracks may promote derailment when load resistance is transferred from a failed element to another element, even though the structure is redundant.

15.8.1.3.3 Field connections shall be designed for high-strength bolts unless otherwise approved by the Authority. The use of high-strength steel bolts shall be governed by "Specification for Structural Joints Using ASTM A325 or A490 Bolts". This includes a prohibition of galvanizing for A490 bolts and hot-dip galvanizing for A325 bolts of Type 2. The bolt type to be used shall be identified in the design specifications.

15.8.1.3.4 Threaded bolts of ASTM A36, A307, galvanized shall be used for anchors and other applications. Swedged bolts shall not be used.

15.8.1.3.5 End diaphragm between steel girders shall be provided at the bearings. Intermediate diaphragms shall be provided at 25 feet maximum spacing.

15.9 REINFORCED AND PRESTRESSED CONCRETE DESIGN

15.9.1 Cements

15.9.1.1 Type I Portland Cement ordinarily shall be specified for concrete mix design; however, consideration shall be given to the use of an approved expansive type cement, manufactured to compensate for the normal drying shrinkage of Portland Cement concrete.

15.9.1.2 Type II Portland Cement shall be specified for concrete construction in soils having low pH values or high sulphate content.

15.9.1.3 Type III Portland Cement may be specified for concrete mix design requiring a high early strength, except where soil conditions make the use of Type II necessary.

15.9.1.4 Shrinkage Compensating Cement may be used if approved by the Authority.

15.9.1.5 All of these Portland Cement Mixes (except Type III) may utilize Blast Furnace Slag or Fly Ash as a percentage of Portland Cement content in accordance with WMATA Specification. Corrosion inhibitor with Calcium Nitrite base shall be used in all concrete exposed to elements.

15.9.2 Reinforcing Steel

15.9.2.1 All mild steel reinforcement shall be ASTM A706 or ASTM A615, Grade 60.

15.9.2.2 All reinforcing steel in the platform slab, pedestrian bridge and their immediate support structure shall be epoxy coated.

15.9.3 Concrete Design

15.9.3.1 For all underground structures:

15.9.3.1.1 Cast-in-place concrete f'_c = 4000 psi unless otherwise approved by the Authority, and. shall be designed by the "Alternate Design Method" of ACI 318-99, using the following values:

$n = 8$

f_c in flexure = 1,800 psi for station arches

f_c in flexure = 1,600 psi for other underground structures

15.9.3.1.2 f'_c for precast members shall not be less than 5,000 psi except that precast tunnel liners shall be not less than 6,000 psi. Use of strengths higher than 7,000 psi concrete will require prior approval of the Authority. Use of concrete with f'_c greater than 7,000 psi shall be limited to columns only. Concrete with f'_c greater than 10,000 psi shall not be used.

15.9.3.1.3 f'_c for prestressed concrete shall be not less than 5,000 psi. Unbonded and ungrouted prestressing steel shall not be used. Use of higher strengths than 7,000 psi will require prior approval of the Authority. Use of concrete with f'_c greater than 7,000 psi shall be limited to columns only. Concrete with f'_c greater than 10,000 psi shall not be used.

15.9.3.2 For all above ground structures:

15.9.3.2.1 Cast-in-place concrete f'c = 4,000 psi unless otherwise approved by the Authority. See Section 15.2.2.4. f'_c for precast members shall not be less than 5,000 psi except that precast tunnel liners shall be not less than 6,000 psi. Use of strengths higher than 7,000 psi concrete will require prior approval of the Authority. Use of concrete with f'_c greater than 7,000 psi shall be limited to columns only. f'_c for pre stressed concrete shall be not less than 5,000psi. Unbonded and ungrouted prestressing steel shall not be used. Use of higher strengths than 7,000 psi will require prior approval of the Authority. Use of concrete with f'_c greater than 7,000 psi shall be limited to columns only.

15.9.3.2.2 For precast/prestressed concrete parking structure, refer to Section 15.21.

15.9.3.2.3 Where existing parking use will be disrupted during construction, precast construction should be considered to minimize disruption. Where construction time is of little consequence or special construction features are required, post tensioned cast-in-place construction may be required and will be accepted.

15.9.3.3 For all structures:

15.9.3.3.1 Precast Prestressed Concrete:

15.9.3.3.1.1 All exposed concrete edges shall be chamfered. Chamfers shall be 3/4 inch by 3/4 inch unless noted otherwise.

15.9.3.3.1.2 Concrete Strength

15.9.3.3.1.2.1 Unless noted otherwise, all precast prestressed concrete shall attain 28-day minimum compressive strength (f'_c) of 6,000 psi with a maximum water-cement ratio of 0.40 and contain a corrosion inhibitor as specified in Section 15.21.25.

15.9.3.3.1.2.2 High performance concrete of strength up to 10,000 psi, for columns only, may be considered with Authority's prior approval.

15.9.3.3.1.2.3 The compressive strength of concrete at the time of initial prestress (f'_{ci}) shall not be less than 4,000 psi nor less than $0.6 f'_c$.

15.9.3.3.1.2.4 For allowable tensile stresses in rapid transit aerial structures see Section 15.5.1.5.3.

15.9.3.3.1.3 Concrete Stresses in Structural Members Not Carrying Transit Loads

15.9.3.3.1.3.1 Extreme fiber stress in tension immediately after prestress transfer (before time-dependent prestress losses) shall not exceed $6/f_{ci}$ even if bonded auxiliary reinforcement is provided.

15.9.3.3.1.3.2 Extreme fiber stress in tension, in precompressed tensile zone at service loads (after prestress losses) shall not exceed $6/f'_c$.

15.9.3.3.1.4 Connections

15.9.3.3.1.4.1 The precast manufacturer shall design and provide all embedded items necessary for connections.

15.9.3.3.1.4.1.1 All connection hardware shall be Stainless Steel.

15.9.3.3.1.4.1.1.1 Use ASTM A706 weldable reinforcing for all reinforcing which is required to be welded.

15.9.3.3.1.5 Full attention shall be given to restrict corrosion of reinforcement, embedded steel and any other exposed steel at connections. Silane penetrating sealers (min 45% solids), on exposed horizontal surfaces, shall be required as well as use of corrosion-inhibitor in concrete. The corrosion-inhibitor shall be calcium nitrite-based admixture, DCI as manufactured by W.R. Grace & Co. or approved equal.

15.9.3.3.1.6 Provision shall be made to install Fiber Optic Sensors in the precast concrete aerial structures, as required by the specifications.

15.9.3.3.2 End diaphragm between girders, both precast and cast in place, shall be provided at the bearings, however, clearance shall be provided for bearing replacement lifting devices. End diaphragm depth shall be same as the girder depth. The end diaphragm shall be cast-in-place concrete.

15.9.3.3.3 Intermediate diaphragms shall be provided between girders at 40' maximum spacing. The depth of intermediate diaphragm shall not be less than one half of the girder depth. The intermediate diaphragm shall be cast-in-place concrete.

15.9.4 Reinforcing Steel Details

15.9.4.1 Spacing

15.9.4.1.1 Temperature and shrinkage reinforcement for aboveground structures shall meet the requirements of the ACI code.

15.9.4.1.1.1 Temperature and Shrinkage reinforcement for underground concrete structural units not exceeding 50 feet in length shall be at least 0.15% of the gross concrete area, with a maximum of #7 bars at 18" centers in each face except for lower station arch units where it shall be #7 at 12" centers on the outside face and #7 at 9" centers on the exposed face in order to minimize cracking. This steel shall be placed as close to the exposed face as possible and permissible.

15.9.4.2 Splices

15.9.4.2.1 All typical splices of main reinforcement shall be indicated on the drawings and the lengths of these lap splices given. Only a statement that all splices shall be in accordance with ACI code is not acceptable.

15.9.4.2.2 Mechanical tension splices of reinforcing bars shall be made by the use of Cadweld or NMB splices. Other mechanical splices / couplers may be accepted on a case by case basis and this acceptance shall be at the sole discretion of the Authority. All mechanical couplers shall comply with the requirements of the applicable code.

15.9.4.3 Joints

15.9.4.3.1 For expansion joints in overlaying members, Of Above Grade Structures see Section 15.9.9.1., and for Precast Prestressed Parking Structures see Section 15.21

15.9.4.3.2 For tunnel units longer than 50 feet between contraction joints, construction procedures shall be specified and adequate reinforcement shall be provided to reduce cracking to a minimum. The above requirements do not apply to rock tunnels.

15.9.4.3.3 Rock tunnels may have vertical contraction joints in arch, vertical or sloping construction joints in the invert or may be continuous without joints, with prior approval of the Authority. All construction joints shall be bonded.

15.9.5 Architectural Considerations - In order to assure uniformity of structural concrete color in public areas of the stations, it will be necessary to standardize concrete mix and strength throughout, as approved by WMATA.

15.9.5.1 This will apply to all concrete exposed to public view within the stations and for a distance of approximately 100 feet beyond the ends of platforms.

15.9.5.2 The structural element such as mezzanines within a station requiring the highest strength concrete will determine the single strength to be used for all elements.

15.9.5.2.1 Deleted.

15.9.6 Roofs over Station Mezzanines and Mezzanine Structure - These criteria refer to pertinent data in cast-in-place concrete roofs over mezzanines in above ground stations.

15.9.6.1 Design Assumption

15.9.6.1.1 Long span of 60 feet and more roof structures shall be two-way posttensioned with a minimum prestress of 100 psi and not more than 250 psi, longitudinally and transversely to reduce the cracking of concrete.

15.9.6.1.2 For spans up to 80 feet mezzanine structures may be designed using high strength precast prestressed concrete.

15.9.7 Architectural Details - Include details of block outs at tensioning points to assure corrosion protection and continuity of architecture features of the structure.

15.9.8 Roofs, Lightweight Insulating Concrete Fill - Lightweight insulating concrete fill will not be permitted in roof construction.

15.9.9 Crack Control and Waterproofing of Above-Ground Structures for station mezzanine, platform, track support, ancillary structures and parking structures:

15.9.9.1 Joints or pour strips shall be used to control concrete cracking, especially where the structure has re-entrant corners, geometrical or loading asymmetry or other features which tend to cause cracking of concrete. Expansion Joints in overlaying members shall always coincide with Structural joints (e.g. station platform setting bed and tile expansion joints must coincide with structural slab expansion joint). Jointing hardware shall ensure complete water tightness.

15.9.9.2 Maximum spacing of expansion joints 100' - Locate joints judiciously to ensure that the electrical and mechanical rooms are not impacted.

15.9.9.3 Movement due to shrinkage, temperature variation, prestress elastic shortening and creep, which must be allowed by expansion joints, shall be calculated, taking joint geometry into account.

15.9.9.3.1 The movement shall be 1" minimum (which may be reduced for spacing less than 100' - minimum allowable movement proportional to spacing).

15.9.9.3.2 All expansion joints introduced by design must have assured free movement and rotation where applicable, without any obstruction.

15.9.9.3.3 Expansion joints shall be sealed with either lock-in or extruded strip seal as shown in Drawing DD-S-120.

15.9.9.3.3.1 The seal shall be neoprene and continuous along the length of the expansion joint.

15.9.9.3.3.2 Seals shall have a width 115% of the maximum and 250% of the minimum joint opening.

15.9.9.4 Joint installations shall provide continuous, full-width watertight seals with gutter like terminations which are durable and readily renewable. Design documents shall require the on-site participation and recommendations to the Engineer of a seal manufacturer representative to ensure proper installation and easy replacements in the future.

15.9.9.5 Expansion joint anchors shall be integrated with the deck reinforcement, and finished concrete in the vicinity of joint surfaces shall be sound.

15.10 DESIGN OF CIRCULAR SEGMENTAL TUNNEL LINERS

15.10.1 For Contracts which include soft-ground tunneling, the Designer/Builder shall develop a segmental tunnel liner based upon design recommendations provided in the Geotechnical Design Report (GDR). A two-pass system utilizing a PVC waterproof membrane system is preferred. The GDR shall provide recommendations concerning tunneling method and appropriate equipment types. Tunnel liner segments shall be designed to resist individual jack thrust of at least 125 tons spaced at approximately 2'-6" on centers.

15.10.2 One-Pass System Circular Earth Tunnels

15.10.2.1 One-pass tunnel support shall consist of reinforced precast concrete segmental lining with waterproofing gaskets and bolts as depicted on Drawings DD-S-141, DD-S-142, DD-S-143, DD-S-144 and DD-S-145.

Precast concrete compressive strength f'c shall not be less than 6000 psi.

15.10.2.2 For shield driven tunnel construction, segmental linings shall be designed for support of ground loads and shield jacking forces.

15.10.2.3 The use of 7 segments (6 pieces plus key) is preferred.

15.10.3 Two-Pass System Circular Earth Tunnels

15.10.3.1 The two-pass tunnel support system shall consist of a precast reinforced concrete initial liner and a cast-in-place non-reinforced concrete final liner, both designed as permanent tunnel liners. The inside diameter of the final liner shall be 16'-8". A continuous waterproofing membrane must be provided along the entire circumferential surface between the initial liner and the final liner. Details for the membrane, relief drains, and barriers () are provided by Drawings DD-S-123, DD-S-124, DD-S-125, DD-S-126, DD-S-127 and DD-S129. The Designer shall adopt these details as required and necessary.

15.10.3.2 The Designer shall specify tunneling machine operational requirements including tunnel guidance system, alignment tolerances, grouting and stability requirements for the precast rings of the initial liner. The initial liner shall be comprised of segments with a maximum width of four feet and a minimum thickness of 9 inches. Based on the geological conditions it should be decided if rings should be expanded in place without gaskets or they need to be bolted with gaskets to keep the water out of the tunnel.

15.10.3.3 Initial Precast Liner

15.10.3.3.1 The design of the initial precast liners of the two pass system tunnels shall be performed by the Designer. The initial liners shall be designed for the short term loads, as noted below. The liner segments shall be not less than 9 inches in thickness. The minimum compressive strength of concrete f'c of the initial liner concrete shall be 6,000 psi at 28 days, and the design shall be in accordance with the "Alternate Design Method" of the current ACI 318-99. The Designer shall include in the contract specifications and note on the drawings that the Contractor is responsible for verifying and increasing reinforcement of the initial liner as necessary to sustain loads imposed during handling and transportation, erection, jacking and grouting. The contract specification shall include the Contractor submit, working drawings and pertinent design calculations for approval.

15.10.3.3.2 Lining Installation Method Options

15.10.3.3.2.1 One installation method is by expanding the lining against the earth. This is a suitable method when it is not necessary to make the initial liner fully waterproof. A single-point or two-point jacking method shall be considered. Use an expansion ring for such jacking scheme. The initial gap before expansion may vary between 4Eand 10E. When using two jacks axial thrust shall be produced in the liner segments in the tangential direction along the entire circumference, to maintain proper contact between segments, during expansion. Jacks shall be of adequate capacity recommended capacity is a minimum of 100 tons each. The expanded gaps shall be supported by steel Dutchman and filled with concrete, to maintain the axial thrust in the ring.

15.10.3.3.2.2 Another optional method is the use of bolted segments. Gasketed and bolted segments are beneficial in high water table areas. When bolted segments are used the contact between the segment and the surrounding soil is to be achieved by contact grouting.

15.10.3.3.2.3 All lining installation methods require full grouting of the contract between the segment and the surrounding soil, and within a specified time interval. The construction documents shall require the Contractor to protect utilities, assure face support, prevent settlement, and obtain full contact between the initial liner and the ground.

15.10.3.3.2.4 The Contractor shall be required to complete the precast tunnel (first pass) and achieve a stable configuration of the rings before the final liner is cast. The Contractor shall be required to prove stability has been achieved and maintained by convergence monitoring.

15.10.3.3.3 Design Loads and Other Considerations

15.10.3.3.3.1 WMATA tunnels shall be designed for short-term and long-term loads as shown in Figure 15.17,

15.10.3.3.3.2 For the two-pass system, the initial liner is designed for short term loads shown in Figure 15.17 only. Reduction of vertical pressure due to development of side shear in the soil is not permitted. The final liner is designed only for long-term loads.

15.10.3.3.4 Final Cast-in-Place Concrete Liner:

15.10.3.4.1 Final liner design shall be performed by the Designer/Builder. The final liner shall be designed for long term loads shown in Figure 15.17. The Designer/Builder's geotechnical consultant may revise this loading with approval of the Authority. Hydrostatic pressure shall be considered when applicable.

15.10.3.4.2 The final liner, if not provided with steel reinforcing shall be a minimum of 16 inches thick. To account for possible tunnel misalignment, the tunnel final liner shall be designed as having a minimum thickness of 12 inches. Contraction joints shall be located at a spacing of no greater than 50 foot along the length of the tunnel arch. Contraction joints shall be spaced at no more than 150 foot for the invert. The minimum compressive strength (f'c) of the final liner concrete, at 28 days, shall be 4000 psi. The strength shall be obtained without consideration for added fiber reinforcement. Design of non-reinforced plain concrete shall be based on the requirements of the current edition of ACI 318.1 (Structural Plain Concrete). Plain concrete for the final liner shall have fiber reinforcement added for shrinkage control. The Designer shall consider the case when the tunnel is misaligned and a minimum liner thickness of 12 inches is not possible. If the minimum thickness of the misaligned tunnel liner is less than 12 inches but greater than 9 inches, the Designer shall provide contingency reinforcement. Reinforcement provided in the final liner arch because of contingency requirements shall be discontinued at each arch contraction joint regardless of invert joint spacing and a water barrier provided. Note that even if the invert may be poured in 150 foot segments the invert reinforcement shall be made discontinuous at each contraction joint of the arch, and a water barrier shall be provided all around the circumference of the final liner including invert. If the final liner thickness is less than 9 inches due to misalignment, the Contractor shall be required to re-mine to obtain adequate liner thickness.

15.10.3.4.3 The Designer/Builder shall provide a computer analysis of the tunnel liner design, modulus of subgrade reactions shall be as specified by the Designer's Geotechnical Consultant, and reviewed and approved by the Authority. Use of radial springs for the computer model is recommended. All tension springs on the tunnel models must be released. Selective checks, using hand calculations shall be performed to establish the applicability of the computer analysis.

15.10.3.4.4 Tunnel/Structure Interface - When non-reinforced final lining is used, the Designer shall provide reinforcement in transition portions at the interface with stiff structures such as, fan shafts, emergency access shafts, etc.

15.10.4 Investigation of Construction Adjacent to Tunnels

15.17.7.11 In areas of probable development adjacent to the tunnels, the Designer shall investigate the adequacy of the tunnel liner utilizing Loading Case II, (Section 15.4.2.1.2), Full Vertical Load, with "long-term" horizontal load on one side and "short-term" horizontal load on the opposite side (loading as recommended by the Designer's Geotechnical Consultant), acting on the combined initial and final liner. Such areas in which the tunnel liners are designed for Loading Case II shall be marked on the design drawings.

15.11 TEMPORARY STREET DECKING SYSTEMS

15.11.1 **Temporary Decking Systems**, including decking, beams, piles, lagging, bracing, struts, railings, curbs, sidewalks, and other elements shall be designed by the Contractor, based on information provided on Drawing ST-S-009 and Drawing DDS-063. The design shall be prepared by an engineer registered in the jurisdiction of the locality of the work.

15.11.2 Drawing. ST-S-009 and WMATA Standard Specifications require Primary Bracing Members other than slurry walls be prestressed to 50 percent (and 100% when tiebacks are used) of their design load to minimize movement of the retained soils and reduce the possibility of damage to adjacent buildings, utilities, or other structures. In localities where there are no sewers, water lines, or other utilities which could be affected by the work, the50 percent prestressing requirement may be reduced with Authority approval. The Designer shall investigate prestressing requirements for the site in conjunction with their geotechnical consultant and modify this requirement if approved by the Authority. The requirement for 100% prestressing for slurry wall braces shall be retained in all cases.

15.11.3 Emphasis shall be placed by the Designer on adequate design and detailing of member connections. Web stiffeners should be specified at all strut to wale connections and other points of concentrated forces.

15.11.3.1 The Designer shall indicate in the contract drawings and cover comprehensively in the specifications, detailed arrangements for traffic diversions, allowable restrictions, and necessary construction stages which have been approved by the public authorities.

15.11.3.2 Acceptable locations shall also be indicated for construction access ramps or any other construction facility which affects the temporary street decking system design.

15.12 CONSTRUCTION, GENERAL

15.12.1 Fire Hazard Rating: NFPA 130 and NFPA 220.

15.12.1.1 In case where no suitable material conforms with these requirements, minor quantities of an accessory material may be permitted if prior approval in writing is obtained from the Authority.

15.12.1.2 Underwriters' Laboratories, Inc., label or listing, satisfactory test results from the National Institutes of Standards and Technology, or certified report from an approved testing laboratory, will be required to indicate that fire hazard ratings for materials proposed for use conform to the above.

15.12.2 Ancillary Rooms at Stations

15.12.2.1 Walls

15.12.2.1.1 For a distance of approximately 100 feet beyond the ends of the station platform the exposed concrete in the walls and ceiling of the tunnel shall be the same color as that in the station vault. Undamaged forms shall be used to produce a smooth finish as in the station. Reinforced concrete walls shall have a smooth finish but need not be rubbed.

15.12.2.1.2 Partition walls of ancillary rooms shall have fire ratings in accordance with the following unless otherwise specified in NFPA 130 or the local jurisdiction:

15.12.2.1.2.1 Traction Power Substation - 3 hrs from all other occupancies

15.12.2.1.2.2 AC Switchboard, Battery, DC Breaker, Train Control and Communications Rooms - 2 hours from all other occupancies

15.12.2.1.2.3 Cleaner's Rooms - 2 hours from all other occupancies

15.12.2.1.2.4 Public areas shall have a 2 hour separation from all non-public areas

15.12.2.1.2.5 Openings between station public areas and non-transit occupancies shall have a 3 hour separation

15.12.2.1.3 The partition walls shall comply with the applicable local Code with respect to lateral support if such is necessary.

15.12.2.1.4 Each Mechanical Equipment Room shall have an 8' x 8' removable panel of concrete block to permit removing the air conditioning equipment from the room into the tunnel. The panel shall have a 2-hour fire rating.

15.12.2.1.5 **Doors** -All door sizes and UL requirements shall be those listed on the Architectural Door Schedule Drawings.

15.12.3 See Section 15.21.36 for Masonry

15.12.4 A match casting technique shall be employed, if the Precast segments are utilized in the platform construction.

15.12.5 Areas/buildings where the Slab on grade (SOG) will be subjected to rack posts/fork lift trucks/vehicle loads:

- SOG shall be designed for a minimum concentrated load of 15kips /post. The most unfavorable post configuration shall be considered (four posts can be located in a two feet square area) where the whole area is covered by racks.
- Areas subjected to fork lift trucks or other vehicle loads, a minimum axle load of 15kips /wheel (30 kips/axle, increase 33% for impact and safety).
- However, the loads shall be increased if storage/rack or vehicle loads dictate.
- The SOG reinforcement shall be designed per applicable codes and CBR (a minimum value of 8)
- SOG to be placed on a minimum 6" thick free-draining crushed gravel base, with 10 mil polyethylene vapor barrier.
- Compact subgrade to 100% of the maximum dry density (MDD) at optimum moisture content as determined in accordance with ASTM D698 (standard proctor) or 95% of MDD as per ASTM D1557 (modified proctor).

15.12.5.1 For minimum thickness and reinforcing requirements:

- Areas/buildings where the SOG will be subjected to rack post/vehicle loads: 8" thick concrete slab with #4@12" O.C. (Top and Bottom, Each way)
- Areas/buildings where the SOG will be subjected to a uniformly distributed floor load of 250psf or less: 6" thick concrete slab with #4@12" O.C. (Each way)

15.13 EARTH STRUCTURES

15.13.1 Earth Structures Include Fill Embankments, Cut Slopes, or Combinations Thereof. The design of each earth structure shall be established in consultation with a geotechnical consultant and approved by the Authority. Design considerations and procedures shall be in accordance with, but not limited to, those outlined in the AREMA Manual, Chapter 1, Part 1.

15.13.2 Slopes

15.13.2.1 Slopes of cuts and fills shall not be steeper than two horizontal to one vertical unless approved by the Authority.

15.13.2.2 Shoulders of cut slopes shall be rounded.

15.13.2.3 Provide interceptor ditches at the top of cut slopes where runoff is anticipated.

15.13.2.4 An intermediate drainage bench or benches ten feet in width shall be provided for slopes which exceed thirty vertical feet.

15.13.2.5 Slopes shall be protected from surface erosion by a cover of grass or other vegetation suitable for the particular location and soil condition.

15.13.2.5.1 Slopes steeper than two horizontal to one vertical, where specifically permitted by the Authority, shall be protected in a like manner.

15.13.2.5.2 Special consideration shall be given to slopes shaded from light and precipitation.

15.13.2.6 Where protection by grass or other vegetation is not feasible, grouted field stone rip-rap or other approved form of slope protection shall be provided.

15.14 TUNNEL PORTAL DESIGN

15.14.1 Tunnel and Box Section Entrance Portals shall be designed in a manner to minimize the rate-of-change of pressure on a train passing through the portal. The pressure rise is a function of both the cross-sectional area of the portal entrance and the entrance speed of the train (See Figure 15.9).

15.14.2 Acceptable Design Methods

15.14.2.1 Provide the entrance with a flared transition so that the increase in cross sectional area approximates the cross-sectional area of a 6 degree conical flare starting at the constant area section of the tunnel or box and extending to the portal opening as shown on drawing DD-S-064. This flared transition can be formed using any combination of tapers on the top and sides, provided no plane or surface of the transition section is at an angle in excess of 6 degrees relative to the center line of the tunnel and provided the side tapers are symmetrical with the center line. For the required length of the flared transition see Figure 15.10 and for the required cross-sectional area at the portal see Figure 15.11.

15.14.2.2 Design both the top and vertical sides of the entrance without a flare and provide a tapering slot in the top as shown on drawing DD-S-065. From a one foot minimum width at the constant area section the slot should increase to a maximum at the portal at a taper rate of 12 feet per 100 feet of length. The slot opening should therefore be 13 feet wide at the portal for a 100-foot long transition or 7 feet wide at portal for 50-foot long transition. For the required length of transition, see Figure 15.10.

15.14.3 Exceptions - Exceptions that do not require special transition portals are:

15.14.3.1 Tunnels less than 200 feet in length.

15.14.3.2 Single track horseshoe tunnels with train velocity 45 mph or less.

15.14.3.3 Box earth tunnels and single track circular tunnels with train velocity 40 mph or less.

15.15 ELEVATORS

15.15.1 Surface Structure Design Loadings

15.15.1.1 The surface structure shall be designed for the following loads. All loads shall be applied simultaneously with allowable stresses increased in accordance with applicable codes.

15.15.1.1.1 Dead load, 40 psf wind load and 30 psf snow load.

15.15.1.1.2 In addition, the canopy frame shall be designed for a 100 pound per linear foot live load at the free edges.

15.15.1.1.3 For traction type elevators, the surface structure shall be designed to support elevator beams. The end reaction of each elevator beam shall be 18,000 lbs. minimum. The locations of elevator beams vary with type of elevator and its relative machine room location. Designer shall coordinate with elevator manufacturers for the elevator beam locations.

15.16 SOLDIER PILES

15.16.1 Installation

15.16.1.1 Soldier piles shall be installed in pre-bored holes unless driven piles are acceptable under the following conditions:

15.16.1.1.1 The Designer has studied all available soils and cost data and other relevant factors and has made recommendations concurred in by his geotechnical consultant and the Authority. The following are representative of items which should be considered:

15.16.1.1.1.1 The noise of driving piles will not be objectionable in the given locality or in conflict with local ordinances or OSHA Code.

15.16.1.1.1.2 The underlying rock is not higher than 5 feet below the bottom of the invert, and the soil characteristics do not make penetration difficult because of boulders or high blow count.

15.16.1.1.1.3 Driving piles will not result in incorrect pile alignment or encroachment on the neat lines of the structure.

15.16.1.1.1.4 Driving piles will not alter soil characteristics with resulting damage to existing structures.

15.16.1.1.1.5 There will be a reduction in cost.

15.16.1.1.2 Note on the contract drawings where prebored piles are required and where driven piles are permitted.

15.17 UNDERGROUND STORAGE TANKS

15.17.1 Underground storage tanks shall be designed and installed in accordance with the following:

15.17.1.1 40 CFR 280 and the state equivalent regulations

15.17.1.2 NFPA 30 (latest update)

15.17.1.3 Local jurisdiction requirements

15.17.2 Because of the potential presence of stray current in the vicinity of WMATA facilities, only fiberglass-reinforced plastic (FRP) tanks and piping shall be used.

15.17.3 When a steel tank is encountered during renovation or construction operations, the tank shall be removed or abandoned in accordance with the code and regulations specified in Q.1. Steel tanks shall be replaced with FRP tanks.

15.17.4 Tanks shall have the appropriate leak detection system in accordance with local jurisdiction requirements.

15.17.5 Underground storage tanks and related piping shall not be located within 100 feet of a WMATA subsurface structure.

15.17.6 Vault Tanks: Generally, vault tanks shall not be constructed. When a vault tank is necessary, design and construction shall be coordinated with the Authority.

15.17.7 New tanks shall be provided as follows:

15.17.7.1 Tanks material will be FRP.

15.17.7.2 Tanks shall be of double wall construction, and shall have a minimum 30 year life.

15.17.7.3 Fiberglass tanks shall be in compliance with ASTM specification 04021-81, and UL 1316-83. Tanks shall bear the UL label.

15.17.7.4 Tanks shall comply with National Fire Protection Association (NFPA) 30, "Flammable and Combustible Liquid Code" and applicable local requirements.

15.17.7.5 Tanks shall be installed per manufacturer's recommendations which must include the following:

15.17.7.5.1 Bedding material

15.17.7.5.2 Requirements for surface traffic protection

15.17.7.5.3 Allowable depth of installation

15.17.7.5.4 Special tank supporting system if required.

15.17.7.6 The material used in tank construction or lining shall be compatible with the substance to be stored.

15.17.8 In most cases, corrosion protection will not be required because tank and piping construction will be FRP materials. When required because of steel tank or steel piping construction, corrosion protection shall be accomplished by the following method:

15.17.8.1 Use of cathodic protection in accordance with the National Association of Corrosion Engineers Standard RP-01-69 (1983 Rev.).

15.17.8.2 Corrosion protection shall be designed by a qualified corrosion engineer.

15.17.9 Tanks shall be equipped with a leak detection system. The detection system shall have a master control that will provide both visual and audible alarm when a leak is sensed. A Veeder-Root® or equivalent system (as determined by WMATA) shall be used. As a minimum, detection systems shall comply with the following:

15.17.9.1 The detection system shall be Underwriter's Laboratory and Factory Mutual approved.

15.17.9.2 Double wall tanks shall have annular or interstitial space monitoring to detect leakage or break down in either or both inner and outer walls.

15.17.9.3 Where single wall tanks are located within a concrete vault, external monitoring shall be accomplished by observation wells strategically located around the tanks within the confines of the vault.

15.17.10 All related piping, valves and fittings of Class I, II and III flammable and combustible liquids shall conform to NFPA Code 30.

15.17.10.1 Piping shall be UL labeled and corrosion resistant to combustible liquids and corrosive soils.

15.17.10.2 Piping material shall be FRP. Piping shall be installed in accordance with the manufacturer's instructions, and shall have a minimum 30 year life.

15.17.10.3 Distribution piping shall be provided with a secondary containment system. A double wall piping system shall be provided. This system shall be tested prior to backfilling to achieve system integrity equal to that of the double wall tank. The piping system shall be designed to as to preclude tank contents from standing in the piping system during non-flow periods.

15.17.11 No connection (such as venting or drainage) of any storage and related piping of Class I and II flammable liquids to Metro subsurface structure shall be permitted.

15.17.11.1 All tanks shall be atmospherically vented, in accordance with state and local air pollution codes.

15.17.11.2 Venting of any Class I, II and III flammable and combustible liquid storage structure shall not be permitted within 30 feet clear of the WMATA surface opening, subway entrance, or emergency opening.

15.17.12 The surface around pump islands shall be graded to drain away from any Metro grating or other opening in a manner to divert possible spills away from the subsurface and shall be surrounded by a curb at least 6" high. Provisions shall be made for draining of accumulations of ground or rain water or spills of flammable or combustible liquids.

15.17.13 Excavation operations shall not be performed directly above, below, or within 100 feet (measured horizontally) of any existing tank until the tank is pumped clean and purged of all vapor. Pressure tests of storage tanks shall be performed prior to excavation operations. Combustible gas detection analyzers shall be used during operations.

15.17.14 Aerial and at-grade structures shall be built in such a manner that their support loads are not transmitted to an adjacent tank. Where this is not possible the tanks shall be removed and, after consideration of soil and bearing conditions, properly placed in a location so that loads on the tank will not occur. The minimum horizontal distance shall be established in accordance with the requirement of NFPA 30, the local authority having jurisdiction and a qualified soils engineer after consideration of the soil bearing conditions.

15.17.15 Underground vaults and tanks shall be so located with respect to adjacent building foundation and supports that the loads carried by the latter cannot be transmitted to the vault or tank.

15.17.16 Tanks shall be tested in accordance with the provisions of NEPA 30 and manufacturer's criteria to assure total tank and piping system integrity.

15.17.17 During pipe pressure testing, piping shall be isolated from tank and pump.

15.18 METRO UNDERGROUND STRUCTURES DESIGN FOR AIR PRESSURE CAUSED BY RUNNING TRAINS

15.18.1 The following air pressure shall be considered in addition to other loading:

15.18.1.1 Fan and vent shaft dampers and ancillary area walls, doors and hardware inside tunnels or adjacent to stations and portals shall be designed to withstand a dynamic force, reversible in its direction, of 70 psf pressure.

15.18.1.2 Normally, no doors or walls shall be constructed in cross-passages separating two tunnels. However, when they must be constructed to satisfy safety or other requirements, the design pressure shall be as defined in Section 15.18.1.1.

15.18.1.2.1 Doors located in areas stated in Section 15.18.1.1 and used as emergency exits shall be concave pivot doors. If concave doors are not feasible, other suitable doors satisfying the criteria may be used.

15.18.1.2.2 For retrofit of existing doors in areas defined in Section 15.18.1.1, where replacements with concave pivot doors are not feasible, medium range blast doors shall be used. All related hardware must satisfy the criteria mentioned in Section 15.18.1.1

15.18.1.3 Station structures including ceiling and other components shall be designed to withstand a minimum wind load of 40 psf.

15.19 ROOF DRAINAGE - See Section 3.10.8.

15.20 WATERPROOFING

15.20.1 Underground facilities and below-grade portion of structures shall be designed to prevent water infiltration.

15.20.2 Design for water tightness shall include but not be limited to the following items:

15.20.2.1 Provide water stops at expansion, construction and contraction joints.

15.20.2.2 Provide sloping roof and floor slabs in underground areas to assure positive drainage and prevent surface depressions, i.e., "bird baths."

15.20.2.3 If a wall is adjacent to earth or rock, provide a waterproofing membrane on the outside face of the wall and provide relief drainage if necessary. Use applicable details of WMATA standard and design drawings (ST and DD-Drawings)

15.20.2.4 Provide drip shields in all aboveground structures.

15.20.2.5 Joints in the floor, ceilings or walls of rooms or buildings containing electrical equipment, such as Traction Power Substations, Tie-breaker Stations, AC Switchboard rooms, Battery rooms, Automatic Train Control and Communication rooms should be avoided and kept to a minimum where essential. Joint locations in rooms containing electrical equipment shall be coordinated closely with the Authority to insure proper equipment location.

15.20.2.6 Structures containing electrical equipment shall have continuous waterproofing all around outside face of walls including the bottom slab and roof.

15.20.2.7 Waterstops, keyways and joint details - Details and notes shown in WMATA standard and design drawings (ST-S-001 and DD-S-134) shall be applied to all underground facilities and below-grade portion of structures. Details shown in these drawings may be adjusted for proper application but modified details/notes are subjected to WMATA review and approval.

15.20.3 Waterproofing membrane

15.20.3.1 Waterproofing membrane shall comply with a minimum of 100 years durability requirements. Testing standards for 100 years durability shall be provided, subject to Authority review and approval.

15.20.3.2 All seams and lap joints shall be double wedge welded seams unless otherwise approved by Authority. All seams and lap joints shall be air pressure tested. Visual inspection of seams and lap joints shall not be permitted.

15.21 PRECAST PRESTRESSED CONCRETE PARKING STRUCTURES: - In addition to the requirements of this design criteria, the structural design of the precast prestressed parking structure shall also satisfy the following requirements Precast and Prestressed Concrete Institute (PCI) Design Handbook and Building Code Requirements for Masonry Structures (ACI 530/ASCE 5) and Specifications for Masonry Structures (ACI 530.1 /ASCE 6) and, ADAAG: ADA Accessibility Guidelines for Buildings and Facilities.

15.21.1 Loads: - The following loads shall be the basis for structural design:

15.21.1.1 Live:

15.21.1.1.1 Parking Roof - 80 PSF (which includes 30 PSF snow load),

15.21.1.1.1.1 Or two 4 kip concentrated loads, each acting on an area of 4.5 inches by 4.5 inches, at a spacing of 6'-0". The distribution of the concentrated load on the cantilever portion of double tees, shall be based on a 45 degree angle.

15.21.1.1.1.2 For roofs without car access , See Section 15.3.2.13.

15.21.1.1.2 Typical Parking - 50 PSF or two 4 kip concentrated loads, each acting on an area of 4.5 inches by 4.5 inches, at a spacing of 6'-0". The distribution of the concentrated load on the cantilever portion of double tees, shall be based on a 45 degree angle

15.21.1.1.3 Stairs & Elevator Lobby shall be designed for a uniform load of 150 psf (no area reduction factor allowed). Stairs shall also be checked for a minimum concentrated load of 300 pounds (on an area of 4 square inches) on stair treads. In the District of Columbia, stair treads only shall be designed for a uniform load of 100 psf plus a concentrated load of 300 pounds.

15.21.1.1.4 Car Impact - 10 kips (Ultimate) Horizontal. Load at 18 inches above driving surface.

15.21.1.1.5 Elevator Machine Room- 150 PSF or Actual Weight of Mechanical or Electrical Equipment Whichever is Larger.

15.21.1.1.6 Wind:

15.21.1.1.6.1 Basic Wind Speed - The minimum basic (normal) wind speed shall be 105 mph (3 second gust, V_{asd}=105 mph).

15.21.1.1.6.2 Wind Exposure "C"

15.21.1.1.7 Snow:

15.21.1.1.7.1 A minimum of 30 psf snow load shall be applied on parking roofs without drifting load. The parking roof live load includes this 30 psf snow load. See Section 15.21.1.1.1.

15.21.1.1.7.2 Other snow loads such as partial loading, unbalanced roof snow loads, drifts, sliding snow, rain-on-snow surcharge load, ponding instability shall be calculated as per ASCE-7.

15.21.1.1.8 Seismic

15.21.1.1.8.1 In accordance with IBC and information from the soils report.

15.21.1.2 Dead Load:

15.21.1.2.1 Dead Loads shall be in accordance with IBC.

15.21.1.2.2 Provisions shall be made for an uniformly distributed super imposed load of 5 psf for all levels as a contingency load.

15.21.1.2.3 In addition, dead load of other miscellaneous cast-in-place (CIP) concrete for such items as raised walkways, wheel stops in accessible parking spaces, etc., shall be included in the design.

15.21.2 Loading combinations shall be in accordance with the IBC

15.21.3 Limits on the Concrete Stresses:

15.21.3.1 Extreme fiber stress in tension in concrete immediately after prestress transfer (before time-dependent prestress losses) shall be as noted in Section 15.9.3.3.1.3. Increase in the depth of the members, and/or the use of draped tendons or a judicious use of additional tendons can be used to maintain stresses within the above-mentioned recommended limits. Bonded auxiliary reinforcement if used, shall consist of many small bars distributed uniformly over the face rather than a few large bars.

15.21.3.2 Extreme fiber stress in tension, in precompressed tensile zone at service loads (after prestress losses) shall be as given in Section 15.9.3.3.1.3.

15.21.4 Unless noted otherwise, all cast-in-place concrete shall be air entrained normal weight concrete.

15.21.5 Concrete Strengths:

15.21.5.1 Cast-in-place concrete placed on precast concrete elements shall attain 28 day minimum compressive strength of 6,000 psi and shall have a water-cement ratio of 0.38 or less. This concrete shall be fiber reinforced concrete with a minimum of 0.1 % by volume of Fiber mesh 300 or approved equal. All other cast-in-place concrete shall have a compressive strength of 4,000 psi, at 28 days, with a water-cement ratio of 0.45 or less.

15.21.5.2 Unless noted otherwise, all precast prestressed concrete shall attain 28-day minimum compressive strength of 6,000 psi with a maximum water-cement ratio of 0.38 and contain a calcium nitrite-based corrosion inhibitor as specified in Section 15.21.25.

15.21.6 Double Tees:

15.21.6.1 For a 60 feet clear span parking bay a column grid of 62 feet by 45 feet is recommended. For such a bay the normal length of the DT is considered as 60 feet. As shown on drawing DD-S-PF-004, the minimum depth of the DT shall be 34 inches. For serviceability and longevity, in addition to the maximum allowable stresses, limit the maximum deflection of double tees to inch at roof and inch at other levels at the center under live load including snow load at the roof level. In an unusual situation if longer DT has to be used, then the DT spans of over 60 feet, limit the minimum natural frequency of the beam system to 3 Hz. as flexural members. See drawing DD-S-PF-004 for the dimensions of the 10 ft., 12 ft. and 15 ft. wide DT's. Avoid dapping the DT's as much as possible. Flanges of double-tees shall be connected with stainless steel hardware as shown in Design Drawing DD-S-PF-003 at 4'-0" spacing maximum, or use of stainless steel Vector Connectors at an average spacing of 3'-6". All other structural steel connections and associated components shall be hot-dipped galvanized after fabrication.

15.21.6.2 For expansion joints between the DT flanges see Section 15.21.13.

15.21.6.3 Galvanized connections that are subsequently field-welded shall be touched up with zinc rich paint after welding, as per the Technical Requirements/Specifications.

15.21.7 **Concrete Reinforcement**: All reinforcing steel for concrete shall conform to ASTM Specifications A615, Grade 60 for bars (A 706 where required for welding) and A1064 for welded wire fabric. Reinforcing details shall be in accordance with current ACI "Manual of Standard Practices for Detailing Reinforced Concrete Structures". Bar laps shall be Class "B" tension laps. Provide concrete cover over reinforcing bars in accordance with ACI 318 (unless noted otherwise). Hooks shown shall be standard hooks unless otherwise dimensioned

15.21.8 **Mechanical Tension Splices** of reinforcing bars made by the use of Cadweld or NMB Splices. All mechanical couplers shall comply with the seismic requirements of ACI 318 latest edition or ACI 318-99 when designing by the Alternate Design Method. Other mechanical splices/couplers may be accepted on a case by case basis at the sole discretion of the Authority.

15.21.9 **The Shop Drawings**, prepared by the fabricator or the pre-caster, shall include the precast foundation reactions for all the loading combinations. All column connections to the piers, and all light wall connections to the foundations about their minor axes shall be hinged connections. All column connections to the piers, for parking garages having a maximum of three levels may be designed as fixed at the foundation and detailed accordingly, with the prior approval of the Authority.

15.21.10 **Lateral Loads** shall be transmitted to shearwalls and light-walls through the roof and floors acting as horizontal diaphragms. Any torsional effects due to unsymmetrical location of the shearwalls and the lateral loads shall considered in the design. Minimum 5% eccentricity shall be assumed in design.

15.21.11 Connections: The precast manufacturer shall design and provide all embedded items necessary to adequately anchor the precast member to the foundation including anchor bolts. Any additional foundation details required for proper transfer of forces between the precast members and the foundation not already shown in the design shall be submitted with the shop drawings by the precast manufacturer

15.21.12 The Inverted Tee Beams (ITB):

The Inverted Tee Beams (Itb) shall be at Least 44 Inches Deep, with a minimum stem width of 22 inches at the top and 38 inches at the bottom. For ITB spans over 45 feet, the span to depth ratio shall not exceed 12.5. Provide embedded steel bearing plates at both ends of ITB's. Provide adequate protection of the prestressing strands after they are cut off. The design of the bearing of ITB's shall consider the effect of eccentric loading during construction. Also as a minimum, closed ties in the lower section of the beams as shown in the Standard/Project Drawings shall be provided. The minimum shear reinforcement shall be as shown on the Standard/Project Drawings. Provide inverted U-shaped bars, in the IT stem, extending into the wash strip on top level and at all other levels.

15.21.13 For the precast concrete parking structure, the expansion (isolation) joint shall be placed at a location not farther than 150 feet from the center of restraint. If the center of restraint is at the middle of structure, the expansion joint could be placed at 150 feet on each side providing a total length of 300 feet without expansion joint. If however the structure is longer or wider than 150 feet, say 252 feet, and the restraint is located at the outer edge of the building, an expansion joint would be required at a distance not to exceed 150 feet. If circumstances warrant extending this limit, prior approval of the Authority*s Representative shall be obtained and documented in the design calculations and be noted on the Final Design Drawings. The spacing for the sliding connections at expansion joints shall be designed for the loads specified and to make sure that double tee beams on both sides of the expansion joint work together as a unit when a wheel either passes along the expansion joint on one double tee or crosses the joint from one beam to another.

15.21.14 Expansion Joints shall be placed where area floor systems are graded with washes constructed cast in place concrete (only, not precast) such that water will not pass over an expansion joint, except the sealed expansion joints in ramps.

15.21.15 Inverted Tee or Expansion Joint washes shall be graded so that water does not flow over the wash.

15.21.16 At the expansion Joint between the flanges of Double Tees (DTs), a flange support system shall be used to transfer the moving load from the flange of one DT to the flange of the other DT to eliminate a bump at the expansion joint, see drawing DD-S-PF-003, for a recommended 'Flange support at Expansion Joints.

15.21.17 Cast-in-place Concrete Wash Strips at Inverted Tee Beams and cast-in-place concrete wash areas at Ell Beams and any other wash areas: The minimum thickness of concrete in these cast-in-place concrete washes shall be a minimum of - one and one half inches. The concrete in these wash areas shall be adequately reinforced with epoxy coated WWF or epoxy coated reinforcing bars.

15.21.18 Deleted

15.21.19 The Bearing Pads shall be either Fabreeka, Capralon or Masticord per Authority's approval (see drawing DD-S-PF-001). Galvanized steel plate support or embedded galvanized steel plates shall be provided under the bearing pads.

15.21.19.1 The design of bearing pads shall take into account the effect of beam camber, deflected shape, and the slope of the floor beams and double tees.

15.21.20 The Support for the Itb*s, spandrels, Ell-beams shall be designed for the maximum load acting as an edge load acting at any place along the bearing pad. When the beams are supported on corbels or brackets, the moment at the corbel column interface will be maximum when the load is at the farthest edge of the bearing pad. Effect of torsion, if any, shall also be considered.

15.21.21 The Corbels and Brackets shall be designed for the maximum load noted above and the maximum lateral load due to thermal, wind and seismic effects.

15.21.22 The Effect of Lateral Movement of the structure due to wind and seismic effects, including effects on bearing pads and bearing connection shall be considered in the design.

15.21.23 The Connections of Horizontal Diaphragms with the vertical members transferring horizontal loads shall be such that there will not be any distress due to deformation of the bearing pads.

15.21.24 Full Attention Shall Be Given to Restrict Corrosion of reinforcement, embedded steel and any other exposed steel at connections. Silane penetrating sealers as specified previously shall be required as well as use of corrosion inhibitor in concrete. The corrosion-inhibitor shall be calcium nitrite-based admixture DCI or approved equal.

15.21.25 **For Precast Concrete Elements** and for cast-in-place concrete overlay topping over inverted tee beams on top level and for cast-in-place concrete in wash strips and wash areas on all levels, use four (4) gallons per cubic yard of the corrosion inhibitor when the water-cement ratio is 0.40 or less and use three and a half gallons (3-1/2) per cubic yard when water-cement ratio is 0.38 or less. To increase the service life of the structure, use epoxy coated Welded Wire Fabric (wwf) and reinforcing bars in the double tee flanges on the top level, in cast-in-place concrete overlay topping on top level, and all inverted U-shaped bars in the cast-in-place concrete wash strips (over inverted tee beams) and all wwf in cast-in-place concrete wash areas on all levels. No other epoxy coating of reinforcement is required unless so directed.

15.21.26 **Provide Lateral Prestressing in the Flange Slab at Each End of Double Tees**, to prevent cracking and other damage during handling and transportation. Two full loops of prestressing strands (each 360E) at each end shall be provided. This can be accomplished by using one continuous strand or two strands.

15.21.27 **The Fabricator (Precaster)** shall participate in the Precast/Prestressed Concrete Institute (PCI) Certification Program and be designated as a PCI certified plant for product categories A1 and C3. The fabricator shall have continuous experience and is to be regularly engaged in the fabrication of precast/prestressed concrete products as per the requirements of the RFP and as stated in the Technical Proposal as finally accepted.

15.21.28 All structural steel, unless otherwise noted, shall conform to ASTM A36, ASTM A709 and A992, and all anchor bolts shall conform to ASTM A307, unless approved otherwise by the Authority.

15.21.29 All structural steel used for connections shall be hot-dip galvanized after fabrication except as noted otherwise.

15.21.30 Unless otherwise shown, all bolted framing connections shall be 3/4-inch diameter bolt ASTM A325 bolts designed and detailed as slip-critical connections in accordance with the AISC specifications. For structural joints using ASTM A325 or 490 bolts (surface condition shall be Class A or better and fastener tension in accordance with Table 4). Connections not shown shall be designed for a minimum shear capacity of 55-percent of maximum beam carrying capacity under uniform load for the span indicated. All welded framing connections shall have a capacity, no less than that for the span indicated

15.21.31 All welding electrodes shall conform to E70XX except for stainless steel. Welding electrodes for stainless steel shall be in accordance with AWS and shall be approved by the Authority*s Representative prior to use.

15.21.32 Tee Beams Ending at Skewed Walls/Column Lines: If skewed deck plan has to be used, it is recommended that the Designer should consider the use of flat precast panels to span relatively short spans. However, for long spans with skewed ends the Designer shall pay particular attention to the details required where the tees end at skewed wall/column lines including but not limited to, use of diaphragms and added reinforcing to assure superior strength and durability and to avoid the potential for concrete cracking. The design shall account for constructability, uneven stiffness of double tees, and special details at the bearings.

15.21.33 Column and wall footings shall be designed based on the proposed precast building systems components, configurations, loads and locations shown. The Designer/Builder shall coordinate all precast details and dimensions to insure that the proposed foundation system is compatible with precast system used.

15.21.34 It is the Designer/Builder*s responsibility to insure the stability of the structure during construction by providing temporary supports, bracing and other means as required. Where temporary connections are to be used, they shall be noted on the shop drawings along with the anticipated forces.

15.21.35 It is also the Designer/Builder’s responsibility to ensure that the erected portions of the structure, part or full, do not deform or deviate from their installed positions, after the temporary supports, bracing etc. are removed. The general erection scheme should be submitted to the Authority, for review and approval.

15.21.36 Masonry:

15.21.36.1 Concrete masonry units shall conform to ASTM C90 –1 and shall have minimum compressive strength of 2,000 PSI on the net area. Masonry mortar shall be type “S”. Provide 9-gauge truss-type joint reinforcing at 16 inches O.C. in all masonry walls.

15.21.36.2 All masonry accessories shall be hot-dipped galvanized or stainless steel to meet Standard Specifications.

15.21.36.3 The masonry shall be designed (using ASD method) and constructed in accordance with applicable codes and standards.

15.21.36.4 Provide 1-#5@32" O.C. (full height) as a minimum vertical reinforcement. Reinforced cores shall be grouted solid.

15.21.37 GEOTECHNICAL DESIGN:

15.21.37.1 The design criteria for the geotechnical portion of the Work shall be in accordance with the Designer’s geotechnical evaluation or the following, whichever is more conservative

15.21.37.2 Soil Parameters:

15.21.37.2.1 Unit Bulk Weight 130 PCF

15.21.37.2.2 Submerged Unit Weight 68 PCF

15.21.37.2.3 Coefficient of Friction Between Concrete and the Foundation Soils –0.35

15.21.38 Foundations:

15.21.38.1 Foundation design shall be based on subsurface exploration and recommendations provided in the Designer's Geotechnical Design Report (GDR) prepared by an Authority-approved Geotechnical Engineer registered as a professional engineer in the jurisdiction of the work.

15.21.38.2 Spread footings, piles or caissons may be used as foundations. The maximum settlement of any column shall not be greater than 1 inch nor the differential settlement between any two adjacent columns greater than ½ inch.

15.21.38.3 Not Used

15.21.38.4 Caissons must be designed by and fully justified by Designer's approved Geotechnical Engineer registered as a professional engineer in the Jurisdiction of the proposed Parking Structure.

15.21.38.5 Any variations to the approved design shall be reported to the Authority Representative in writing before the construction of the foundations.

15.21.39 Compacted Structural Backfill:

15.21.39.1 Placement requirements and material properties for compacted structural backfill against interior ramp walls and retaining walls shall be in accordance with the Technical Requirements.

15.21.39.2 Only hand-operated compaction equipment (less than 2,000 pounds) shall be used within ten feet of any structure.

15.21.39.3 All subgrade surfaces shall be proof-rolled with at least two passes of a fully loaded 10 wheel dump truck prior to placement of previous material or backfill within the building area and at least five feet beyond the outer edge of the footings.

15.21.40 Slab-On-Grade

15.21.40.1 A 6" thick concrete slab on grade pavement reinforced with epoxy coated Welded Wire Fabric (WWF 6x6-W5.5xW5.5) shall be used on the base floor.

15.21.41 The criteria set forth herein shall be treated as minimum requirements. The responsibility for production, and erection of structurally adequate and sound precast members without structural cracks or damage lies with the Designer/Builder.

TABLE 15.1

AVERAGE VERTICAL LOAD (P_R) ON ROCK TUNNELS

TUNNEL TYPE		Single Track	Double Track	Station
Excavated Dimensions		20' Wide 18' High	35' Wide 24' High	70' Wide 40' High
Type I Lining: Minimum Cover of "Relatively Sound or Sound Rock" required for Type I lining. (see Note 4)		10'	15'	30'
Type II Lining: Type II lining is used for the following conditions		AVERAGE VERTICAL LOAD P_R		
(A)	Portal Sections, or where rock cover of any quality is #0.4 of minimum rock cover for Type I lining, or where thicker rock cover is highly jointed and weathered.	Full Overburden Ó V	Full Overburden Ó V	Full Overburden Ó V
(B)	Rock cover "relatively sound or sound" is $0.4, but is #0.6 of minimum rock cover for Type I lining.	(0.15)x(Ó V)	(0.30)x(Ó V)	(0.60)x(Ó V)
(C)	Rock cover "relatively sound or sound" is $0.6, but is #0.8 of minimum rock cover for Type I lining.	(0.10)x(Ó V)	(0.20)x(Ó V)	(0.40)x(Ó V)
(D)	Rock cover "relatively sound or sound" is $0.8, but is #1.0 of minimum rock cover for Type I lining.	(0.05)x(Ó V)	(0.10)x(Ó V)	(0.20)x(Ó V)
(E)	Rock cover $1.0 of minimum rock cover for Type I lining, but is not "relatively sound or sound" at tunnel top.	0.5 ksf	1.0 ksf	2.0 ksf

Notes:

(1) Ó V = Total pressure of overburden, soil plus rock, above tunnel top.

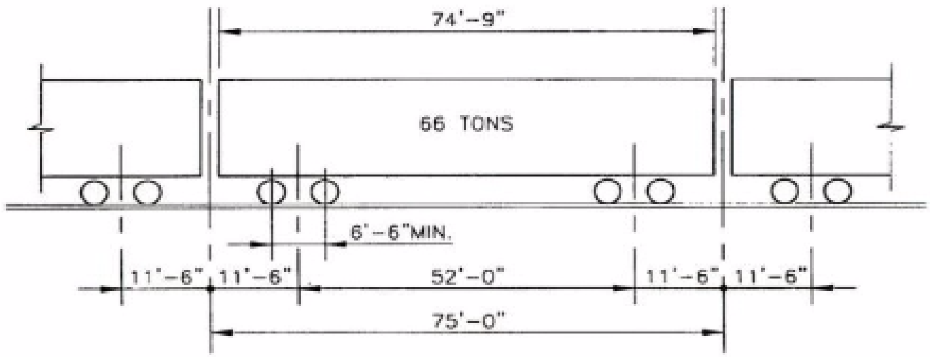
(2)Rock described in D. U. Deer report of November 1, 1967 as "good to excellent"' with RQD values greater than 65 to 75 percent generally qualifies as "relatively sound or sound" rock cover.

(3) Rock described on the geological sections in the WMATA soils reports prepared by MRCE, as "relatively sound or sound", with RQD values greater than 60 to 70 percent generally qualifies as

"relatively sound or sound" rock cover.

(4) No vertical load is considered for the design of the tunnel lining, in "relatively sound or sound" or better rock and is called Type I lining.

(5) These are the minimum values of P_R. Higher values may be used if ascertained by the Designer's Geotechnical Consultant.



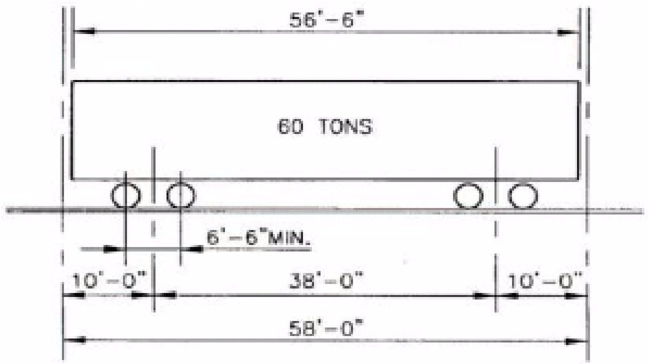
1. DESIGN Loads — VEHICLE — 82,000 LB.
   PASSENGERS — 50,000 LB.
   TOTAL RAPID TRANSIT LOADING (LL) — 132,000 LB.
2. AXLE LOAD — 33,000 LB.
3. IMPACT — AS SPECIFIED
4. CENTRIFUGAL FORCE — [0.0012 x SPEED ^{2} (MPH) x DEGREE OF CURVE (DEG)] % LL
5. ROLLING FORCE — 10% LL
6. LONGITUDINAL BRAKING AND TRACTIVE FORCE — 15% LL
7. LOADING COMBINATIONS — FOR COMBINATIONS OF ABOVE LOADS REFER TO SECTION E

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES

RAPID TRANSIT VEHICLE DESIGN LOADING

FIGURE 15.1

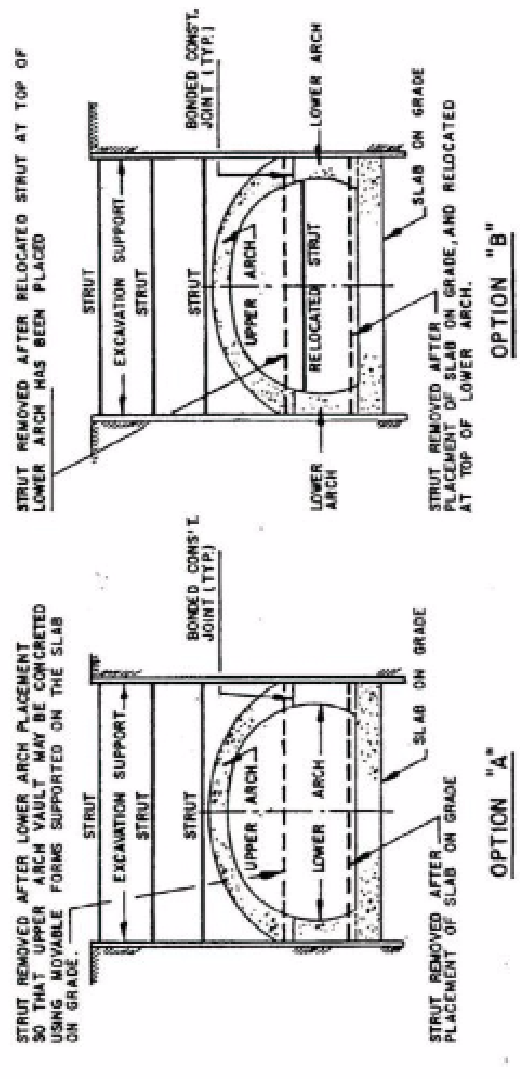


1. DESIGN Loads ______ CAR ______ 80,000 LB.
   PAYLOAD ______ 40,000 LB.
   TOTAL CRANE CAR LOADING (LL) ______ 120,000 LB.
2. AXLE LOAD ______ 30,000 LB.
3. IMPACT ______ AS SPECIFIED
4. CENTRIFUGAL FORCE ______ [$0.0012 \times \text{SPEED}^2$ (MPH) $\times$ DEGREE OF CURVE (DEG)] % LL
5. ROLLING FORCE ______ ±10% LL
6. LONGITUDINAL BRAKING AND TRACTIVE FORCE ______ 15% LL
7. LOADING COMBINATIONS ______ FOR COMBINATIONS OF ABOVE LOADS REFER TO SECTION E

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	CRANE CAR DESIGN LOADING

FIGURE 15.2



SUPPORT - OF - EXCAVATION STRUT LOCATION FOR STATIONS

NOT TO SCALE

NOTE : INDICATED LOCATIONS OF STRUTS ARE SCHEMATIC ONLY.

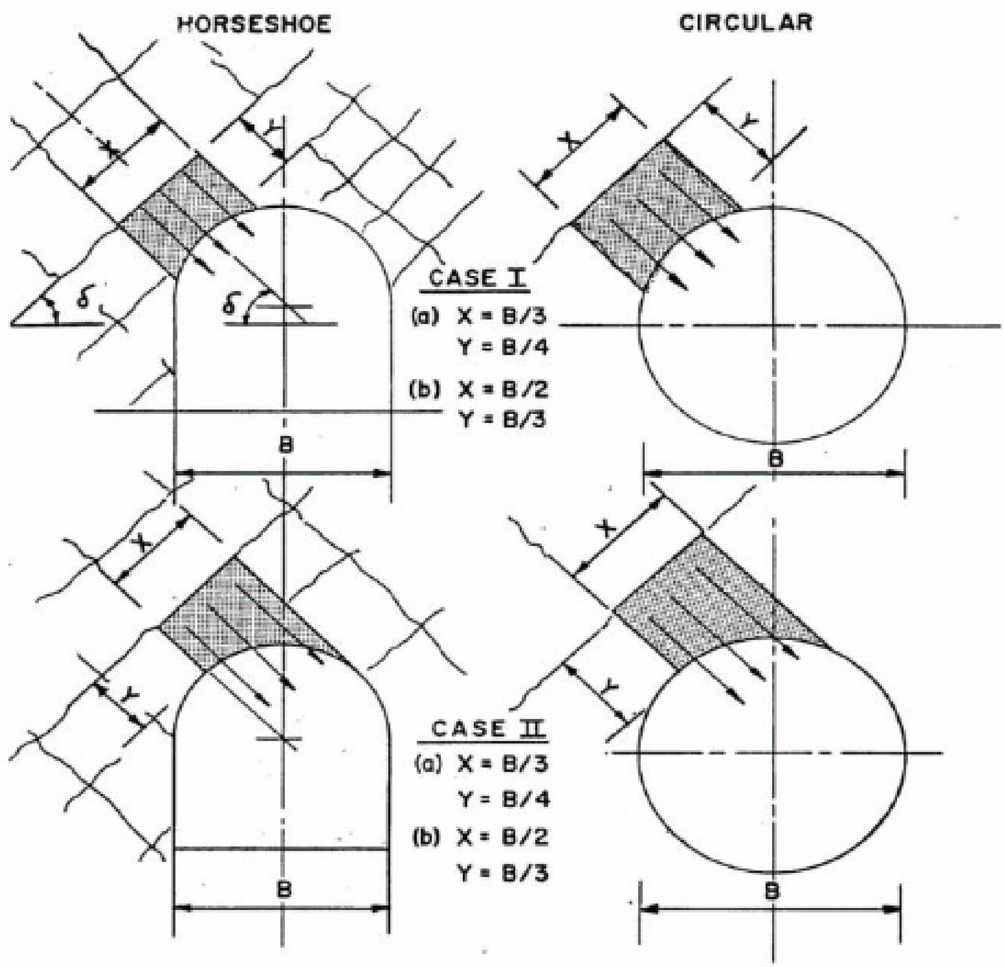
OPTION "A" PERMITS CONSTRUCTION OF THE UPPER ARCH USING MOVABLE FORMS SUPPORTED ON THE SLAB ON GRADE, WITH BRACING OF THE EXCAVATION SUPPORT BEING FURNISHED BY THE SLAB ON GRADE, THE LOWER ARCHES AND THE STRUTS ABOVE THE TOP OF THE UPPER ARCH.

OPTION "B" PERMITS CONSTRUCTION OF THE UPPER ARCH USING FIXED FORMS SUPPORTED ON THE SLAB ON GRADE, WITH BRACING OF THE EXCAVATION SUPPORT BEING FURNISHED BY THE SLAB ON GRADE, THE RELOCATED STRUT INSTALLED BEFORE THE STRUT ABOVE THE LOWER ARCHES HAS BEEN REMOVED AND THE STRUTS ABOVE THE TOP OF THE UPPER ARCH, AS ILLUSTRATED. OTHER OPTION "B" ALTERNATIVES WOULD PERMIT CONSTRUCTION OF THE ARCH USING MOVEABLE FORMS IF TIEBACKS ARE USED OR, IF AFTER PLACEMENT OF THE SLAB ON GRADE EXCAVATION SUPPORT IS ADEQUATE TO PERMIT REMOVAL OF STRUTS IN CONFLICT WITH THE STRUCTURE.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	DESIGN OF STATION ARCH FOR OPTIONAL CONSTRUCTION METHODS

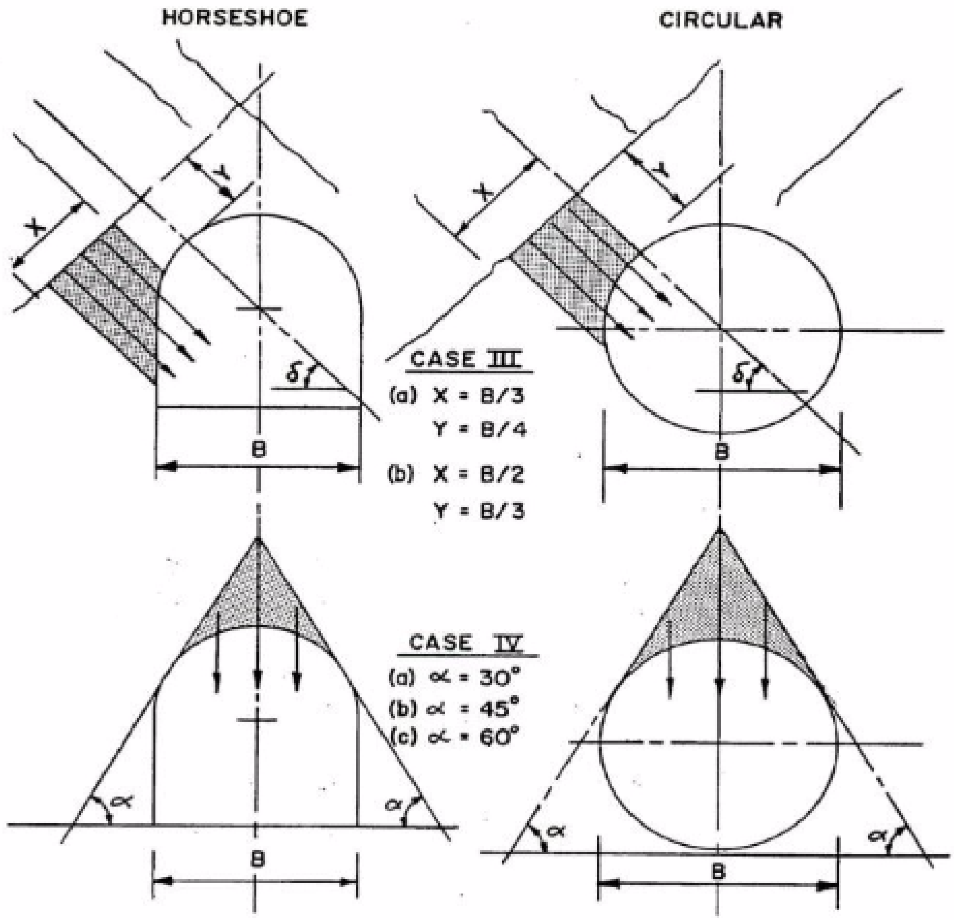
FIGURE 15.3



FOR CASES I & II, ANGLE δ TO BE DETERMINED FROM SUBSURFACE DATA
Note: FRICTION ANGLE OF 15° AT SLIDING JOINTS CASE I THRU III.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	LOADING CONDITIONS RUNNING TUNNELS

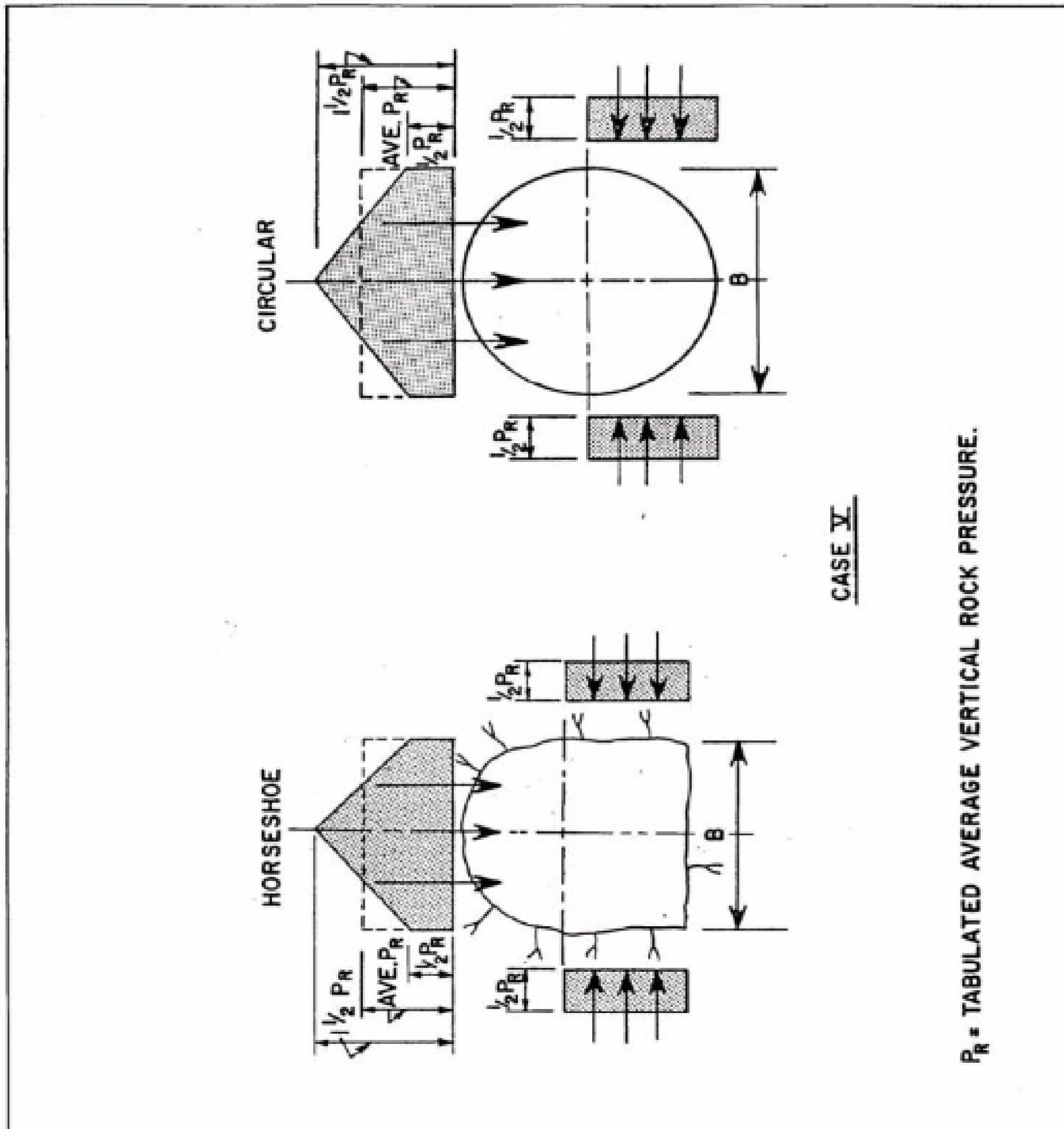
FIGURE 15.4



FOR CASE III, ANGLE δ TO BE DETERMINED FROM SUBSURFACE DATA.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	LOADING CONDITIONS RUNNING TUNNELS

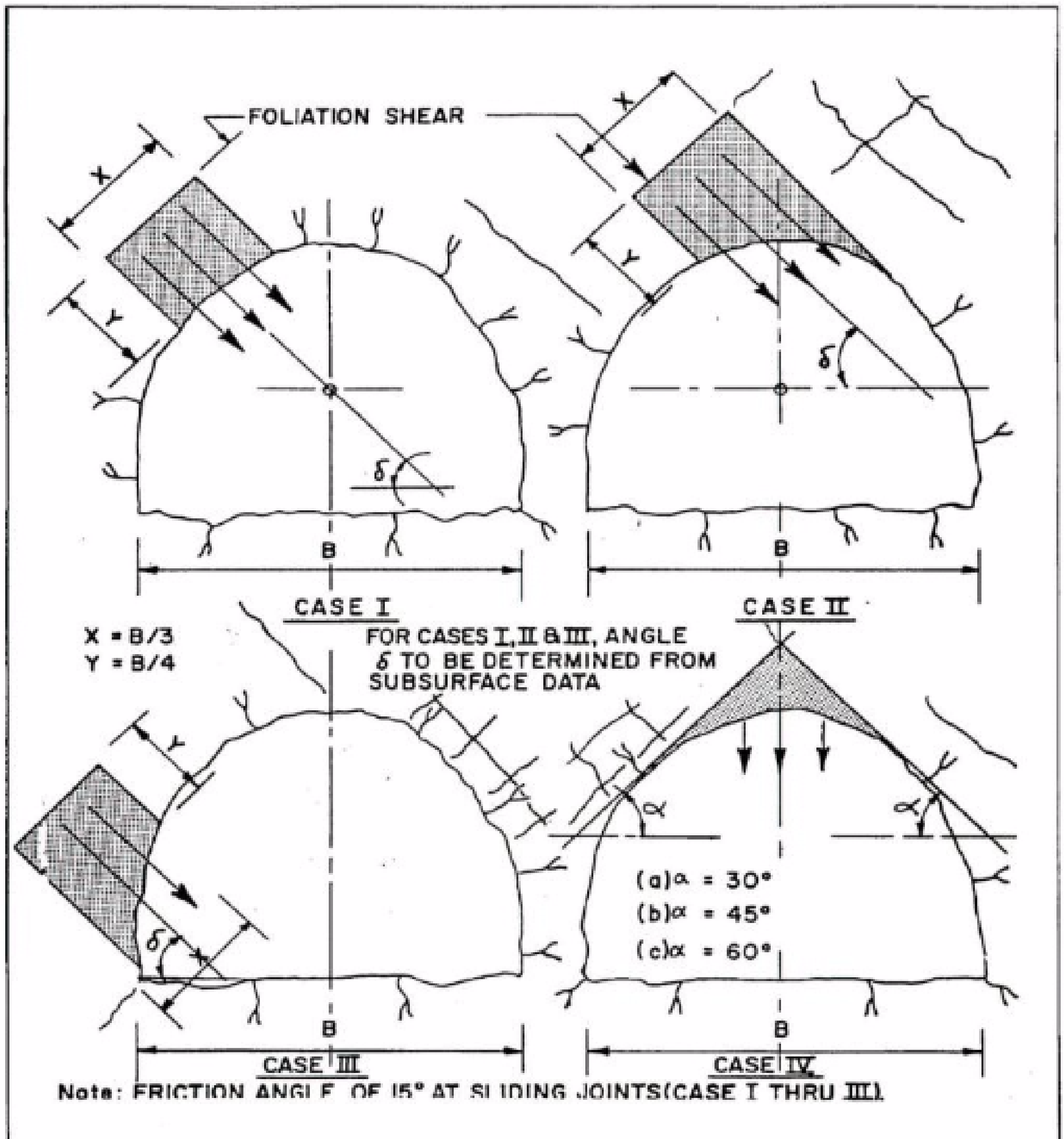
FIGURE 15.5



WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	LOADING CONDITIONS RUNNING TUNNELS

See Table 15.1

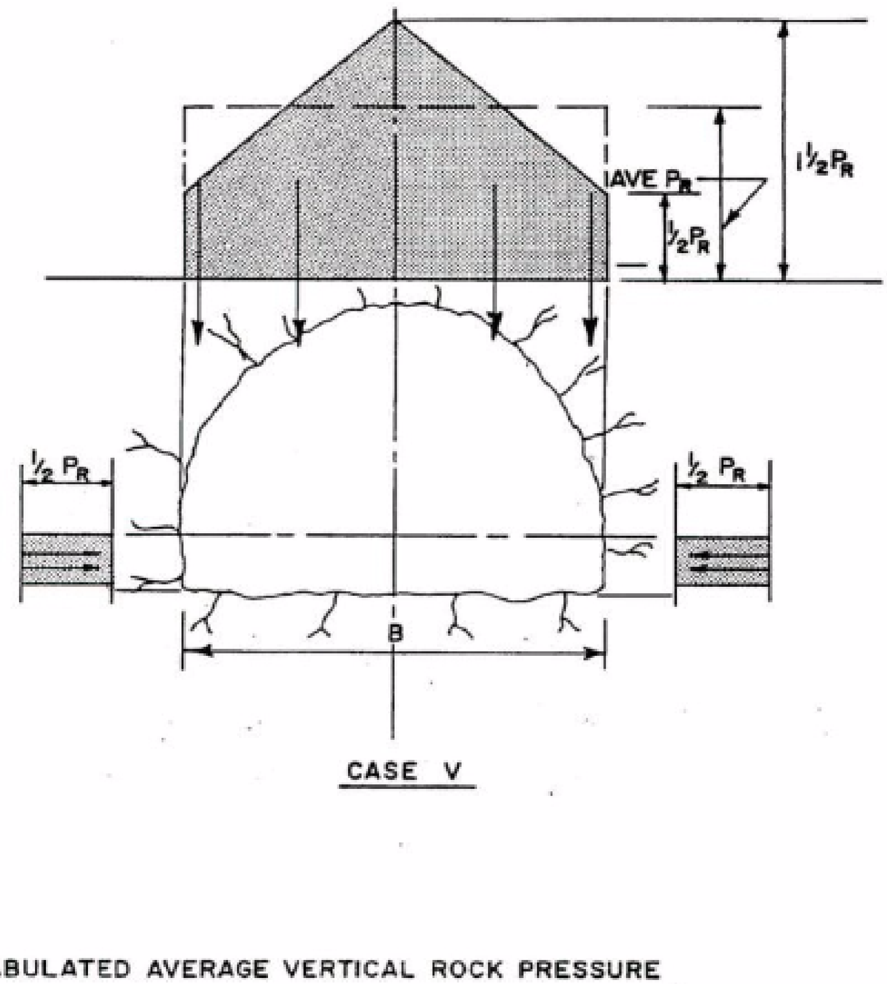
FIGURE 15.6



WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	LOADING CONDITIONS STATIONS

See Table 15.1

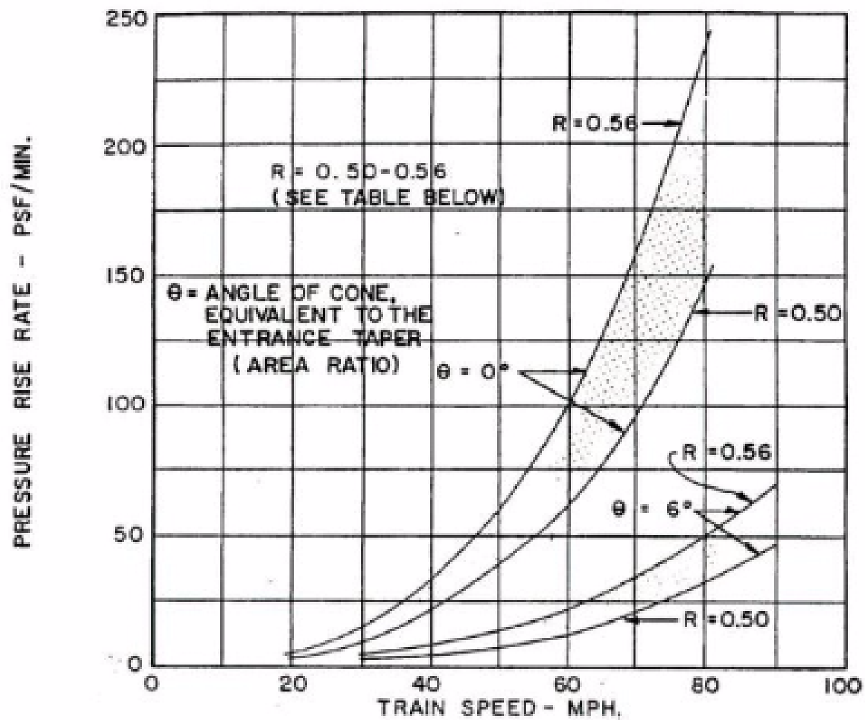
FIGURE 15.7



WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	LOADING CONDITIONS FOR STATIONS

See Table 15.1

FIGURE 15.8



ESTIMATED PRESSURE RISE RATE VS. TRAIN SPEED FOR TUNNEL ENTRANCES WITH NO TAPER [θ = 0°] AND WITH 6° CONICAL TAPER [θ = 6°], OR EQUIVALENT.

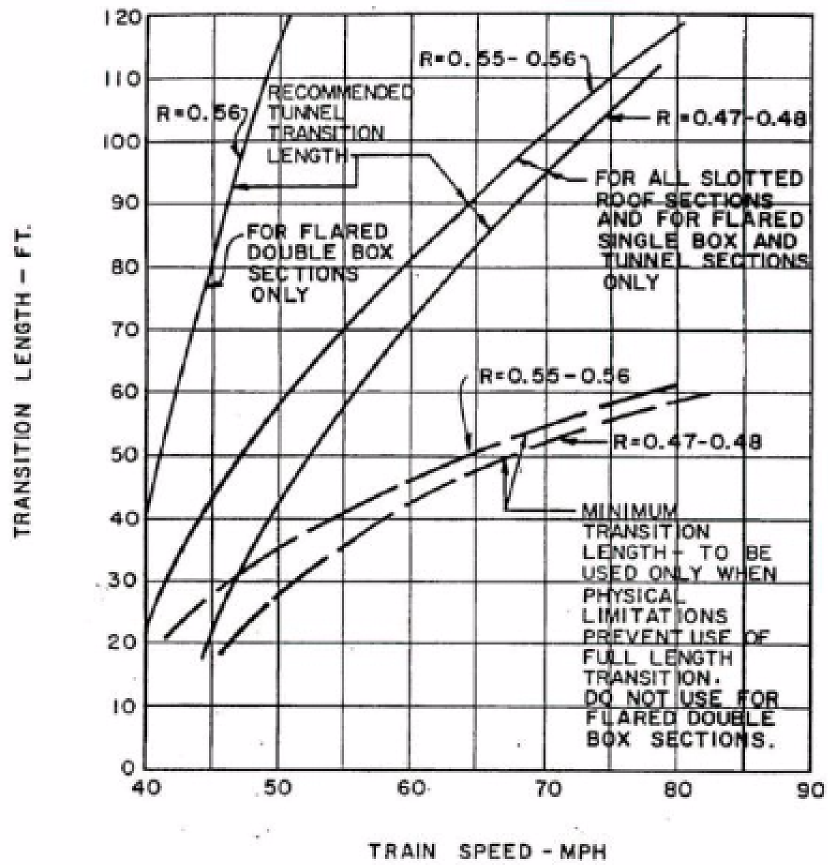
TYPE OF TUNNEL	CROSS-SECTIONAL AREA	R
SINGLE BOX, CUT AND COVER	174 sq. ft.	.55
DOUBLE BOX, CUT AND COVER	171	.56
CIRCULAR EARTH TUNNEL	203	.47
HORSESHOE EARTH TUNNEL	199	.48
HORSESHOE ROCK TUNNEL	180	.53

$$R = \frac{\text{CAR CROSS-SECTIONAL AREA}}{\text{TUNNEL CROSS-SECTIONAL AREA}}$$

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	PRESSURE RISE RATE VS. TRAIN SPEED

FIGURE 15.9

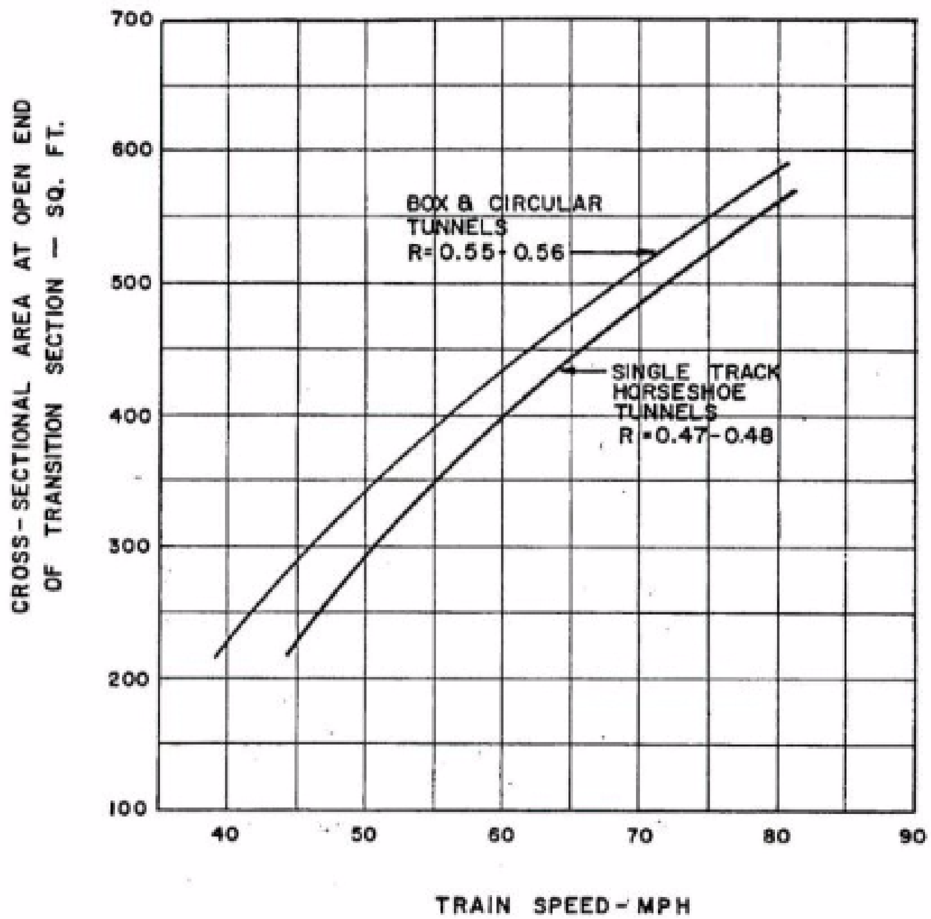


RECOMMENDED LENGTH OF TUNNEL PORTAL TRANSITION AS A FUNCTION OF TRAIN VELOCITY FOR METRO SYSTEM SINGLE TRACK TUNNELS.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	TUNNEL TRANSITION LENGTH VS. TRAIN SPEED

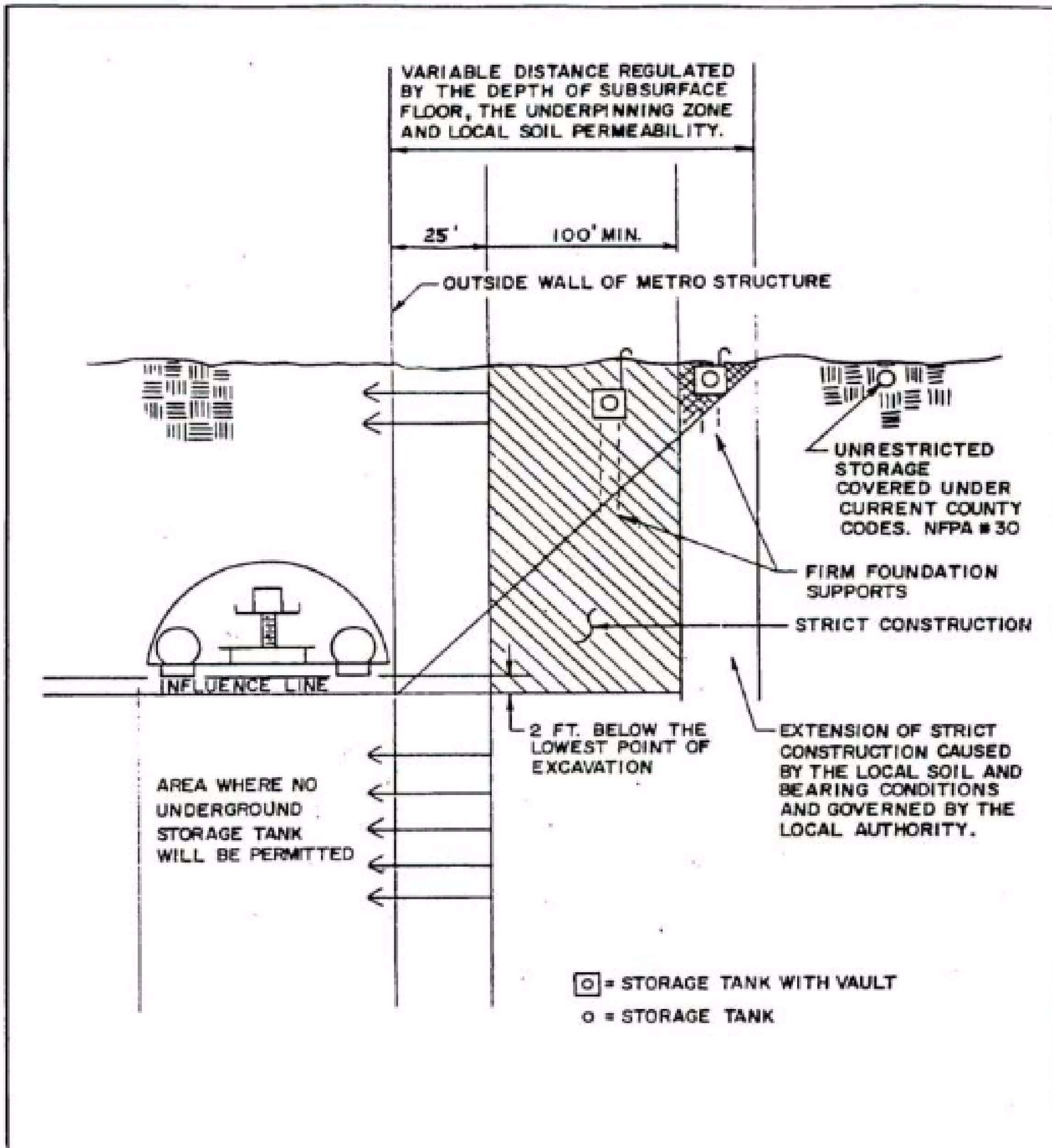
FIGURE 15.10



WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

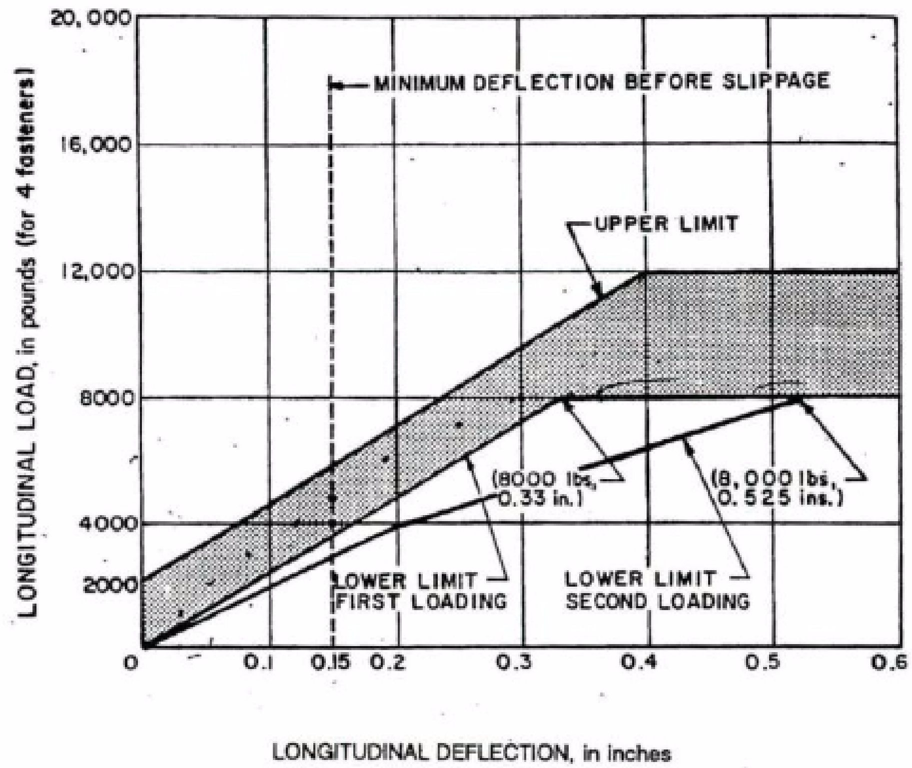
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	RECOMMENDED AREA AT PORTAL OF TUNNEL OR BOX SECTION WITH FLARED TRANSITION

FIGURE 15.11



WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	METRO CONSTRUCTION AND FUEL STORAGE TANKS

FIGURE 15.12



DEFLECTION OF SET OF FOUR FASTENERS

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER-FACILITIES	DIRECT FIXATION RAIL FASTENER LONGITUDINAL RESTRAINT TEST ACCEPTANCE CRITERIA

FIGURE 15.13

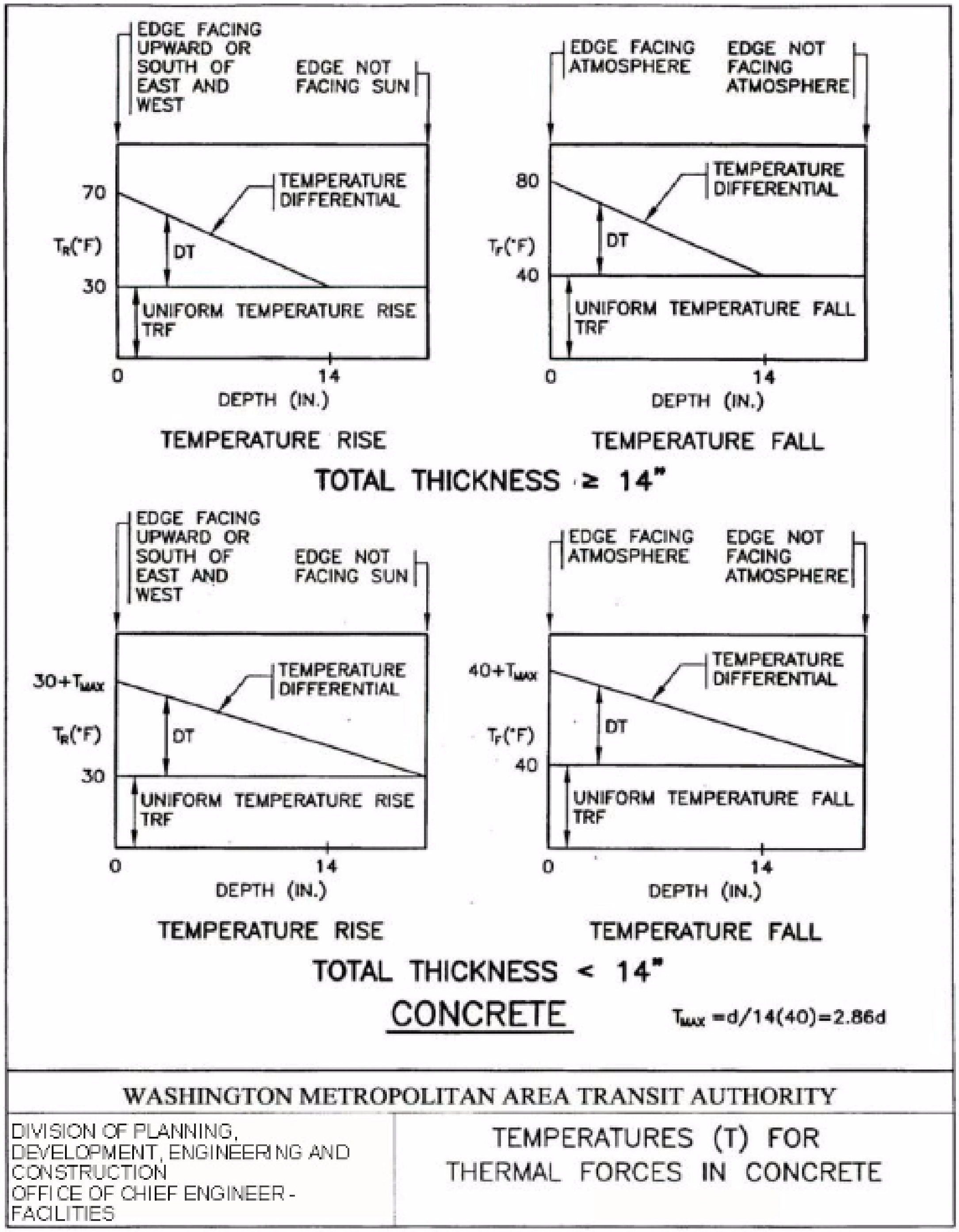
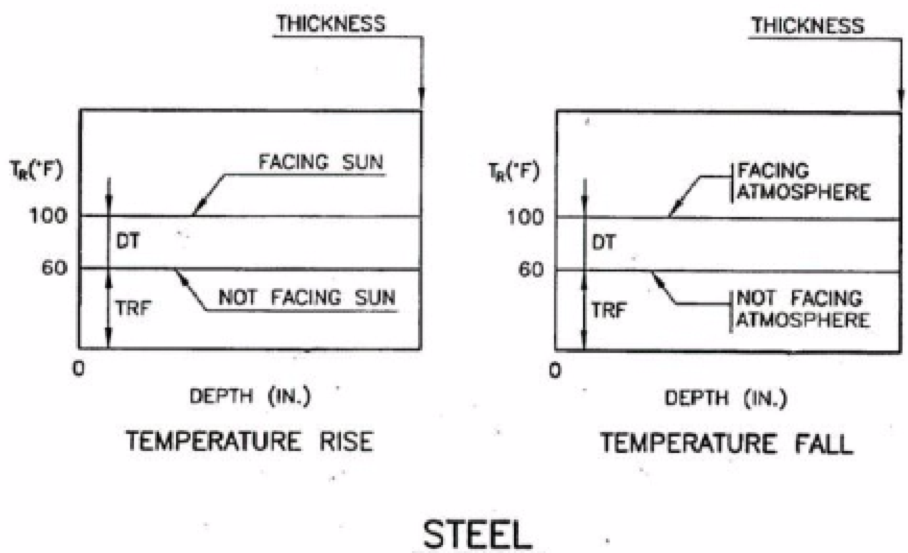


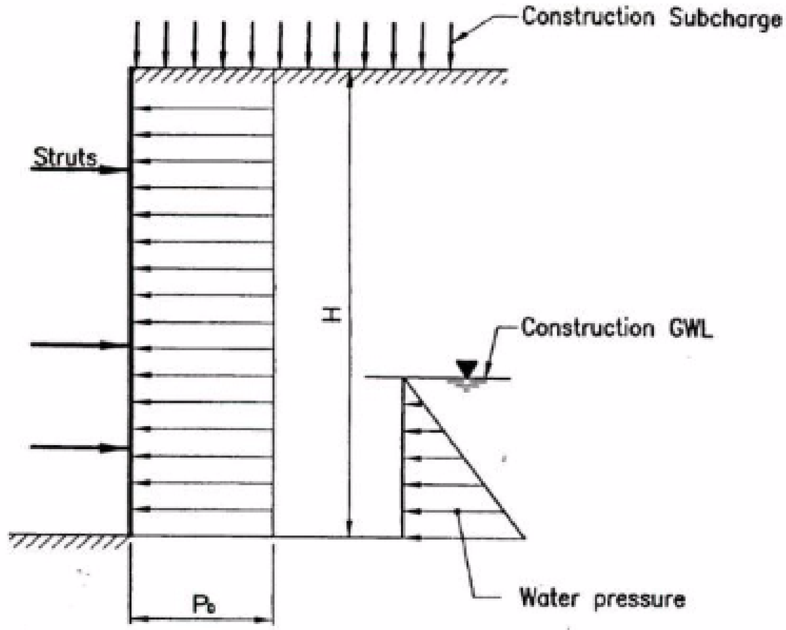
FIGURE 15.14a



WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	TEMPERATURES (T) FOR THERMAL FORCES IN STEEL

FIGURE 15.14b



APPARENT PRESSURE DIAGRAM FOR STRATIFIED SANDS WITH STIFF TO HARD CLAY AND SILT LAYERS

WATERTIGHT RIGID WALLS

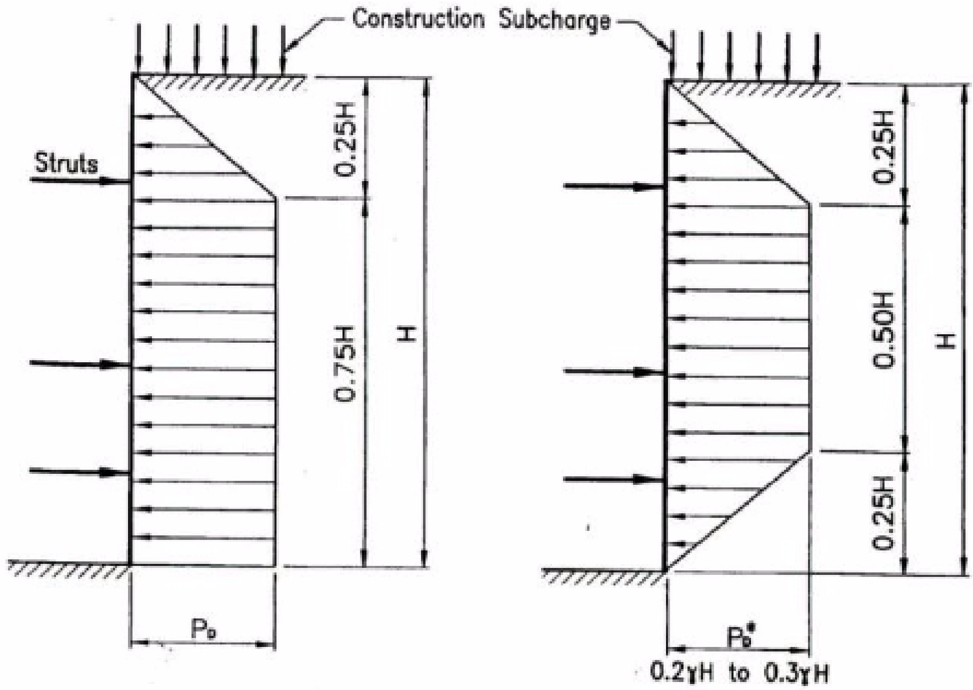
NOTES:

1. Effective earth pressure is equal to the average of active and at-rest pressures distributed as a rectangle with P_b ordinate.
2. Total thickness of clay and silt layers as much as 50% of the depth of the cut.
3. Use effective soil friction shown on Table V.2 in estimating the active and at-rest earth pressures.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	DESIGN LOADING–TEMPORARY COFFERDAM STRATIFIED SANDY SOILS

FIGURE 15.15a



(a) SOFT TO MEDIUM CLAYS N_b >5
WATERTIGHT RIGID WALLS

(b) STIFF TO HARD CLAYS N_b >5
WATERTIGHT RIGID WALLS

APPARENT PRESSURE DIAGRAMS FOR STRATIFIED CLAYS WITH SAND LAYERS AND LENSES

NOTES:

1. Diagrams (a) and (b) can be used in stratified clays, where the total thickness of sand layers or lenses does not exceed 25% of the depth of the cut.
2. Soil Pressure for soft to medium clays is equal to the average of active and at-rest pressures distributed as a trapezoid with P_D ordinate. P_D shall be not less than $0.3\gamma H$.
3. Use effective soil friction shown on Table V.2 in estimating the active and at-rest earth pressures.
4. Presence of groundwater level does not have any effect on magnetude of lateral pressure.

LEGEND

$N = \frac{\gamma H}{Su}$ = Base stability factor

Sub = Average undrained shear strength below base of cut.

γ = Total soil unit weight.

P^*_D = $0.2\ \gamma H$ for very stiff intact nonfissured clays.

P^*_D = $0.3\ \gamma H$ for fissured or slickensided clays.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	DESIGN LOADING–TEMPORARY COFFERDAM STRATIFIED CLAY SOILS

FIGURE 15.15b

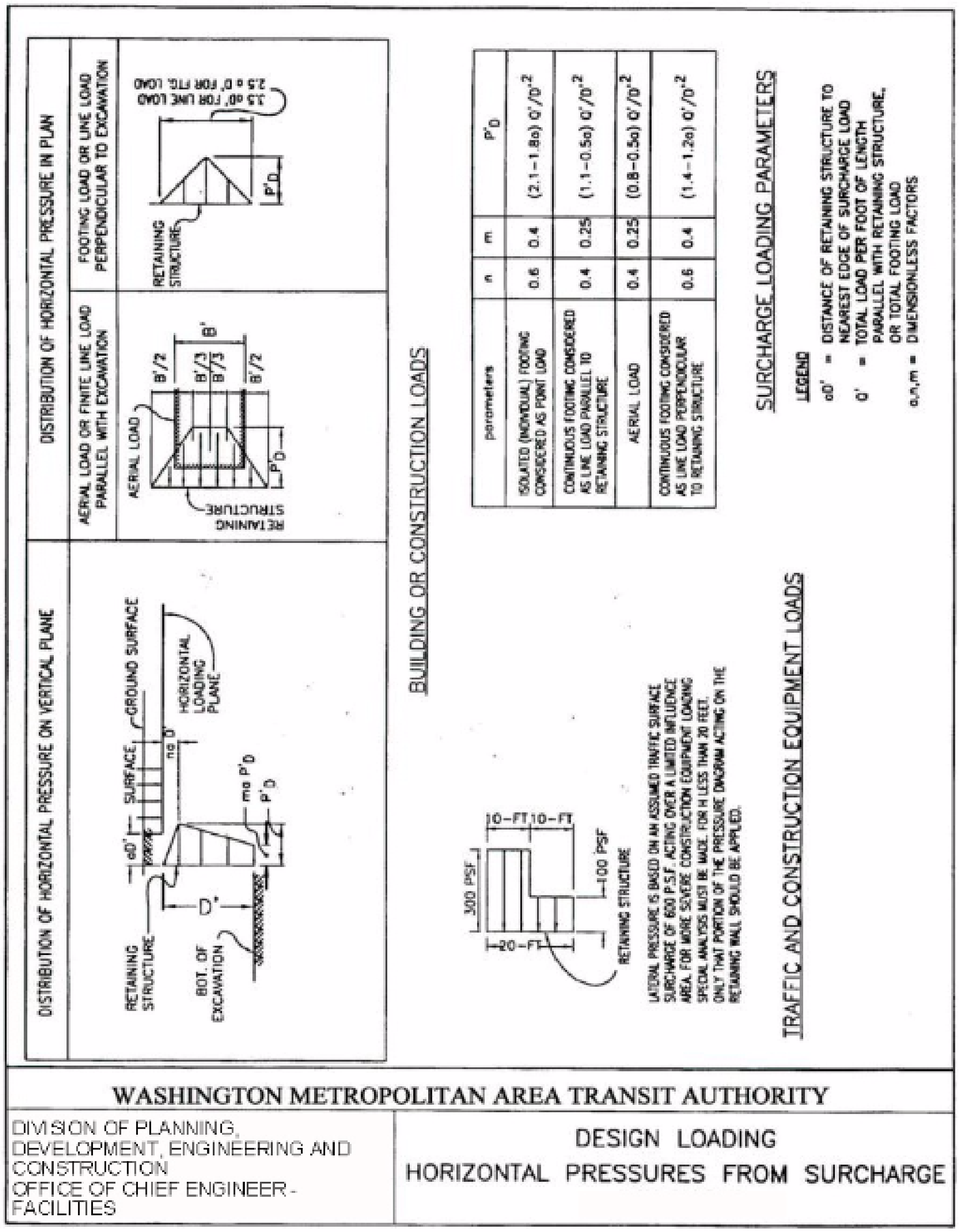

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
DESIGN LOADING
HORIZONTAL PRESSURES FROM SURCHARGE

FIGURE 15.16

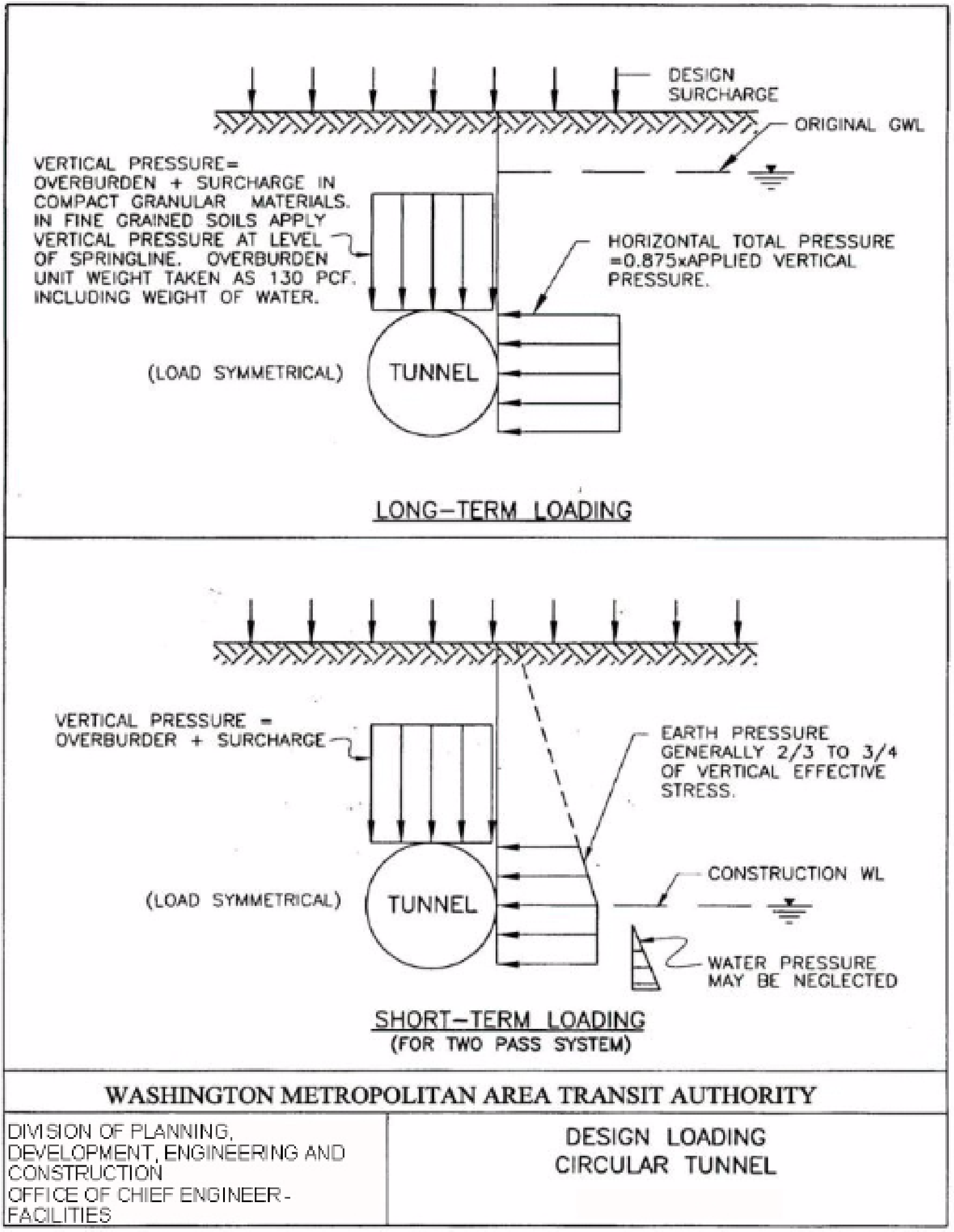
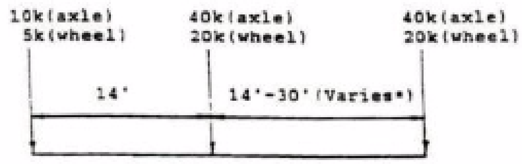

DESIGN
SURCHARGE
ORIGINAL GWL
VERTICAL PRESSURE=
OVERBURDEN + SURCHARGE IN
COMPACT GRANULAR MATERIALS.
IN FINE GRAINED SOILS APPLY
VERTICAL PRESSURE AT LEVEL
OF SPRINGLINE. OVERBURDEN
UNIT WEIGHT TAKEN AS 130 PCF.
INCLUDING WEIGHT OF WATER.
HORIZONTAL TOTAL PRESSURE
=0.875xAPPLIED VERTICAL
PRESSURE.
(LOAD SYMMETRICAL)
TUNNEL
LONG–TERM LOADING
VERTICAL PRESSURE =
OVERBURDER + SURCHARGE
EARTH PRESSURE
GENERALLY 2/3 TO 3/4
OF VERTICAL EFFECTIVE
STRESS.
CONSTRUCTION WL
(LOAD SYMMETRICAL)
TUNNEL
WATER PRESSURE
MAY BE NEGLECTED
SHORT–TERM LOADING
(FOR TWO PASS SYSTEM)
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING,
DEVELOPMENT, ENGINEERING AND
CONSTRUCTION
OFFICE OF CHIEF ENGINEER -
FACILITIES
DESIGN LOADING
CIRCULAR TUNNEL

FIGURE 15.17

All components of new highway structures shall be designed to accommodate the following loadings:

A. For all bridge spans 35' and over in length, and all other structures an HS25 loading shall be used. The axle and lane loadings to be utilized shall be 125% of the AASHTO HS20-44 loading.

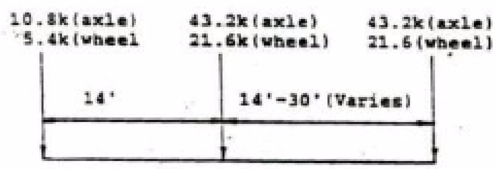
HS25



*Spacing to be used is that which produces maximum stresses.

B. For all bridge simple spans less than 35' in length an HS27 loading shall be used. The axle and lane loadings to be utilized shall be 135% of the AASHTO HS20-44 loading. This category only applies to simple span structures.

HS27



*Spacing to be used is that which produces maximum stresses.

Commentary: This special loading was developed to simulate the 65,000 pound three axle MD Dump Truck configuration loading.

C. The concrete bridge deck portion of bridges with longitudinal stringers shall be designed with HS25 loading.

D. All structures shall be designed to accommodate additional loadings of 25 pounds per square foot for a future 2 inch wearing surface and 15 pounds per square foot when the use of steel stay in place bridge deck forms are required.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	ROADWAY LOADING

FIGURE 15.18

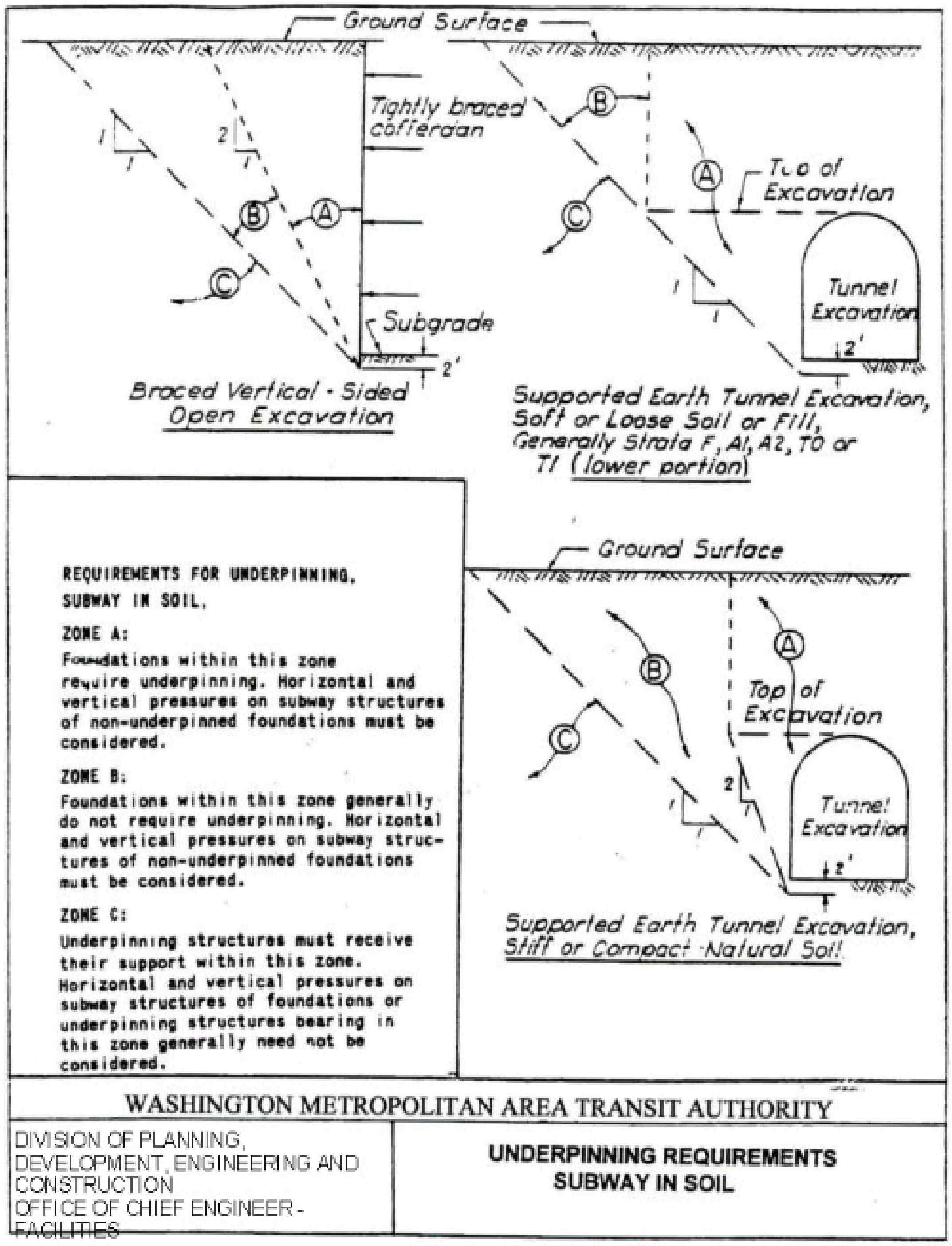
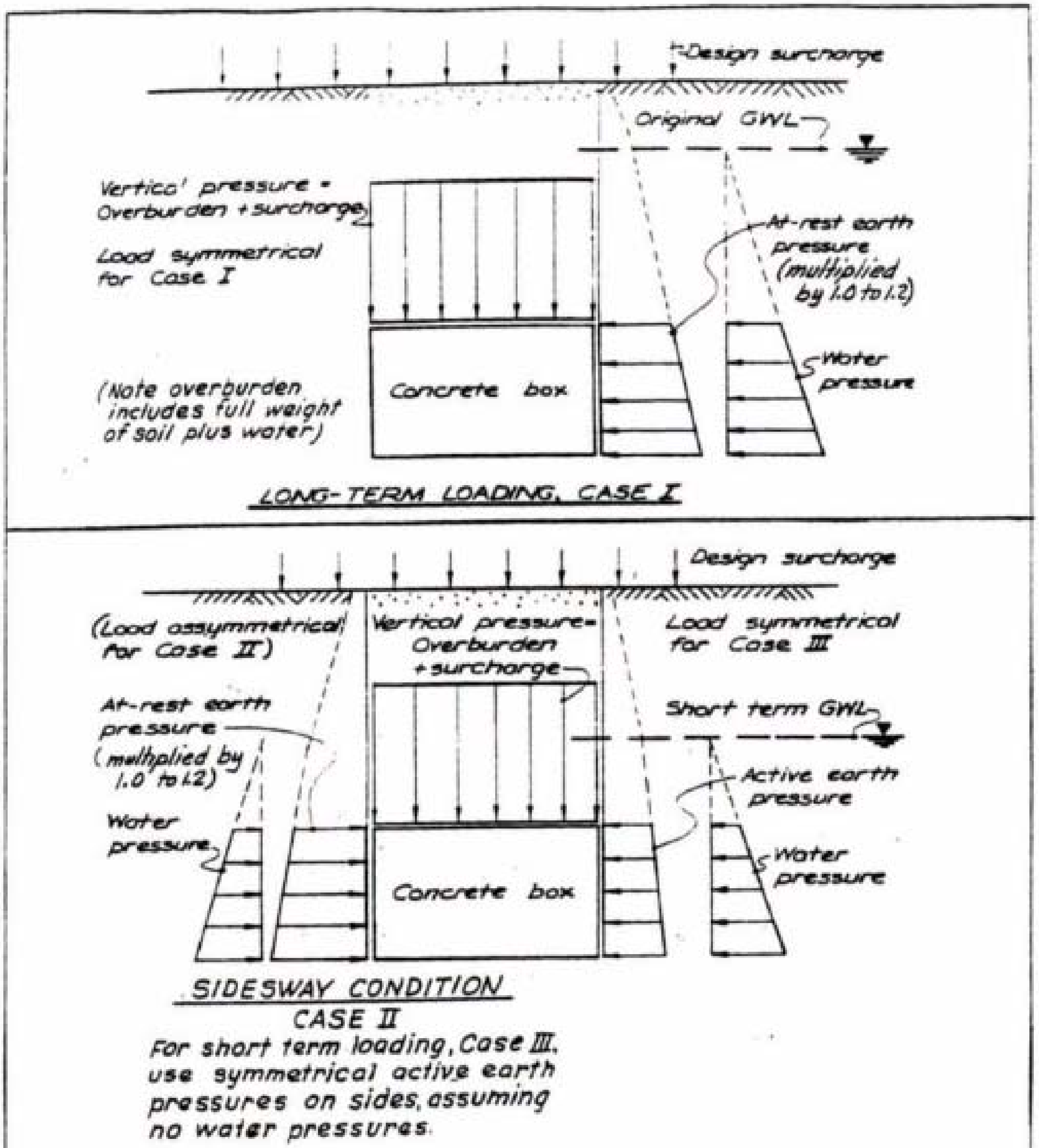

Ground Surface
Tightly braced cofferdan
2
1
(A)
(B)
(C)
Subgrade
2'
Braced Vertical - Sided Open Excavation
Top of Excavation
Tunnel Excavation
Supported Earth Tunnel Excavation, Soft or Loose Soil or Fill, Generally Strata F, A1, A2, T0 or T1 (lower portion)
REQUIREMENTS FOR UNDERPINNING, SUBWAY IN SOIL,
ZONE A:
Foundations within this zone require underpinning. Horizontal and vertical pressures on subway structures of non-underpinned foundations must be considered.
ZONE B:
Foundations within this zone generally do not require underpinning. Horizontal and vertical pressures on subway structures of non-underpinned foundations must be considered.
ZONE C:
Underpinning structures must receive their support within this zone. Horizontal and vertical pressures on subway structures of foundations or underpinning structures bearing in this zone generally need not be considered.
Supported Earth Tunnel Excavation, Stiff or Compact Natural Soil
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION
OFFICE OF CHIEF ENGINEER - FACILITIES
UNDERPINNING REQUIREMENTS
SUBWAY IN SOIL

FIGURE 15.19



WASHINGTON METROPLITAN AREA TRANSIT AUTHORITY

DIVISION OF PLANNING, DEVELOPMENT, ENGINEERING AND CONSTRUCTION OFFICE OF CHIEF ENGINEER - FACILITIES	**DESIGN LOADING CONCRETE BOX SECTION**

FIGURE 15.20

TABLE V-2 SOIL PROPERTIES FOR DESIGN

UNIFIED SOIL CLASSIFICATION PRIMARY	UNIFIED SOIL CLASSIFICATION SECONDARY	SHORT DESCRIPTION	MRWJ* SYMBOLS	FILL DESCRIPTION/SOURCEAGE	SHEAR STRENGTH AND CONSOLIDATION CONDITION OF A COHESIVE STRATA	MIN UNIT WEIGHT (PCF)	COEF OF SUBGRADE REACTION (KCF)	UNDRAINED SHEAR STRENGTH (KSF)	YOUNG MOD. OF SUBGRADE (KSI)	COEF. OF AT REST PRESS.	MAX. EFFECTIVE ANGLE OF FRICTION (DEGREES)	MAX. ALLOWABLE BEARING CAPACITY (TSF)
				FILL								
ML & SM	SC & CL	FILL	F	FILL GENERALLY COMPOSED OF INORGANIC SOIL OBTAINED FROM NEAR BY NATURAL MATERIALS. MAY BE DERIVED FROM TERRACE, CRETACEOUS SOIL OR DECOMPOSED ROCK.	PLACED OVER MARSH, MIXED WITH CINDERS. NO CONSOLIDATION	120					28	NONE, ORDINARILY
					FROM PLEISTOCENE SOILS	120					30	1.0 TO 1.50
					FROM DECOMPOSED ROCK (NW OF ROCK CREEK)	120					30	1.5 TO 2.0
					FROM CRETACEOUS CLAYS (NEAR UNION STATION). MAX. SHEAR STRENGTH, COHESIVE STRATA: 0.8 KSF	120					25	0.75
					MIXED WITH ORGANIC SOILS (SOUTH OF ROSSLYN)	120					28	
					OTHER LOCATIONS	120					30	1.0 TO 1.50
				RIVER ALLUVIUM OF POST GLACIAL TIMES.								
CL, CH, OH	OL & PT	ORGANIC CLAY	A1	VERY SOFT TO MEDIUM STIFF DARK GRAY ORGANIC CLAY WITH LENSES OF HIGHLY ORGANIC MATERIAL (WHERE LOCATED UNDER WATER). SOFT TO STIFF MOTTLED GRAY-BROWN SLIGHTLY ORGANIC SILTY OR SANDY CLAY (WHERE LOCATED IN LAND).	BENEATH FILL OVERCONSOLIDATED 0.2 TO 0.3 TSF. STRENGTH 0.5 TO 0.7 KSF.	120					23	NONE, ORDINARILY
		ORGANIC CLAY			BENEATH WATER OVERCONSOLIDATED AS MUCH AS 0.2 TSF. STRENGTH 0.2 TO 0.3 KSF.	110					23	NONE
		ORGANIC CLAY			MAX. SHEAR STRENGTH, COHESIVE STRATA: 0.9 KSF	110					23	0.75
SM	SP	SILTY SAND	A2	LOOSE TO MEDIUM COMPACT GRAY OR DARK BROWN SILTY FINE TO MEDIUM SAND WITH OCCASIONAL POCKETS OR LENSES OF SMALL GRAVEL. MAY BE SLIGHTLY TO MODERATELY ORGANIC.		110					30	2 TO 2.5
		SILTY SAND				110					30	3

TABLE V-2 , page 1 of 5

TABLE 15.2 page 1 of 5

TABLE V-2 SOIL PROPERTIES FOR DESIGN

UNIFIED SOIL CLASSIFICATION		SHORT DESCRIPTION	MRWJ* SYMBOLS	FULL DESCRIPTION/SOURCE/AGE	SHEAR STRENGTH AND CONSOLIDATION CONDITION OF A COHESIVE STRATA	MIN. UNIT WEIGHT (PCF)	COEF OF SUBGRADE REACTION (KCF)	UNDRAINED SHEAR STRENGTH (KSF)	YOUNG MOD. OF SUBGRADE (KSI)	COEF. OF AT REST PRESS.	MAX. EFFECTIVE ANGLE OF FRICTION (DEGREES)	MAX. ALLOWABLE BEARING CAPACITY (TSF)
				PORTIONS OF THE "25-FOOT" "50 FOOT" AND "90 FOOT" TERRACES. DEPOSITED BY RIVERS IN PLEISTOCENE TIMES.								
CL & OL	CH & OH		TB	MEDIUM STIFF TO STIFF DARK GRAY ORGANIC CLAY WITH NUMEROUS WOOD FRAGMENTS. USUALLY FOUND INTERLENSED WITH STRATUM T4.	MAX. SHEAR STRENGTH, COHESIVE STRATA: 1.4 KSF	130					25	1.2 TO 1.5
CL, CL & CH	LENSES OF SM OR SC		T1	STIFF TO MEDIUM STIFF LIGHT BROWN OR GRAY OR MOTTLED BROWN GRAY SILTY CLAY OR CLAYEY SILT WITH LENSES OF BROWN SILT FINE SAND. IN SOME AREAS, SEVERAL SEPARATE LAYERS OF PLEISTOCENE CLAYS HAVE BEEN ENCOUNTERED, WHICH ARE DISTINGUISHED BY A LETTER SUFFIX: T1A, T1C, ETC.								
		SILTY SAND			(DEPTH: 0 TO 40 FT) MAX. SHEAR STRENGTH, COHESIVE STRATA: 1.0 KSF TO 1.5 KSF	130					25	1.5 TO 2.0
		SILTY SAND			(DEPTH > 40 FT) MAX. SHEAR STRENGTH, COHESIVE STRATA: 1.0 TO 1.5 KSF	130					25	1.0 TO 1.5
		SILTY CLAY	T1(A) & (G)		OVERCONSOLIDATEDD 3 TO 5 TSF. STRENGTH 1.5 TO 2.5 KSF, HIGHER NEAR SURFACE.	130					25 TO 28	1.50 TO 2.50
		ORGANIC CLAY	T1 (B)		OVERCONSOLIDATED 1.5 TO 2.5 TSF. STRENGTH 2 TO 3 KSF.	130					25	3
		SILTY CLAY	T1 (C) & (F)		OVERCONSOLIDATED 0.5 TO 1 TSF. STRENGTH 0.7 TO 0.9 KSF, HIGHER AT SURFACE.	130	150				25	1 OR LESS
		PLASTIC CLAY	T1(D)		OVERCONSOLIDATED 2.5 TO 3.0 TSF. STRENGTH 2.5 TO 3.5 KSF.	130					25	2.0 TO 3.0
		MEDIUM PLASTIC CLAY	T1(E)		OVERCONSOLIDATED 3.0 TSF. STRENGTH 2 TO 3 KSF.	130					25	2.0 TO 2.50
SM & SC	SP & SW	SILTY SAND	T2	MEDIUM COMPACT TO VERY COMPACT BROWN AND RED-BROWN SILTY OR CLAYEY FINE TO MEDIUM SAND WITH TRACE OF GRAVEL AND OCCASIONAL BOULDERS		130					34	2.0 TO 3.0
SW & SM	SP & GM	GRAVELLY SAND	T3	COMPACT TO VERY COMPACT BROWN AND RED BROWN FINE TO COARSE SAND WITH SOME SILT AND SMALL GRAVEL AND VARIABLE AMOUNTS OF COBBLES AND BOULDERS		130	170				34-38	3.6 TO 4.0
SM & SP	SW	SILTY SAND	T4	MEDIUM COMPACT TO COMPACT GRAY AND GRAY-BROWN FINE TO MEDIUM SAND WITH SOME SILT AND SMALL GRAVEL, CONTAINING LENSES OF DARK GRAY CLAY, OCCASIONALLY SLIGHTLY ORGANIC.		130					30 TO 34	2.0 TO 3.0

TABLE V-2 , page 2 of 5

TABLE 15.2 page 2 of 5

TABLE V-2 SOIL PROPERTIES FOR DESIGN

UNIFIED SOIL CLASSIFICATION		SHORT DESCRIPTION	WMATA* SYMBOLS	FULL DESCRIPTION/SOURCE/AGE	SHEAR STRENGTH AND CONSOLIDATION CONDITION OF A COHESIVE STRATA	MIN. UNIT WEIGHT (PCF)	COEF OF SUBGRADE REACTION (KCF)	UNDRAIND SHEAR STRENGTH (KSF)	YOUNG MOD. OF SUBGRADE (KSI)	COEF. OF AT REST PRESS.	MAX. EFFECTIVE ANGLE OF FRICTION (DEGREES)	MAX. ALLOWABLE BEARING CAPACITY (TSF)
SW & SM	SP & GM	GRAVELLY SAND	Tf	COMPACT TO VERY COMPACT GRAY AND GRAY-BROWN FINE TO COARSE SAND WITH SOME GRAVEL, SOME TO TRACES OF SILT AND VARIABLE AMOUNTS OF COBBLES AND BOULDERS, OFTEN CONCENTRATED AT BASE OF LAYER		130					32 - 38	2.5 TO 4.0
				BRANDYWINE FORMATION OF EARLY PLEISTOCENE OR PLIOCENE TIMES.								
SM & SC		SILTY SAND	Q1	LOOSE TO MEDIUM COMPACT LIGHT BROWN SILTY OR CLAYEY FINE TO MEDIUM SAND WITH TRACE OF SMALL GRAVEL.		130					30	2.5
SM & SC	SP	GRAVELLY SAND	Q2	LOSE TO MEDIUM COMPACT LIGHT BROWN OR TAN SILTY OR CLAYEY MEDIUM TO FINE SAND WITH SOME SMALL GRAVEL.		130	100	0.01 0.02	12-15	0.4	33	3.0
				MARINE DEPOSITS OF TERTIARY OR UPPER CRETACEOUS PERIODS								
SM & CH	SP & CL		C	MEDIUM COMPACT GRAY AND TAN SILTY FINE SAND OR MEDIUM STIFF TO STIFF DARK GRAY TO OLIVE-GREEN CLAY. CALVERT FORMATION OF MIOCENE AGE.								
			Cc	PLASTIC CLAY, SILTY AND SANDY CLAY OR CLAYEY SILT		130	100	1.5-2.5	6-8	0.55	25	1.5-2.0
			Cs	FINE SAND, TRACE TO SOME SILT. CLAY AND CLAKY FINE SAND		130	140		8-10	0.5	30-32	2.5 -3.0
				AQUIA FORMATION OF EOCENE AGE.								
MH & CH	ML & CL		E	MEDIUM STIFF DARK GREEN OR BROWN CLAY AND SILTY CLAY. AQUA FORMATION OF EOCENE AGE.								
			Es			130	140		8-10	0.5	30-32	1.5-2.0
			Ec			130	100	2.0-3.5	6-8	0.55	25	2.5 -3.0
				UPPER CRETACEOUS PERIOD								
MH & CL	MH & CH		M	MEDIUM STIFF TO STIFF GREEN OR BROWN SILT AND CLAY. MONMOUTH FORMATION OF UPPER CRETACEOUS AGE.								
			Mc	SLIGHTLY ORGANIC FINE SANDY SILT AND CLAYEY SILT		130	120	3.0-3.5	8-10	0.6	25	2.0-4.0
			MS	SLIGHTLY ORGANIC MICACEOUS SILTY OR CLAYEY FINE SAND		130	100		10-12	0.45	32-34	2.0-4.0
				POTOMAC GROUP OF CRETACEOUS PERIOD,								

TABLE V-2 , page 3 of 5

TABLE 15.2 page 3 of 5

TABLE V-2 SOIL PROPERTIES FOR DESIGN

UNIFIED SOIL CLASSIFICATION		SHORT DESCRIPTION	MRWJ* SYMBOLS	FULL DESCRIPTION/SOURCE/AGE	SHEAR STRENGTH AND CONSOLIDATION CONDITION OF A COHESIVE STRATA	MIN. UNIT WEIGHT (PCF)	COEF OF SUBGRADE REACTION (KCF)	UNDRAIND SHEAR STRENGTH (KSF)	YOUNG MOD. OF SUBGRADE (KSI)	COEF. OF AT REST PRESS.	MAX. EFFECTIVE ANGLE OF FRICTION (DEGREES)	MAX. ALLOWABLE BEARING CAPACITY (TSF)
CH	CL	PLASTIC CLAY	P1	HARD MOTTLES RED-BROWN AND GRAY LIGHT GRAY AND TAN PLASTIC CLAY WITH OCCASIONAL POCKETS OF FINE SAND. GENERALLY CONSISTS OF PATAPSCO FORMATION BUT MAY INCLUDE RARITAN FORMATION AT UPPER LEVELS.	NORTH & WEST OF NEW JERSEY AVE. OVERCONSOLIDATED 15 TO 20 TSF. STRENGTH 4 TO 5 KSF BUT ERRATIC.	130	200	3.0 TO 5.0	10-15	0.6	28	3.0 TO 5.0
CL		SANDY CLAY				130	200	4.0-4.5	10-14	0.6	30	3.0-6.0
		PLASTIC CLAY			PARTIALLY WEATHERED ALONG B&O RIGHT-OF-WAY IN PHASE VII PROVIDE STRENGTH AND BEARING CAPACITY IN LOWER PORTION OF THE RANGE NOTED.	130					28	2.0 TO 5.0
SM & SP	SP	SILTY SAND	P2	COMPACT TO VERY COMPACT LIGHT GRAY OR TAN SILTY OR CLAYEY FINE TO MEDIUM SAND WITH POCKETS OF SILTY CLAY AND TRACE OF SMALL GRAVEL, OCCASIONAL LIGNITE FRAGMENTS. ALSO INCLUDES MAGOTHY FORMATION OF UPPER CRETACEOUS AGE.		130	200			0.5	31 TO 34	3.5 TO 6.0
G		SAND, SOME GRAVEL				130	200			0.5	34	3.0 TO 6.0
		SILTY SAND				130	200				31 TO 36	3.0 TO 6.0
					OVERCONSOLIDATED 15 TO 20 TSF. STRENGTH 4 TO 6 KSF.	130					34	4.0 TO 7.0
SM & SW	SP & GM	GRAVELLY SAND	P4	VERY COMPACT MOTTLED LIGHT GRAY, TAN BUFF OR WHITE SILTY OR CLAYEY FINE TO MEDIUM SAND WITH SOME GRAVEL AND SCATTERED LIGNITE FRAGMENTS FREQUENTLY WITH DENSE NESTS AND POCKETS OF ANGULAR ROCK FRAGMENTS, COBBLES AND BOULDERS.		135					34 TO 38	4.0 TO 7.0
				WEATHERED IN SITU FROM CRYSTALLINE BEDROCK								
ML & SM	MH	DECOMPOSED ROCK	D	DECOMPOSED ROCK: HARD ORANGE-BROWN OR YELLOW-BROWN MICACEOUS FINE SANDY SILT OR VERY COMPACT LIGHT GRAY AND GREEN MICACEOUS SILTY FINE TO MEDIUM SAND WITH VARIABLE AMOUNTS OF HARD, INCOMPLETELY DECOMPOSED ROCK FRAGMENTS AND LAYERS. PROPORTION OF HARD ROCK FRAGMENTS INCREASES WITH DEPTH TOWARD THE BEDROCK SURFACE.	HIGH QUASI-OVERCONSOLIDATED STRENGTH INCREASE WITH DEPTH: 1.5 KSF TO 3.5 KSF AND MORE.	140					36	5

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TABLE V-2 SOIL PROPERTIES FOR DESIGN													
UNIFIED SOIL CLASSIFICATION		SHORT DESCRIPTION	MRWJ* SYMBOLS	FULL DESCRIPTION/[illegible]	SHEAR STRENGTH AND CONSOLIDATION CONDITION OF COHESIVE STRATA	MIN. UNIT WEIGHT (PCF)	COEF OF SUBGRADE REACTION (KCF)	UNDRAINED SHEAR STRENGTH (KSF)	YOUNG MOD. OF SUBGRADE (KSI)	COEF. OF AT REST PRESS.	MAX. EFFECTIVE ANGLE OF FRICTION (DEGREES)	MAX. ALLOWABLE BEARING CAPACITY (TSF)
	REQUIRE DIAMOND CORE DRILLING TO ADVANCE BOREHOLE			TRANSITION ZONE								
		WEATHERED JOINTED BEDROCK	WB	WEATHERED AND JOINTED BEDROCK. WEATHERING ALONG JOINTS AND ALSO AFFECTING THE MINERAL FABRIC. RQD GENERALLY LESS THAN 50%.	BECOMING MORE ROCK LIKE WITH DEPTH, TOO HARD TO OBTAIN SOIL SAMPLE FOR TEST.	150 TO 160					32 TO 38	5.0 TO 15.0
		JOINTED BEDROCK	J	JOINTED TO MODERATELY JOINTED BEDROCK. WEATHERING OF JOINTS BUT RELATIVELY SMALL EFFECT ON MINERAL FABRIC. RQD GENERALLY BETWEEN 50% TO 75%.	MODERATELY JOINTED TO RELATIVELY SOUND. COMPRESSIVE STRENGTH 5 TO 25 KSI.	170					45	30.0 TO 60.0
		BEDROCK	B	RELATIVELY SOUND TO SOUND BEDROCK, OCCASIONALLY MODERATELY JOINTED. WEATHERING CONFINED PRINCIPALLY TO JOINTS. RQD GENERALLY GREATER THAN 75%.	MODERATELY JOINTED TO RELATIVELY SOUND. COMPRESSIVE STRENGTH 5 TO 25 KSI.	170					45	30.0 TO 60.0

1. THIS TABLE IS INTENDED PRIMARILY FOR USE IN DESIGN OF PERMANENT STRUCTURES. IN ANY CASE, SPECIFIC BORING AND LABORATORY TEST INFORMATION AT THE LOCATION OF INTEREST SHOULD BE CONSULTED IN SELECTING THE PARAMETERS FOR DESIGN SINCE THE VALUES TABULATED ABOVE ARE GENERALIZED OVER A WIDE AREA.

2. "SHEAR STRENGTH" TABULATED FOR "COHESIVE STRATA" IS APPROXIMATE UNDRAINED COHESION AND IS NOT INTENDED TO BE COMBINED WITH OR SUPERPOSED ON THE "EFFECTIVE FRICTION ANGLE" FOR DRAINED SHEAR.

3. IN EVALUATING APPLIED PRESSURES OR STABILITY CONDITIONS IN THE TRANSITION ZONE AND VARIOUS BEDROCK ZONES, THE BORING INFORMATION ON ATTITUDE AND CHARACTER OF THE DISCONTINUITIES SHOULD BE TAKEN INTO CONSIDERATION. IF THERE IS EVIDENCE OF SLICKENSIDES, SHEARED ZONES OR SURFACES OR SMOOTH JOINTS DIPPING UNFAVORABLY INTO THE EXCAVATION, EFFECTIVE FRICTION ANGLES ON THESE DISCONTINUITIES CAN BE IN A RANGE OF 10 DEGREES TO 20 DEGREES.

NOTES: a) TABLE IS BASED ON WMATA GEOTECHNICAL INFORMATION FOR THE METRO PREVIOUS PROJECTS.

b) INFORMATION (ALLOWED LIMITS) NOT GIVEN IN THE TABLE SHALL BE PROVIDED BY DESIGNER/DESIGN-BUILDER FOR SPECIFIC PROJECT AS NECESSARY

*MUESER RUTLEDGE WENTWORTH & JOHNSTON

Updated: September 6, [illegible]

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SECTION 16 - ENVIRONMENTAL

16.1 GENERAL ENVIRONMENTAL REQUIREMENTS

It is the policy of WMATA to commit the necessary resources to establish, implement and maintain comprehensive environmental management programs and systems that ensure full compliance with environmental laws, regulations, policies, procedures and programs. To that end, all design projects for construction of new facilities or renovation of existing facilities shall incorporate elements that will ensure compliance with all applicable environmental laws and permits during construction and during subsequent operation. Further, designs shall consider environmental sustainability to improve the quality and health of the community and environment. Finally, the design and construction of all new and substantially rehabilitated WMATA facilities shall be accomplished with a goal of obtaining LEED Silver certification.

16.2 Storm Water Management All storm water discharges shall comply with the requirements of all federal, state and local jurisdictions. WMATA strives to develop and redevelop facilities in a manner that maintains or restores storm water runoff to the maximum extent technically feasible. All WMATA operations and facilities are located within the boundaries of the US EPA's Chesapeake Bay Program Office; therefore, storm water designs must comply with Chesapeake Bay TMDLs and all related state and local requirements.

16.2.1 Storm water management designs for facility operation shall comply with all requirements of federal, state and local jurisdictions. Additionally, temporary storm water management measures throughout construction, including sediment and erosion control, shall comply with all requirements of federal, state and local jurisdictions.

16.2.2 Storm water management system design shall be prepared by a Professional Engineer licensed by local jurisdiction. Provide storm water calculations and hydrographs prepared for design within the design package submittal.

16.2.3 Control storm water runoff by implementing appropriate best management practices (BMPs) accepted by the state and local jurisdiction. Select BMPs that will reduce the availability, detachment and transport of pollutants to both ground and surface waters.

16.2.4 Designer shall consider and implement green infrastructure/low impact development (LID) wherever possible.

16.2.5 Storm water quality structures shall be installed to treat stormwater prior to discharge to the storm sewer system. Storm water runoff from parking areas must be pretreated through an oil/water separator, or equivalent structure, prior to discharge to the storm sewer system. No storm water runoff shall flow off the site without appropriate treatment.

16.2.6 All discharges to the storm sewer system, including those from discharge pumping stations, shall comply with the requirements of the state and local jurisdiction and General NPDES permits.

16.2.6.1 Obtain permit for any planned discharge to the storm sewer system.

16.2.6.2 Provide structures dedicated for stormwater observations and sampling to satisfy requirements to demonstrate compliance with discharge permits. Place structures prior to discharge of stormwater off site. Minimize total number of sampling structures; however, structures shall not include contribution from off-site sources.

16.2.7 For each pretreatment structure, design must accommodate maintenance using a vacuum truck and the following additional requirements.

16.2.7.1 Each pretreatment structure shall include a separate, dedicated sediment/grit chamber directly accessible for maintenance by vacuum truck.

16.2.7.2 For each pretreatment structure, design shall include a separate, dedicated oil/product collection chamber directly accessible for maintenance by vacuum truck.

16.2.7.2.1 In bus parking areas, provide structure with capacity to store a minimum of 125 gallons of petroleum product.

16.2.7.2.2 Proximate to each non-revenue vehicle fueling area, provide structure with capacity to store petroleum product:

At bus divisions: 50 gallons

At rail yards: 100 gallons

16.2.7.2.3 Where pre-engineered stormwater quality structures will be installed (e.g., Storm Filter, Bay Saver, or similar), system and filter media must be acceptable to the local jurisdiction.

16.2.8 For parking garages where the top deck is not covered, only top deck drains may discharge to the storm sewer. Discharge must be treated through an oil/water separator, or equivalent structure.

16.2.8.1 All storm water management structures must be accessible for maintenance using a vacuum truck (min. clearance 14 feet above finished grade) or design must provide underground piping for vacuum truck connection at building exterior.

16.2.8.2 Maintain separate water quantity storage vaults for waters that will discharge to storm sewer and sanitary sewer systems.

16.2.8.3 Cleaning in parking garages shall be accomplished using only vacuum truck recovery; uncontrolled washdown shall not be performed.

Recovered wastewater shall be hauled off site for proper disposal and shall be properly manifested.

16.2.9 Re-infiltration of storm water under buildings, including parking garages, is not allowed unless approved by WMATA and the state or local jurisdiction.

16.2.10 On design drawings, provide maintenance requirements for storm water management system.

16.2.11 Provide access to all stormwater structures for inspection and maintenance. Access to each storm water pretreatment and grit structure shall be through a 36" diameter manhole with a composite H-20 rated cover.

16.2.11.1 All stormwater structures, regardless of location, shall accommodate maintenance using a vacuum truck. Vacuum truck design considerations include min. clearance of 14 feet above finished grade and min. turning radius of 44 feet. Additionally, access route for vacuum truck shall be capable of supporting a 50,000 pound load and shall provide for vehicle turnaround area.

16.2.11.2 At each storm water pond, provide vehicle access to the outlet structure. Provide an anti-vortex trash rack, or similar device, to prevent discharge of large debris through the outlet structure. Plant native species to maintain a minimum 3-foot buffer around pond. In public areas, provide security fence around pond.

16.2.11.3 At each parking garage, structures must be accessible for maintenance using a vacuum truck or design must provide underground piping for vacuum truck connection at building exterior. Access to structure opening shall be located outside of main travel lane.

16.2.12 Bulk Salt Storage

16.2.12.1 Where bulk salt is stored on WMATA property, provide a building in which to stockpile the chemical and an adjacent impermeable pad that serves as a loading area for trucks.

16.2.12.2 Finished floor of salt storage facility shall be elevated a min. of 4 inches above surrounding grade and provided with interior perimeter curb a min. of 12 inches above finished floor, except at entry.

16.2.12.3 Provide ramp for equipment access to chemical stored within facility. Locate ramp to minimize storm water runoff into storage facility.

16.2.12.4 Entry to salt storage facility shall be provided with a means to retain chemical within the facility when not in use.

16.2.12.5 Provide curbing to prevent runoff to adjacent permeable areas.

16.2.12.6 Do not locate bulk storage or loading areas within 25 feet of storm drain inlet.

16.2.13 Flood Control

16.2.13.1 Design shall address current flood standards and compliance with applicable Executive Order(s).

16.2.13.2 Critical structures must be built 3 feet above the 100-year floor plan, or out of the 500-year flood plain.

16.2.13.3 Non-critical structures must be built 2 feet above the 100-year flood plain or out of the 500-year flood plain.

16.3 Wastewater Discharge: All discharges to the sanitary sewer system shall comply with requirements of the local public-owned treatment works (POTW) (i.e., wastewater treatment plant) and discharge permits.

16.3.1 Provide pretreatment systems for industrial operations prior to discharge to the sanitary sewer system to meet discharge requirements of the POTW, including conventional discharge limits. Pretreatment systems must include, but are not limited to, the following:

16.3.1.1 Install pretreatment system at rail car wash to adjust pH prior to discharge. Install control equipment to prevent discharge if pH is outside of POTW and/or permit limits. Provide separate grit chamber inside car wash to collect sediment. Provide dedicated space and/or separate room in which pretreatment system will be installed. Ensure adequate access around equipment for inspection and maintenance.

16.3.1.2 Install pretreatment system at each steam clean area, pressure wash area, chassis wash area, and /or blow pit to collect oil and grease prior to discharge. Provide separate grit chamber to collect sludge, grease and sediment.

16.3.1.3 Install pretreatment system at bus service lanes to collect oil and grease prior to discharge. Provide separate grit chamber to collect product and sediment.

16.3.2 For each pretreatment structure, design shall include installation of a sediment/grit chamber directly accessible for maintenance by vacuum truck.

16.3.3 For each pretreatment structure, design shall include installation of a separate oil /product collection chamber directly accessible for maintenance by vacuum truck.

16.3.3.1 In bus service lanes, provide structure with capacity to store a minimum of 500 gallons of product.

16.3.4 Where pretreatment systems are installed to meet permit requirements beyond oil/water separation, systems shall have remote communication capabilities.

16.3.4.1 Provide connection to LAN line for intranet monitoring.

16.3.4.2 Design, install and program PLC with controller to report data that is outside permit limits and to send real-time system status and alert notifications.

16.3.4.3 Provide a telephone-based (analog or digital) auto dialer to call alarm conditions to assigned staff. Auto dialers shall be ANTX Dialog Elite, or equal.

16.3.5 Design wastewater collection pits (e.g., steam clean pit, chassis wash bay) with sloped floor to assist maintenance and cleaning activities

16.3.6 Segregate industrial wastewater from sanitary discharge. Provide dedicated structures for sampling to satisfy requirements and demonstrate compliance with discharge permits (site-specific permits and/or limits of the POTW). Minimize the number of sampling structures and place the structures prior to discharge of industrial wastewater to sanitary sewer system.

16.3.6.1 Sample structure shall include flow meter for industrial discharge from the facility (rate and total flow) with remote totalizing meter accessible to the local sewer authority and WMATA.

16.3.7 For parking garages, all drains on decks below the top deck shall discharge to the sanitary sewer (unless otherwise directed by local jurisdiction). Discharge must be pretreated through an oil/water separator, or equivalent structure.

16.3.7.1 Pretreatment structures must be accessible for maintenance using a vacuum truck or design must provide underground piping for vacuum truck connection at building exterior. Maintain separate water quantity storage vaults for waters that will discharge to storm sewer and sanitary sewer systems.

16.3.7.2 Cleaning in parking garages shall be accomplished using only vacuum truck recovery; uncontrolled washdown shall not be performed. Recovered wastewater shall be hauled off site for proper disposal and properly manifested.

16.3.8 In general, floor drains are discouraged except in cleaning and maintenance areas where discharge to the sanitary sewer is an intentional design requirement.

16.3.8.1 No floor drains shall be present in paint spray booths, paint prep areas or battery storage areas (including traction power substations and tie breaker buildings).

16.3.8.2 No floor drains shall be present in bus fueling areas. Trench drains may be installed perpendicular to bus traffic at entry and exit to the bus service area.

16.3.9 Elevators and escalators shall have a sump that discharges to the sanitary sewer system through the use of an Oil Minder pump, or equal.

16.3.10 For facilities where maintenance activities will be completed, provide aqueous based, recycling parts washers with oil and sludge removal. No solvent cleaning systems shall be installed. Where pretreatment systems are not installed, parts washers must be accessible for maintenance with a vacuum truck, or install piping connection to building exterior.

16.3.11 At facilities that do not generate significant wastewater from industrial operations (e.g., less than 1,000 gallons/week), provide gray water systems rather than pretreatment systems. Gray water systems shall store wastewater generated by floor scrubbers, parts washers and mop water until the water is removed by vacuum truck. Within the facility, provide a building sump with floor grate into which parts washers drain and floor scrubber/mop water can be directly dumped. Gray water shall be stored aboveground or underground.

16.3.11.1 Water from the sump is pumped into a minimum 1,000-gallon fiberglass above ground storage tank, vented to the building exterior that is accessible for clean out with a vacuum truck. Provide a 3" diameter female cam and groove coupler connection at the base of the tank for cleanout.

Or...

16.3.11.2 Water from the sump may gravity drain to a concrete underground structure located outside the building, with piping trap that is accessible for clean out with a vacuum truck. Provide a mininum 36" diameter manhole with H-20 rated cover.

16.3.11.3 For each graywater storage system, design, install and program controls that prevent overfilling the storage structure.

16.3.12 On design drawings, provide maintenance requirements for wastewater pretreatment systems.

16.3.13 Provide access to all wastewater structures for inspection and maintenance. Access to each sanitary pretreatment and grit structure shall be through a minimum 36" diameter manhole with a H-20 rated cover.

16.3.13.1 All wastewater structures, regardless of location, shall accommodate maintenance using a vacuum truck. Vacuum truck design considerations include min. clearance of 14 feet above finished grade and min. turning radius of 44 feet. Additionally, access route for vacuum truck shall be capable of supporting a 50,000 pound load and shall provide for vehicle turnaround area.

16.3.13.2 Wastewater structures must be directly accessible for maintenance using a vacuum truck or design must provide underground piping for vacuum truck connection at building exterior.

16.4 Air Emissions: All discharges to the air shall comply with the requirements of the federal, state and local jurisdiction.

16.4.1 Evaluate fuel-burning equipment (such as generators and boilers) and other potential air emission sources (such as paint booths, printing operations, fire suppression systems, and CNG fueling systems) to determine permitting requirements in the state and local jurisdiction.

16.4.1.1 Wherever feasible, design facility to limit air emission sources below Title V permit requirements.

16.4.2 Obtain permits to construct and operate air emission sources prior to installing new equipment or performing significant changes to existing equipment.

16.4.3 Equipment that has been engineered to reduce air emissions to levels within the regulations must be certified.

16.4.4 For each facility, design shall provide a dedicated area and certified equipment to crush fluorescent tubes and to evacuate aerosol cans.

16.5 Noise: Noise shall be controlled such that it is within levels required by the local jurisdiction.

16.5.1 Noise is regulated for mobile and stationary sources.

16.5.2 Minimize the adverse impact of system operations and construction on the community by controlling transmission of noise and vibration to adjacent properties.

16.5.3 Provide noise and vibration control consistent with economic constraints and appropriate technology.

16.5.4 For each facility, jurisdiction noise standards shall be those documented in regulations at the time of final design.

16.5.5 Specific criteria for noise and vibration are provided in Section 16.11 (below).

16.6 Hazardous Material/Waste Storage: For each facility, design shall provide for dedicated and proper storage of hazardous materials and/or wastes.

16.6.1 For drum storage areas, including all material storerooms, provide spill containment pallets and signage for proper storage.

16.6.2 Containment curbs may be installed in lieu of individual pallets where a designated room will be used for drum storage.

16.6.3 For cylinder storage areas, including all material storerooms, provide materials required to properly segregate and secure cylinders and provide signage.

16.6.4 Provide separate, dedicated and secured hazardous and non-hazardous waste storage sheds. Sheds shall be large enough to hold a minimum of eight 55-gallon drums on one level, be accessible with forklift for loading material contained on pallets, and shall include integral spill containment. Sheds shall be located on an impervious surface atleast50 feet from the property line and no less than 25 feet from storm drain inlets. Provide signage to indicate “Hazardous Waste Storage Area” and “Non Hazardous Waste Storage Area” on applicable shed.

16.6.5 For battery storage rooms, provide containment curbs and appropriate epoxy coating on floor that extends no less than 18 inches above the floor on all walls. Provide mechanical ventilation in accordance with NFPA and other applicable codes.

16.6.6 Flammable cabinets that will be installed in exterior locations shall be weathertight, self-closing and shall include forklift pockets.

16.6.7 At each facility, provide dedicated space for a minimum of three dumpsters: one for solid waste, one for recyclables and one for scrap metal. Dumpsters shall not be located within 25 feet of a storm drain inlet.

16.6.8 Provide dedicated space and appropriate equipment for spill response (i.e., “spill kit”) adjacent to, and within easy access of, fueling areas, drum storage areas and battery storage areas (including traction power substations and tie-breaker stations).

16.7 Building Environmental Issues: For buildings to be renovated or demolished, designer shall identify environmental hazards that may impact construction activities and waste disposal. These issues include, but are not limited to, the presence of asbestos containing materials (ACMs), lead-based paint (LBP), biohazards (e.g., toxic mold or animal waste), electrical equipment or fixtures that contain polychlorinated biphenyls (PCBs), and lamps or other equipment that contain mercury. Where present, project design must identify the extent of these materials and must include specifications for proper abatement and waste disposal in accordance with all regulations.

16.7.1 For new construction, to the extent possible, specify building materials that do not contain environmental hazards.

16.8 Subsurface Environmental Issues: Designer shall identify and characterize subsurface environmental conditions that are likely to impact construction and operation. Designer shall review any available data, including but not limited to Environmental Impact Statements (EIS), Phase I and Phase II Environmental Site Assessments, and geotechnical data and shall collect additional data as necessary to adequately characterize subsurface contaminants. EIS mitigation requirements and contaminant pretreatment, including storm water discharge shall be implemented. For example, building dewatering systems or the tunnel discharge pumping stations may require pH adjustment or treatment to remove oil and grease prior to discharge to the sewer system. Temporary treatment requirements due to construction activities and materials (e.g. grout and concrete user) must also be implemented.

16.8.1 Obtain permits from federal, state and local agencies for planned discharges prior to construction.

16.8.2 Design discharge from areas with subsurface contaminants to meet requirements of discharge permits.

16.8.3 Whenever possible, remove contaminant source during construction, if located on WMATA property. If design does not incorporate source removal, prepare and submit a cost-benefit analysis for source removal vs. long-term corrective action and monitoring.

16.8.4 When an underground steel storage tank is encountered during renovation or construction operations, the tank shall be removed or abandoned in accordance with codes and regulations. Provide notification to WMATA's Environmental Management & Industrial Hygiene.

16.9 Environmentally Sustainable Design and Construction: Environmental sustainability refers to the implementation of building design and construction that satisfies the needs of the present without diminishing the ability of future generations to meet their needs. Design and construction must implement environmental building principles that include, but are not limited to, energy efficiency, water efficiency, and waste minimization.

16.10 Storage Tank Systems: Tank systems (underground storage tanks, aboveground storage tanks, associated piping systems, and dispensing systems and tank monitoring systems) shall be designed in accordance with applicable codes and regulations, including but not limited to the following: API, ASTM, NFPA, PEI, UL, US EPA, DCMR, COMAR and VAC.

16.10.1 Aboveground Storage Tanks (ASTs)

16.10.1.1 Whenever possible, install ASTs for product storage as a preference over underground product storage.

16.10.1.2 ASTs shall be double-walled steel, installed in accordance with manufacturer's installation instructions, and warranted for 10 years. The material used for tank construction, or lining, shall be compatible with the substance to be stored.

16.10.1.2.1 Requirements for ASTs apply to generator belly tanks.

16.10.1.2.2 ASTs storing Diesel Exhaust Fluid (DEF) shall be polyethylene or stainless steel.

16.10.1.2.3 Prior to placing tanks into operation, all shipping plugs shall be removed and replaced with compatible steel or stainless steel plugs.

16.10.1.3 ASTs shall meet the requirements of UL 142 When required by the local jurisdiction, ASTs shall meet the requirements of UL 2085.

16.10.1.4 Tanks shall be primed and painted by the manufacturer. Tanks with exposed primer are not acceptable.

16.10.1.5 Tank design shall ensure two spare openings (one 2-inch and one 4-inch opening) are available upon completion of tank system installation.

16.10.1.6 If installed near areas of vehicle travel, ASTs shall be protected by bollards on all sides. Bollards shall be min.6"diameterSch 80 steel pipe bollard, installed min. 4 feet below finished grade, extending min. 3.5 feet above grade, and spaced sufficiently to protect tank from damage.

16.10.1.7 Fill ports shall be located directly over the tank, where possible. Provide ladder access with platform, where necessary. If remote fill port is required, provide stainless steel enclosure with locking fill cap and fusible link. Connection at fill port shall be compatible with delivery vehicle/method.

16.10.1.7.1 Where pressurized remote fill is required, provide an overfill valve/shutoff to prevent overfilling tank.

16.10.1.8 All ASTs shall be provided with audible overfill alarm, prevention, spill containment box, and manual tank gauge.

16.10.1.9 ASTs shall be vented, both primary and interstitial vents, to the building exterior when required by code.

16.10.1.10 Used oil ASTs shall be Safe Waste, or equivalent, supplied with roll-caddy units.

16.10.1.11 Third rail deicer shall be stored at each rail yard in two 5,000-gallon ASTs.

16.10.1.12 DEF stored above ground must be protected for degradation. Tank system materials shall be compatible with DEF and tanks shall have industrial-grade insulated cabinets with heaters.

16.10.1.13 In parking garages, where emergency generator is fueled by diesel, diesel shall be stored in an AST that shall be vented to the building exterior.

16.10.1.14 All ASTs shall be labeled to identify tank capacity and product stored.

16.10.1.14.1 AST labels shall have minimum 2" high text. Labeling shall comply with GHS requirements and include a completed NFPA fire diamond.

16.10.2 Underground Storage Tanks (USTs)

16.10.2.1 Only tanks exceeding 2,500 gallons may be considered for UST installation.

16.10.2.2 USTs shall be double-walled fiberglass with brine in interstice, installed in accordance with manufacturer's installation instructions, and warranted for30 years. The material used for tank construction, or lining, shall be compatible with the substance to be stored.

16.10.2.2.1 USTs storing DEF shall be double-walled fiberglass clad with dry interstitial space. Primary tank shall be constructed of stainless steel, as well as all tank couplings, fittings and accessories.

16.10.2.2.2 All USTs shall have strike plates installed by manufacturer below all tank openings, including manways.

16.10.2.2.3 All USTs with a capacity to store 6,000 gallons or more must have two 24-inch manways installed by manufacturer.

16.10.2.3 USTs shall be installed by certified tank installers.

16.10.2.4 Design UST systems to minimize length of piping runs. Design "safe suction" systems wherever possible.

16.10.2.5 Place tank systems outside of main travel areas (roadways) and within required property setbacks. Provide concrete pad to cover all UST's.

16.10.2.6 UST anchoring shall be accomplished using a reinforced concrete anchor pad; dead men are not acceptable. Anchor pad shall be reinforced using two layers ofNo.4 rebar spaced 12 inches on center each way (OCEW). Where multiple tanks are installed in one tank field, anchor pad shall be one continuous pour and shall be stepped / keyed to accommodate tanks of multiple diameters. Straps, not ropes, shall be used to anchor tank to pad.

16.10.2.7 Use pea gravel to backfill all tank, piping and sump excavations. Pea gravel shall conform to the requirements of ASTM C33. Pea gravel shall be clean, washed, naturally-rounded gravel with sizes no larger than 3/4 inch with no more than 5% passing a #8 sieve. Dry density must be a minimum of 95 pounds per cubic foot.

16.10.2.8 Underground UST system piping, including vent piping, shall be double walled fiberglass; flexible piping is not acceptable. Piping material shall be compatible with the substance to be distributed. Piping must maintain a minimum slope of 1/8 inch per foot to a sump (preferably located on top of the tank) that is connected to a tank monitoring system.

16.10.2.8.1 Piping for heating oil system shall be copper lines installed within FRP containment pipe.

16.10.2.8.2 Piping for DEF system shall be welded stainless steel pipe installed within FRP containment pipe.

16.10.2.8.3 Use stainless steel flexible connectors where required to make connections within piping sumps.

16.10.2.8.4 Use piping transition sumps only when necessary to achieve required pipe slope. Obtain permission from regulatory authority to install. All sumps must have a sensor connected to the tank monitoring system.

16.10.2.9 Provide mechanical line leak detectors on all pressurized underground piping, regardless of product.

16.10.2.10 Fill ports shall be located directly over the tank; remote fills are not acceptable. UST shall have below-grade spill containment sump with a minimum 15-gallon capacity. Fill port drop tube shall have overfill prevention valve that incorporates two-stage shutoff (first stage reduced flow by 90% and second stage shuts off flow).

16.10.2.10.1 Gasoline UST shall have below-grade spill containment sump at Stage I vapor recovery riser.

16.10.2.11 All underground metal pipe risers shall be wrapped and coated to prevent corrosion.

16.10.2.12 Pipe riser for interstitial monitor shall be constructed of PVC.

16.10.2.13 All tank sumps shall be watertight and fiberglass integral to the tank, except the following: spill containment sump and gasoline vapor recovery. All tank sump covers shall be fiberglass press-on type with O-ring seal. No metal connection / clamps shall be used.

16.10.2.14 All penetrations through fiberglass sumps shall be accomplished using fiberglass bulkhead fittings, flexible entry boots are not acceptable.

16.10.2.15 UST manholes shall be H-20 rated, elevated approximately 2 inches above surrounding concrete and shall be the following minimum diameters:

STP sump:	42 inch
Inventory probe:	18 inch
Interstitial probe:	18 inch
Manual stick port:	12 inch

16.10.2.16 Pour reinforced concrete pad over USTs. Pad shall be a minimum of 12 inches thick and shall be reinforced using two layers of No. 4 rebar installed 12 inches OCEW. Additional reinforcement shall be provided at manholes in accordance with manufacturer's recommendations.

16.10.2.17 Fueling facility UST vents shall be located outside the distances indicated by NFPA/NEC that require explosion-proof fixtures within the fueling facility kiosk.

16.10.2.18 Each tank fill port manhole to include 4 inches of surrounding pavement and vent pipe shall be painted to identify product stored in the tank in accordance with WMATA color codes.

16.10.2.19 Install metal tag clamped to each fill port riser that identifies the tank product and capacity.

16.10.2.20 Underground conduit for UST systems shall be PVC-coated, rigid steel, min. 3/4" diameter.

16.10.2.21 Install a minimum of two observation wells/pipes within the backfill of each underground storage tank field. When required by state of local jurisdiction, install additional monitoring wells/pipes.

16.10.2.22 All heating oil systems shall include a day tank to enable CSLD for the UST.

16.10.2.23 Install signage near each tank field to identify the following: 1) WMATA color codes; and 2) tank product and capacity.

16.10.3 Tank Monitoring Systems:

16.10.3.1 All tank systems (except glycol ASTs at Rail Yards) shall have tank monitoring system to be Veeder-Root TLS.

16.10.3.2 Monitoring systems shall provide leak detection for UST systems that meet local jurisdiction requirements. Tank monitoring system console shall be located in an area that can be maintained within the operational range of the unit (i.e., a conditioned space) and does not require explosion-proof electrical accessories.

16.10.3.3 Monitoring systems shall include inventory probe, interstitial sensors, tank sump sensors, dispenser sump sensors, and overfill alarm and acknowledgment switch. Monitoring systems shall provide leak detection for UST systems that meet local jurisdiction requirements.

16.10.3.4 Tank monitoring system shall perform monthly CSLD testing and monthly reconciliation. All system programming shall be completed by the Contractor at the time of installation.

16.10.3.5 Wiring for V-R systems shall be shielded cable.

16.10.3.6 For pressurized line systems, all sump sensors shall be interlocked with pumps such that pumps will be disabled if any liquid is present in any tank sump.

16.10.3.7 Tank monitoring systems shall have remote communication capabilities. Provide connection to LAN line for intranet monitoring. Design, install and program console to report data and system alarms.

16.10.4 Fuel Dispensing Systems:

16.10.4.1 Dispensing areas shall incorporate an oil/water separator capable of containing petroleum product I the following quantiles:

Bus service lanes: 125 gallons

Non-revenue vehicle fueling at Bus divisions: 50 gallons

Non-revenue vehicle fueling at rail yards: 100 gallons.

16.10.4.2 Diesel dispensing systems for revenue vehicles (i.e., buses) shall be capable of delivering fuel at a rate of 40 gpm at the nozzle. Dispensing system shall include overhead tramway fueling system.

16.10.4.3 Each bus service lane shall include a pedestal diesel dispenser (Pump Measure Control Inc. Model MSH-62, or equal) with Posi-Lock coupling and liquid control flow meter with mechanical registration and pulse unit. Liquid control flow meter (M-5-1, or equal) shall be capable of delivering fuel at a rate of 5-60 gpm at 150 psi. Dispensing system shall be compatible with V-R tank monitoring system.

16.10.4.4 Diesel and gasoline dispensing systems for non-revenue vehicles shall be capable of delivering fuel at a rate of 22 gpm at the nozzle.

16.10.4.5 DEF dispensing systems shall provide protection to prevent product degradation and corrosion of dispensing system.

16.10.4.6 Where product piping enters gasoline and diesel dispensers underground, dispensers shall have below-grade dispenser sumps constructed of fiberglass with sensors connected to the tank monitoring system.

16.10.4.7 Rail yards shall include a diesel dispenser to fuel CTEM equipment in the right-of-way. Locate dispenser immediately adjacent to track so that dispenser hose is not placed across track when in use.

16.10.4.7.1 Provide spill containment at fueling area to capture and contain a minimum 100 gallons of product.

16.10.4.8 Each fueling area shall include an emergency shut-off (mushroom) switch located to comply with NFPA requirements. Label each switch using a minimum 2" high text.

16.11 NOISE AND VIBRATION

16.11.1 General Introduction

This document is intended to provide design criteria for all community related noise and vibration control problems relating to the construction and operations of the WMATA Metro System, excluding the transit vehicle noise and vibration control specifications.

Design of maintenance projects at existing facilities, including major renovations, shall conform to the design criteria in existence when the facility was constructed. The construction activity for maintenance shall comply with the construction criteria shown below.

The basic goals of these design criteria are to:

Minimize the adverse impact of system operations and construction on the community by preventing excessive noise and vibration levels from being created and controlling transmission of noise and vibration to adjacent properties.

Provide noise and vibration control consistent with economic constraints and appropriate technology.

Community acceptance of a rail transit system requires control of airborne noise from transit train operations, transit ancillary areas and facilities such as yard operations, fan and vent shafts of the ventilation system, electrical substations, and emergency service buildings. The design should also provide for control of ground borne noise and vibration from transit train operations.

Community acceptance of construction noise and vibration requires that the contractors follow published guidelines by the American Public Transit Association (APTA) and use machinery, equipment and construction methods with efficient noise and vibration suppression devices and that other noise and vibration abatement measures be used for protection of both employees and the public.

The criteria presented are based upon scales that most closely correlate with the subjective evaluation of noise: For most typical noise sources, it has been found that the A-weighted sound level provides excellent correlation with the subjective response to noise. Thus, the A-weighted sound level, which can be read directly from a sound level meter, has been selected for evaluating the response of people to the noise created by transit system construction and operations. However, evaluation of ground-borne noise, with associated low frequency sound pressure levels, requires octave band analyses and C-weighted measurements for effective evaluation.

Note: Definitions of many of the terms used in Section 16 are found in Section 16.11.9.

16.11.2 Measurement Procedures and Assumptions

Unless otherwise indicated, all noise levels are expressed in decibels (dB) referenced to 20 x 10^{-6} Pascals (20 µPa) as measured with the A-weighting network of a standard sound level meter, abbreviated dBA. All noise levels or measurements refer to the use of A-weighting and "slow" response of an instrument complying, at a minimum, with the Type 2 requirements of the latest revision of American National Standard (ANSI) S 1.4, "Specification for Sound Level Meters".

Vibration levels are expressed in decibels (dB) in terms of vibration velocity level referenced to 10^{6} in/sec (1.0 µin/sec) as measured with a velocity transducer or accelerometer with suitably integrated output. Vibration decibels are usually expressed as VdB so as not to confuse the measurement with sound decibels.

16.11.2.1 Transit System Wayside Noise and Vibration Measurements

The WMATA Metro wayside noise criteria are based on measurements taken at appropriate distances and performed in essentially a free-field or open space environment away from reflective or shielding surfaces. Unless otherwise indicated, the vibration criteria are based on measurements of vibration in the vertical direction from building floors.

16.11.2.2 Construction Noise and Vibration Measurements

Construction noise shall be measured in accordance with Section 16.4.1. All impulsive or impact noise levels or measurements refer to use of an impulsive sound level meter complying with the criteria of IEC 179 for impulse sound level meters. As an alternative procedure, a Type .2 General Purpose sound level meter on C-weighting and "fast" response may be used to estimate peak values of impulsive or impact noises.

Noise levels near buildings affected acoustically by the Contractor's operations refer to measurements at points between 3 ft and 6 ft from building facades or building setback lines.

Vibration at buildings affected by construction operations refers to vibration in any direction on the ground surface outside the affected building.

16.11.3 Community Categories and Relation to Criteria for Wayside Noise and Vibration

A wayside community noise design criterion provides a basis from which to determine the type and extent of noise attenuation and reduction measures necessary to avoid annoyance in the community. The wayside noise criteria must be related to the type of activity taking place in the building or community and the ambient noise levels in the absence of transit system noise. Obviously, a pass by noise level of a given magnitude is more objectionable in a quiet residential area at night than in a busy commercial area during the day.

The typical existing ambient or background noise and vibration can vary significantly for different communities. Therefore, it is necessary to evaluate the nature of the community in which the transit system is to be located before determining the appropriate criteria for allowable noise or vibration levels from the transit system in the community.

Table 1 indicates the five generalized categories of wayside areas into which the communities along transit system corridors can be categorized for the purpose of assigning appropriate noise and vibration criteria. The table indicates the description of the areas and the normal expected range of ambient noise levels. These categories and noise levels are based in part, on the information developed from studies of rail transit corridor environments along with the extensive data presented in the 1974 U.S. Environmental Protection Agency (EPA) document, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of safety, usually referred to as the "Levels Document", and other field noise measurement data obtained in many community areas throughout the United States.

Table 1 General Categories of Communities Along WMATA Metro System Corridors

Area Category	Area Description	Typical Ambient Noise Levels dBA (Average or L_{50}*)	Typical Day/Night Exposure Levels L_{dn}**
I	Low Density urban residential, open Space park, suburban residential or quiet recreation area. No nearby highways or boulevards.	40-50 (day) 35-45 (night)	Below 55
II	Average urban residential, quiet apartments and hotels, open space, suburban residential, or occupied outdoor areas near busy streets.	45-55 (day) 40-50 (night)	50-60
III	High Density urban residential, average semi-Residential/commercial areas, urban parks, Museum, and non-commercial public building Areas.	50-60 (day) 45-55 (night)	55-65
IV	Commercial areas with office buildings, retail Stores, etc., primarily daytime occupancy. Central Business Districts.	60-70	Over 60
V	Industrial areas or Freeway and Highway Corridors.	Over 60	Over 65

*** - L_{50} is the long-term statistical median noise level.**
**** - L_{dn} is the day-night sound level.**

The categories defined in Table 1 are used in determining appropriate noise and vibration design criteria. The land use or area categories presented above are similar to those used in the 1970 WMATA Design Criteria and are the same as the categories used in the 1976 WMATA Design Criteria and in the APTA Publication," Guidelines for Design of Rapid Transit Facilities". In most cases, experience with the newer systems now in operation and specifically with the WMATA Metro System has indicated that these categories and the associated criteria provide for adequate results, as most of the neighbors of the transit facility find the noise and vibration levels acceptable.

16.11.4 Wayside Noise and Vibration Due to Transit Train Operations

16.11.4.1 Airborne Noise from Above-Ground Train Operations

Table 2 presents design criteria for single pass by maximum noise levels for airborne noise from transit, trains for various types of buildings in each of the land use area categories listed in Table 1. These criteria are generally applied to nighttime operations because sensitivity to noise is greater at night than during the day time. The maximum levels are based on the maximum level that will not cause significant intrusion or alteration of the pre-existing noise environment and represent noise levels which are considered acceptable for the type of land use in each area. The criteria presented in Tables 2 and 3 are generally applicable outdoors at the nearside of the nearest occupied building or area under consideration, but not less than 50 ft from track centerline.

Table 2 Criteria for Maximum Airborne Noise from Train Operations

	Maximum Pass by Noise Level		
Community Area Category	Single Family Dwellings	Multi Family Dwellings	Commercial Buildings
I Low Density Residential	70 dBA	75 dBA	80 dBA
II Average Residential	75	75	80
III High Density Residential	75	80	85
IV Commercial	80	80	85
V Industrial Highway	80	85	85

For some types of buildings or occupancies maximum noise level limits should be applied regardless of the community area category. The design should reflect careful consideration of noise control when the transit line is near these specific type of buildings or areas. Table 3 presents design criteria for maximum airborne noise from transit operations near these specific types of buildings.

Table 3 - Criteria for Maximum Airborne Noise from Train Operations Near

Specific Types of Buildings or Areas

Building or Occupancy Type	Maximum Pass by Noise Level (dBA)
Outdoor Amphitheaters or Concert Pavilions	65
"Quiet" Outdoor Recreation Areas	70
Concert Halls, Radio and TV Studios, Auditoriums	70
Churches, Theaters, Schools, Hospitals, Museums, Libraries	70

16.11.4.2 Ground borne Noise from Train Operations

Table 4 presents criteria for maximum ground borne noise due to transit train operations for various types of residential communities. Ground-borne noise and ground borne vibration are directly correlated with each other. Ground-borne vibration describes waves in the ground which can be measured using vibration pickups mounted on the sidewalk, foundations, building floors, or stakes in the ground and which can be perceived as mechanical motion. Ground borne noise describes sound generated when the same waves in the ground reach room surfaces in buildings, causing them to vibrate and radiate sound waves in the room.

Wayside impact due to the operation of transit trains in subway is normally described in terms of ground borne noise because in most situations, the noise produced by the vibration of room surfaces is audible at ground borne vibration levels below those which are perceptible to tactile senses. Thus, in most cases, a criterion limiting audible noise levels will provide adequate protection against tactile ground borne vibration levels.

In most cases for surface or aerial transit train operations, the airborne noise is significantly louder than the ground borne noise, and ground borne noise is not perceived separately from the airborne noise. Thus, assessment of the acoustic noise level due to vibration instead of ground vibration levels facilitates comparison with expected interior airborne noise.

TABLE 4 - Criteria for Maximum Ground borne Noise from Train Operations for

Buildings with Sleeping Areas

		Maximum Pass by Ground borne Noise Level		
Community Area Category		**Single Family Dwellings (dBA)**	**Multi-Family Dwellings (dBA)**	**Hotel/ Motel Dwellings (dBA)**
I	Low Density Residential	30	35	40
II	Average Residential	35	40	45
III	High Density Residential	35	40	45
IV	Commercial	40	45	45
V	Industrial/Highway	40	45	50

As with airborne noise, there are some types of buildings for which specific design criteria should be applied, regardless of area category. Table 5 presents design criteria for generally acceptable levels of transient ground borne noise levels in occupied spaces of various types of buildings and occupancies. The table is not intended to be all inclusive, but may be a convenient general guide.

TABLE 5 Criteria forMaximum Ground borne Noise forTrain Operations NearSpecific Types of Buildings

Type of Building or Room	Maximum Pass by Ground borne Noise Level (dBA)
Concert Halls and TV Studios	25
Auditoriums and Music Rooms	30
Churches and Theaters	30-35
Hospital Sleeping Rooms	35-40
Courtrooms	35
Schools and Libraries	35-40
University Buildings	35-40
Offices	35-40
Commercial Buildings	45-55

Ground-borne noise that achieves the design criteria listed above will not be discernable in most cases, however, the level will be sufficiently low with little significant intrusion or annoyance should occur. In most cases, there will be noise from street traffic, other occupants of a building, or other sources, which will create noise intrusion that is equivalent to or greater in level than the noise from transit trains passing by.

A range of the maximum ground-borne noise limit is given in some cases to permit an adjustment of the design criterion to be suitable for the environment and location of the building. For example, at office in a quiet, landscaped office park area, the limit should be at the low end of the range, 35 dBA. For offices located at a busy intersection or in a busy central business district the limit can be at the upper end of the range, 45 dBA.

16.11.4.3 Ground borne Vibration from Train Operations

Table 6 presents the appropriate ground borne vibration criteria for maximum ground borne vibration for various types of residential buildings. The criteria apply to measurements of vertical vibration of floor surfaces within the buildings.

TABLE 6 - Criteria for Maximum Ground borne Vibration from Train Operations for Buildings with Sleeping Areas

Community Area Category	Maximum Passby Ground Borne Vibration Velocity Level (dB 10^{-6} in/sec) Single Family Dwellings	Multi Family Dwellings	Hotel/Motel Buildings
I Low Density Residential	72	72	72
II Average Residential	72	72	75
III High Density Residential	72	75	75
IV Commercial	72	75	75
V Industrial/Highway	75	75	75

As with ground borne noise, there are some types of buildings for which specific design criteria for ground borne vibration should be applied, regardless of area category. Table 7 presents design criteria for transient ground borne vibration levels in occupied spaces of various types of buildings and occupancies. This table is not intended to be all inclusive.

TABLE 7 Criteria for Maximum Ground borne Vibration from Train Operations Near Specific Types of Buildings

Type of Building or Room	Maximum Passby Ground-borne Vibration Velocity Level (xB re 10.6 in/sec)
Vibration Sensitive Industrial or Research Laboratory	60-70
Concert Halls and TV Studios	65
Auditoriums and Music Rooms	70
Churches and Theaters	70

Hospital Sleeping Rooms	70
Courtrooms	70
Schools and Libraries	75
University Buildings	75-80
Offices	75-80
Commercial and Industrial Buildings	75-80

Ground borne vibration that achieves the design criteria listed above will not be imperceptible in all cases; however, the level will be sufficiently low so that no significant intrusion or annoyance should occur. In most cases, there will be vibration from street traffic, other occupants of a building, or other sources, that will create intrusion that is equal or greater in level than the vibration from the transit trains.

A range of the maximum ground borne vibration limit is given in some cases to permit an adjustment of the design criterion to be suitable for the environment and location of the building. For example, at offices in a quiet, landscaped industrial park area the limit should be at the low end of the range, 75 dB. For offices located at a busy intersection or in a noisy central business district the limit can be at the upper end of the range, 80 dB.

16.11.5 Airborne Noise from Transit Ancillary Facilities

16.11.5.1 Introduction

A transit system will generate community noise not only from trains but also from ancillary facilities. The two basic types of airborne noise from ancillary facilities are transient and continuous. For example, transient noise occurs during train passbys and this noise is transmitted from vent shaft openings. Power substations and fan noise may be characterized as continuous ancillary equipment noise. These noises can be obtrusive due to their tonal and continuous nature. The appropriate noise level design criterion depends on the activities of occupants as well as the background noise in the area. The acceptable levels of transient and continuous noises are different. Transient noises are acceptable at higher levels than continuous noises, particularly continuous noises containing pure tones. Table 8 presents the design criteria for transit system ancillary facility noises in each of the community area categories defined in Table 1.

Table 8 - Criteria for Noise from Transit System Ancillary Facilities

Community Area Category		Maximum Noise Level -dBA Transient Noises	Continuous Noises
I	Low Density Residential	50	40
II	Average Residential	55	45
III	High Density Residential	60	50
IV	Commercial	65	55
V	Industrial / Highway	75	65

The criteria in Table 8 should be applied at a distance of 50 ft from the shaft outlet or other ancillary facility or should be applied at the setback line of the nearest buildings or occupied area, whichever is closer.

As previously stated, transient noise design criteria apply to short time duration events such as train pass by noise transmitted from vent shaft openings. Continuous noise criteria apply to noises such as fans, cooling towers, or other long duration noises except electrical transformer hum. The criteria for transformer noise, or other noise sources with tonal components, should be 5 dBA less than given in Table 8.

16.11.5.2 Fan and Vent Shafts

For fan and vent shafts with surface gratings or openings the noise shall be limited in accordance with the criteria for exterior noise from ancillary facilities presented in Table 8.

Vent shaft noise reduction shall be achieved by acoustical absorption treatment in the shafts applied to the walls and ceilings. Fan shaft noise reduction shall be achieved by use of standard duct attenuators in shafts where the fans are near the surface gratings. For shafts with fans located remotely from the grating the noise reduction shall be achieved by the use of standard attenuators and sound absorption treatment applied to the fan room and shaft walls and ceilings with the combination to achieve the total attenuation required. Where absorption treatment is necessary, the treatment shall have a minimum sound absorption coefficient of 0.6 at 250 Hz and 0.8 at 500 Hz.

16.11.5.3 Substations and Emergency Power Generation

Substation and emergency power generation equipment noise shall be limited to 5 dBA less than the sound level listed for continuous noise in Table 8. Reduction of noise from these sources shall be achieved by barriers, enclosures, sound absorption materials and mufflers, as applicable to the individual facility or unit design.

16.11.6 Vibration Isolation of Transit Structures

16.11.6.1 Scope

Vibration isolation shall be provided at any point where a subway, aerial structure column, aerial structure girder or other structure is indirect contact with, supported on, or supporting a building structure), or at any point where a subway structure, station structure or other transit structure is in very close proximity or directly against a building structure or building foundation element.

16.11.6.2 General Considerations

Vibration isolation in the form of a resilient element shall be provided between the transit structure elements and building structure elements to prevent direct transmission of noise and vibration to buildings.

16 .11.6.3 Isolation Elements

For underground transit structures near or at buildings, the resilient element between the two structures shall consist of intervening soil of at least 2 ft thickness or depth. If the separation between the two structures is less than 2 ft, then an elastomer pad plus the intervening soil shall be the resilient element between the transit structure and building. The elastomer pad shall be a 1 in to 2 in thick closed-cell expanded neoprene, selected to give proper support of hydraulic or structural loads with deflection of the elastomer pad not exceeding 10% to 20% of pad thickness.

For aerial structure columns or girders, the transit structures should be separately founded from buildings and resilient bearing pads or elastomer separation elements provided between the transit structures and the building. There shall be no rigid connection between the building elements and the transit structure elements.

16.11.7 Wayside Noise from Service and Inspection Yards

The principal noises that have been found to create annoyance in communities near S&I yards are the noise from the transit cars, including:

- The wheel squeal which results when the cars move on short radius curves entering the yard or on loop tracks
- The noise from auxiliary equipment on the cars
- The noise from car propulsion systems and the wheel and rail interaction when the cars are moving on the track, and
- The pings, clicks and bangs that occur as wheels pass over frogs and joints in the special trackwork included in the yard.

These sources produce randomly occurring noises which are of considerably different character than typical community background noise and if of sufficient level can be noticeable and intrusive. Table 9 presents design criteria for noise control at S & I Yards applicable to residential areas, again using the community categories defined in Table 1. The criteria presented should be applied at the nearest affected residential properties. If necessary to be compatible with existing noise ordinances, the criteria should apply at the S&I Yard property line or the boundary line dividing the industrial/commercial and residential zones.

TABLE 9 - Criteria for Maximum Airborne Noise from Metro Train Operations at Service and Inspection Yards Adjacent to Residential Areas

Community Area	Category	Maximum Noise Level - dBA
I	Low Density Residential	55
II	Average Residential	55
III	High Density Residential	65
IV	Commercial	65
V	Industrial/Highway	70

16.11.8 Construction Noise and Vibration Control

16.11.8.1 General

The requirements of this Section are intended to provide general guidelines to minimize construction noise and vibration and may not be applicable in all situations. More detailed noise and vibration control specifications may be necessary for certain construction contracts. These specifications should be reviewed by a competent acoustical consultant.

Perform construction operations in a manner to minimize noise and vibration. Provide working machinery and equipment with efficient noise suppression devices and employ other noise and vibration abatement measures necessary for protection of both employees and the public. In addition, restrict working hours and schedule operations in a manner that will minimize to the greatest extent feasible the disturbance to the public in areas adjacent to the work and to occupants of buildings in the vicinity of the work. Protect employees and the public against noise exposure in accordance with the requirements of the Occupational Safety and Health Act of 1970 and the current statutory noise limits set by the Occupational Safety and Health Administration, specifically 29 CFR 1910.95 (Occupational Noise Control). Compliance with the requirements of this Section will not relieve the Contractor from responsibility for compliance with state and local ordinances, regulations, and other Sections of this criteria document.

16.11.8.2 Special Requirements

Compliance with the requirements of this Section will require the use of machines with effective mufflers or enclosures and selections of quieter alternative procedures. Compliance may also require the use of completely or partially closed enclosures (tongue and groove plywood or sheathing) around work sites or a combination of closed boarding and effective mufflers or enclosures. It will also be necessary to arrange haul routes to minimize noise and vibration at residential sites and it may be necessary to place operating limitations on machines and trucks. Shop drawings of work sites and haul routes showing provisions for control of construction noise shall be submitted to the Engineer for approval. Calculations of effective noise dampening and attenuation, via noise absorption and transmission data and calculations, shall be evaluated by an Acoustical Engineer.

16.11.8.3 Monitoring

Monitor noise and vibration levels of work operations to assure compliance with the noise and vibration limitations contained herein and retain records of noise and vibration measurements for inspection by the Engineer. Promptly inform the Engineer of any complaints received from the public regarding noise and vibration. Describe the action proposed and the schedule for implementation and subsequently inform the Engineer of the results of the action.

16.11.8.4 Definitions

Daytime refers to the period from 7 a.m. to 7 p.m. local time daily except Sundays and legal holidays. Nighttime, refers to all other times including all day Sunday and legal holidays.

Construction Limits are defined for the purpose of these noise and vibration control requirements as the Right-of-Way lines, Construction Easement Boundary or property lines as indicated on the drawings.

There are two types of Special Zones. The first is that designated at the request of the contractor. These maybe designated outside of the construction site by the agency having jurisdiction where the construction site is located. These specially designated zones shall be treated by the contractor as if they were within the construction limits.

The second type of Special Zone is that designated by the local agency having jurisdiction and may have specific noise level and working tome restrictions.

16.11.8.5 Noise Level Restrictions

In no case expose the public to construction noise levels exceeding 90 dBA (slow) or to impulsive noise levels with a peak sound pressure level exceeding140 dBA as measured on an impulse sound level meteror125 dBA maximum transient level as measured on a general purpose sound level meter on "fast" meter response.

Conduct construction activities in such a manner that the noise levels 200 ft from the Construction Limits or at the nearest affected building, whichever is closer, do not exceed the levels listed in Tables 10 and 11.

Prevent noises from stationary sources, parked mobile sources or any sources or combination of sources producing repetitive or long-term noise lasting more than two hours from exceeding the limits of Table 10.

TABLE 10 LIMITS FOR CONTINUOUS CONSTRUCTION NOISE

Affected Structure or Area	Maximum Allowable

<u>Continuous Noise Level</u>	All locations	
Daytime dBA **Nighttime dBA**		
	60	**50**
Residential		
Single family residential areas, not along a major arterial	**65**	**65**
Along an arterial or in multi-family residential areas, including hospitals	**70**	**60**
In semi-residential/commercial areas, including hotels		
	70	**65**
Commercial		
In semi-residential/commercial areas, including schools	**75**	**70**
In Commercial areas with no nighttime residency		
	80	**80**
Industrial		

Prevent noises from non-stationary mobile equipment operated by a driver or from any source of non-scheduled, intermittent, non-repetitive, short-term noises not lasting more than two hours from exceeding the limits of Table 11

TABLE 11 - LIMITS FOR INTERMITTENT CONSTRUCTION NOISE

Affected Structure or Area	**Maximum Allowable <u>Continuous Noise Level</u>**		
	Daytime dBA	**Nighttime dBA**	
Residential			
Single family residential areas, not along a	**75**	**60**	major arterial
Along an arterial or in multi-family including hospitals	**75**	**65**	residential areas,
In semi-residential/commercial areas,	**80**	**70**	including hotels

Commercial			
In semi-residential/commercial areas, schools	**80**	**80** including	
In Commercial areas with no nighttime	**85**	**85**	residency
Industrial			
All locations	**90**	**90**	

In areas outside of Construction Limits but for which the Contractor has obtained designation as a Special Zone or Special Construction Site from the agency having jurisdiction, the noise limitations for buildings in industrial areas apply.

In zones designated by the local agency having jurisdiction as a special zone or special premise or special facilities, such as hospital zones, the noise level and working time restrictions imposed by the agency shall apply. These zones and work hour restrictions shall be obtained by the Contractor from the local agency.

Where more than one noise limit is applicable, use the more restrictive requirement of determining compliance.

16.11.8.6 Noise Emission Restrictions

Use only equipment meeting the noise emission limits listed in Table 12, as measured at a distance of 50 feet from the equipment in substantial conformity with provisions of the latest revisions of SAE J366b, SAE J88 and SAE J952b or in accordance with the measurement procedures specified herein.

TABLE 12 NOISE EMISSIONS ON CONSTRUCTION NOISE

Type of Equipment	Maximum Noise Limit Date Equipment was Acquired Before 01/01/1990 dBA	 On or After 01/01/1990 dBA
All equipment other than highway trucks; including hand tools and heavy equipment	90	85
Highway trucks in any operating mode or location	83	80

16.11.8.7 Vibration Level Restrictions

Vibration Limits in all areas: In order to minimize annoyance or interference to occupants of affected buildings, the contractor shall conduct construction activities in such a manner that ground vibration at the nearest occupied building do not exceed the following peak particle velocity (PPV) magnitudes in any direction.

	Vibration Velocity Magnitude - in/sec (PPV)
Sustained (>1 hr/day)	0.03
Intermittent (< 1 hr/day)	0.07
Intermittent (< 10 min/day)	0.10

To avoid physical damage to buildings, the contractor shall conduct construction activities in such a manner that the maximum ground vibration magnitude at all times does not exceed 0.2 in/sec(PPV) in any direction for buildings which are in generally sound condition.

For buildings or historical monuments that are considered particularly fragile (as determined by a competent structural engineer) due either to the method of construction or a weakened condition resulting from the age of the structure, the contractor shall conduct construction activities in such a manner that the maximum ground vibration magnitude at all times does not exceed 0.12 in/sec (PPV) in any direction.

In zones designated by the local agency having jurisdiction as a special zone or special premise or special facilities, the vibration level and working time restrictions imposed by the agency shall apply. These zones and work hour restrictions shall be obtained by the contractor from the local agency.

16.11.8.8 Noise and Vibration Control Requirements

Notwithstanding the specific noise and vibration level limitations specified herein, utilize the noise and vibration control measures listed below to minimize to the greatest extent feasible the noise and vibration levels in all areas outside the Construction Limits.

Utilize shields, impervious fences or other physical sound barriers to inhibit transmission of noise.

Utilize sound retardant housings or enclosures around noise producing equipment.

Utilize effective intake and exhaust mufflers on internal combustion engines and compressors.

Line or cover hoppers, storage bins and chutes with sound deadening material:

Do not use air or gasoline driven saws.

Conduct truck loading, unloading and hauling operations so that noise and vibration is kept to a minimum.

Route construction equipment and vehicles carrying spoil, concrete or other materials over streets and routes that will cause the least disturbance to residents in the vicinity of the work. Advise the Engineer in writing of the proposed haul routes prior to securing a permit from the local government.

Site stationary equipment to minimize noise and vibration impact on the community, subject to approval of the Engineer.

Use vibratory pile drivers or auguring for setting piles in lieu of impact pile drivers. If impact pile drivers must be used, their use is restricted to the hours from 8 a.m. to 5 p.m. weekdays in residential and in semi-residential/commercial areas.

16.11.9 Glossary of Terms

16.11.9.1 A-Weighted Sound Level (dBA):

The sound pressure level in decibels as measured on a sound level meter using the internationally standardized A-weighting filter or as computed from sound spectral data to which A-weighting adjustments have been made. A-weighting deemphasizes the low and very high frequency components of the sound in a manner similar to the response of the average human ear. A-weighted sound levels correlate well with subjective reactions of people to noise and are universally used for community noise evaluations.

16.11.9.2 Accelerometer:

A vibration sensitive transducer that responds to the vibration acceleration of a surface to which it is attached. The electronic signal generated by an accelerometer is directly proportional to the surface acceleration.

16.11.9.3 Acceleration Level:

Also referred to as "vibration acceleration level". Vibration acceleration is the rate of change of speed and direction of a vibration. An accelerometer generates an electronic signal that is proportional to the vibration acceleration of the surface to which it is attached. The acceleration level is 20 times the logarithm to the base 10 of the ratio of the RMS value of the acceleration to a reference acceleration. The generally accepted reference vibration acceleration is 10^{-6} g (10^{-5} m/sec).

16.11.9.4 Ambient Noise:

The prevailing general noise existing at a location or in a space, which usually consists of a composite of sounds from many sources near and far.

16.11.9.5 Background Noise:

The general composite non-recognizable noise from all distant sources, not including nearby sources or the source of interest. Generally background noise consists of a large number of distant noise sources and can be characterized by L90 or L99.

16.11.9.6 Community Noise Equivalent Level (CNEL):

The Leq of the A-weighted noise level over a 24-hour period with a 5 dB penalty applied to noise levels between 7 p.m. and 10 p.m. and a 10 dB penalty applied to noise levels between 10 p.m. and 7 a.m.

16.11.9.7 Day-Night Sound Level (Ldn):

The Leq of the A-weighted noise level over a 24-hour period with a 10 dB penalty applied to noise levels between 10 p.m. and 7 a.m.

16.11.9.8 Decibel (dB):

The decibel is a measure on a logarithmic scale of the magnitude of a particular quantity (such as sound pressure, sound power, sound intensity) with respect to a standardized quantity.

A dimensionless unit relating the logarithm of the ratio of the threshold of sound perception to the threshold of pain from sound. The decibel scale of 1 - 140 describes this extremely large range from 20 micropascals to 200,000,000 micropascals.

16.11.9.9 Energy Equivalent Level (Leq):

The level of a steady noise which would have the same energy as the fluctuating noise level integrated over the time period of interest. Leq is widely used as a single-number descriptor of environmental noise. Leq is based on the logarithmic or energy summation and it places more emphasis on high noise level periods than does L50 or a straight arithmetic average of noise level over time. This energy average is not the same as the average of sound pressure levels over the period of interest, but must be computed by a procedure involving summation or mathematical integration.

16.11.9.10 Frequency (Hz):

The number of oscillations per second of a periodic noise (or vibration) expressed in Hertz (abbreviated Hz). Frequency in Hertz is the same as cycles per second.

16.11.9.11 L1, L10, L50, L90 and L99:

The noise (or vibration) levels that are exceeded 1%, 10%, 50%, 90% and 99% of a specified time period, respectively. Environmental noise and vibration data are often described in these terms.

16.11.9.12 Noise Criterion Curves (NC Curves):

A series of curves which specify the maximum sound pressure level in each octave band between 63 Hz and 8,000 Hz used to characterize the noisiness of steady sounds in an occupied indoor space.

16.11.9.13 Noise Exposure Level (NEL):

Noise Exposure Level (NEL), also referred to as Sound Exposure Level (SEL), is a time integrated metric which quantifies the total energy in A-weighted noise (sound) level measured during a particular event referenced to a duration of 1 second.

16.11.9.14 Noise Reduction (NR):

Noise reduction, also referred to as noise level reduction (NLR) is the overall difference between the exterior and interior sound levels of a building space, taking into account the sound transmission loss of all structural elements (walls, roofs, doors, windows, etc.) and the interior sound absorptive characteristics of the space.

16.11.9.15 Noise Reduction Coefficient (NRC):

Noise reduction coefficient is a measure of the acoustical absorption performance of a material, calculated by averaging its sound absorption coefficients at 250 Hz, 500 Hz, 1000 Hz and 2000 Hz.

16.11.9.16 Octave Band - 1/3 Octave Band:

One octave is an interval between two sound frequencies that have a ratio of two. For example, the frequency range of 200 Hz to 400 Hz is one octave, as is the frequency range of 2000 Hz to 4000 Hz. An octave band is a frequency range that is one octave wide. A standard series of octaves is used in acoustics, and they are specified by their center frequencies. In acoustics, to increase resolution, the frequency content of a sound or vibration is often analyzed in terms of 1/3 octave bands, where each octave is divided into three 1/3 octave bands.

16.11.9.17 Reverberant Field:

The region in a room where the reflected sound dominates, as opposed to the region close to the noise source, where the direct sound dominates.

16.11.9.18 Reverberation:

The continuation of sound reflections within an enclosed space after the sound source has stopped.

16.11.9.19 Reverberation Time (RT):

The time taken for the sound pressure level in a room to decrease to one-millionth (60 dB) of its steady-state value after the source of sound energy is suddenly interrupted. It is a measure of the persistence of a sound in a room and of the amount of acoustical absorption present inside the room.

16.11.9.20 Sound Absorption Coefficient (á):

The absorption coefficient of a material is the ratio of the sound absorbed by the material to that absorbed by an equivalent area of an open window. The absorption coefficient of a perfectly absorbing surface would be 1.0 while that for concrete or marble slate is approximately 0.01 (a perfect reflector would have an absorption coefficient of 0.00).

16.11.9.21 Sound Exposure Level (SEL):

See definition of Noise Exposure Level

16.11.9.22 Sound Pressure Level (SPL):

The sound pressure level of sound in decibels is 20 times the logarithm to the base of10 of the ratio of the RMS (root-mean square) value of the sound pressure to the RMS value of a reference sound pressure. The standard reference sound pressure is 20 micro-pascals as indicated in ANSI S1.8-1969, "Preferred Reference Quantities for Acoustical Levels".

16.11.9.23 Sound Transmission Class (STC):

STC is a single number rating, specified by the American Society for Testing and Materials (ASTM), which is used for comparing the sound transmission characteristics (in decibels) of building elements. It is widely used for rating sound insulation characteristics of buildings materials and products for sources such as speech, radio, television and similar sounds within buildings.

16.11.9.24 Velocity Level:

Also referred to as the "vibration velocity level". Vibration velocity is the rate of change of displacement of a vibration. The velocity level is 20 times the logarithm to the base 10 of the ratio of the RMS value of the velocity to the reference velocity. In this report the reported vibration velocity levels are all referenced to 10-6 in/sec. Above approximately 10 Hz, human response to vibration is more closely correlated to the velocity level than the acceleration level.

16.11.9.25 Weighted Velocity Level:

The vibration velocity level to which a weighting factor has been added. The weighting de-emphasizes the low frequencies in a manner similar to human response to vibration.

16.11.9.26 Statistical Distribution Terms

L99 and L90 are descriptors of the typical minimum or "residual" background noise (or vibration) levels observed during a measurement period, normally made up of the summation of a large number of sound sources distant from the measurement position and not usually recognizable as individual noise sources. The prevalent source of this residual noise is distant street traffic. L99 and L90 are not strongly influenced by occasional local motor vehicle passbys. However, they can be influenced by stationary sources such as air conditioning equipment.

- L50 represents a long-term statistical median noise level over the measurement period and does reveal the long-term influence of local traffic.
- L10 describes typical levels or average for the maximum noise levels occurring, for example, during nearby passbys of trains, trucks, buses and automobiles, when there is relatively steady traffic. Thus, while L10 does not necessarily describe the typical maximum noise levels observed at a point, it is strongly influenced by the momentary maximum noise level occurring during vehicle passbys at most locations.
- L1, the noise level exceeded for 1% of the time is representative of the occasional, isolated maximum or peak level which occurs in an area. L1 is usually strongly influenced by the maximum short-duration noise level events which occur during the measurement time period and are often determined by aircraft or large vehicle passbys.

SECTION 17 - RAIL YARDS AND RAIL SHOPS

17.1 GENERAL

This design criteria include design requirements for yards and shops for the Washington Metropolitan Area Transit Authority Metro Rail System. The yards will store the rapid transit trains, provide a storage area for the system maintenance and support the shops. The shops will perform repair, maintenance, and inspection services for the individual transit cars. Car cleaning will be performed in the yards.

17.2 SHOPS

17.2.1 Transit Car Maintenance Philosophy

Efficient operation of the Metro Rail System requires the availability of a completely reliable service fleet of revenue cars sufficient to maintain scheduled service, while minimizing the total number of cars required. In order to accomplish this goal, maintenance operations will be divided into routine maintenance and major repair operations.

Routine maintenance, sometimes referred to as preventative maintenance involves the detection and resolution of minor maintenance problems before the malfunction either necessitates major overhaul of the transit car or causes a breakdown in service. Running repairs also are to be included in routine maintenance.

Major repair operations, sometimes referred to as heavy or specialized maintenance, involves complete rebuilding of cars, change out of major components, and major repairs. Modifications and retrofitting of new cars are to be included also.

The diverse natures of equipment and manpower requirements for these two types of maintenance make it desirable to separate the shop facilities at which these operations are performed. Routine maintenance work will be performed at Service and Inspection Shops, referred to hereafter as S&I Shops, and heavy or specialized maintenance work will be performed at a Major Repair Shop. The design of the shops shall be coordinated with the design of the yards to insure the various functions and yard layout requirements are provided.

The following comparisons of work items and equipment illustrate some of the differences in the maintenance activities of the two shops:

SERVICE AND INSPECTION SHOP

a) Cars are handled as married pairs.

b) Unit parts and components are replaced.

c) Running repairs are made when major disassembly of parts is not involved. Truck work may been an exception to this item.

d) Portable hand tools are the workman's primary aid with few machine tools.

e) Majority of work is on-car requiring relatively small work support areas.

f) Complete cars are rapidly cycled.

g) Lubricants are replenished during servicing procedure.

MAJOR REPAIR SHOP

a) Cars may be handled as single units.

b) Unit parts and components are rebuilt or repaired.

c) Major repairs are made when disassembly of unit pairs or major components are involved.

d) Extensive use is made of machine tools.

e) Majority of work is on major components requiring a relatively large support area.

f) Components are methodically routed through rebuilding process.

g) Lubricants are completely replaced during rebuilding procedure.

17.2.2 Service and Inspection Shops

The shop shall be designed to facilitate the performance of scheduled inspection, minor repair, interior/exterior car cleaning, major truck repair, body repair and painting. The shop layout shall provide for segregation of work functions into designated areas to minimize interference with other functions and time lost in material handling. Aisles shall be kept clear of fixed equipment to allow free flow of materials. The layout shall be based on servicing 75 foot transit cars coupled into 150 ft. married pairs.

17.2.3 Major Repair Shop

The System has two major repair shops, designed to accommodate the following functions:

17.2.3.1 Complete car overhaul, including body repair and painting.

17.2.3.2 Exchange of trucks.

17.2.3.3 Replacement, repair, overhaul and testing of car system components and subassemblies.

17.2.3.4 Extensive modifications.

17.2.3.5 Wheel truing.

17.2.3.6 Repair of miscellaneous system equipment.

17.2.3.7 New car acceptance and preparation.

17.2.3.8 Spare parts storage.

These tasks are oriented toward the rebuilding of complete cars or replacement of entire components and as such will require extensive periods of time. Consequently, the Major Repair Shop will be designed to service individual car operating units rather than complete trains. Accommodations to service at least 5% of the total system car fleet simultaneously are to be provided.

To accommodate staged construction of the WMATA transit system, the major repair shops were designed to incorporate a service and inspection a shop which shall accommodate three two-car units per inspection track.

17.3 YARDS

Yards for the Metro system shall satisfy two basic functions: Storage of trains for operations and support of the shops. Basic to the design of train storage facilities are the desires to minimize reverse movements and non-revenue car mileage, to optimize introduction to and removal of trains from revenue service, and to facilitate changes in train consists during different operating periods. In the design of yard layouts consideration shall be given to the maintenance facilities and equipment required in each yard and to the operation of each yard as it fits into the operating program of its division. Adequate visual and acoustical protection for the area surrounding the yard shall be developed during the design of the yard.

17.3.1 General

Yards are divided into two types according to the functions which are to be performed. These are Storage Yards, and Service and Inspection Yards.

The following criteria shall be met in the design of all yards:

17.3.1.1 The length of car storage tracks shall be designed in multiples of two car modules with the desirable minimum capacity of eight cars.

17.3.1.2 A facility shall be provided for supervisory and yard and train operating personnel. This facility shall have a reporting and dispatching area and locker space.

17.3.1.3 Listed below is a summary of horizontal and vertical track alignment and turnout data for use in yards.

17.3.1.3.1 All curves are to be simple curves, not requiring spiral transitions.

17.3.1.3.2 The absolute minimum radius of a curve shall be 300 feet and the desirable minimum radius of a curve shall be 350 feet.

17.3.1.3.3 1" superelevation is desirable in curves with a radius approaching the minimum radius for frequently used tracks, such as the yard entrance tracks and the yard loop tracks. Superelevation transition is to be accomplished in the first 50 feet and last 50 feet of the curve.

17.3.1.3.4 Single ended storage tracks shall be sloped downward from the yard throat to the bumping post.

17.3.1.3.5 Double ended storage tracks shall have a sag in their profile to prevent transit cars from rolling to either end.

17.3.1.3.6 All tracks connecting with the mainline shall slope downward from the mainline unless otherwise approved by the Authority.

17.3.1.3.7 Yard and secondary tracks shall have a maximum grade of 1.0 percent, and a minimum grade of 0.35 percent, except the desirable maximum grade on storage tracks shall be 0.2 percent downward towards the bumping post.

17.3.1.3.8 Separate car wash buildings shall have a 0.35% gradient upward in the direction of washing.

17.3.1.3.9 A flat gradient shall be used for S&I Shop Building and its lead tracks.

17.3.1.3.10 Connections from main track to yard and secondary track shall be by No. 10 turnout.

17.3.1.3.11 Connections between the yard, secondary and storage tracks shall be No. 6 Guarded turnouts, No. 8 turnouts and No. 10 Crossovers.

17.3.1.3.12 It is desirable for storage and transfer tracks to be on tangent alignment. Curve alignment of the storage or transfer tracks shall require approval of the Authority.

17.3.2 Storage Yards

The principal function of a storage yard is to store trains for operations with facilities provided for exterior and interior car cleaning. Secondary functions of a storage of maintenance equipment and possibly for developing a building which can be used for the performance of system maintenance services.

In addition to the general yard criteria, the following are specific requirements that pertain to storage yard layouts:

17.3.2.1 Yards shall be designed to allow eight-car trains to enter and exit under automatic train operation through the use of transfer tracks.

17.3.2.2 The transfer check shall have direct access to the mainline and shall be segregated from but provided direct access to the storage tracks. To simplify interface with ATO the special trackwork involving both yard and central control should be minimized. The transfer zone shall be a minimum of 650 feet long with a preferred length of 700 feet.

17.3.2.3 For stub ended storage tracks, a 2-ft buffer must be provided between the coupler of the rail car and the front face of the bumper.

17.3.2.4 The storage tracks shall be constructed at alternating track centers of 14 feet minimum and 18 feet to permit access to cars by personnel and equipment. Each storage track's third rail shall have the capability of being independently electrically isolated. Limited air rights facilities can be accommodated with these track centers.

17.3.2.5 There shall be a Yard Operations Building of sufficient size to accommodate the following:

17.3.2.5.1 Yard Office and first aid room.

17.3.2.5.2 Reporting and dispatching area for operating personnel.

17.3.2.5.3 Building mechanical equipment room.

17.3.2.5.4 Lunchroom.

17.3.2.5.5 Locker and wash rooms for operating personnel. Additional facilities shall be provided for car cleaning personnel when the building is located in the end of the car storage tracks.

17.3.2.5.6 Shower rooms.

17.3.2.5.7 Communications equipment room.

17.3.2.5.8 Train control equipment room.

17.3.2.5.9 Electrical equipment room.

17.3.2.5.10 Small parts storage for transit cars.

17.3.2.6 There shall be a Yard Control Building of sufficient size to accommodate the following:

17.3.2.6.1 Yard Control Tower.

17.3.2.6.2 Train control equipment room.

17.3.2.6.3 Communications equipment room.

17.3.2.6.4 Electrical equipment room.

17.3.2.6.5 Building mechanical equipment room.

17.3.2.6.6 Technician's shop and tool room.

The Yard Control Building shall be placed in such a location as to provide the Control Tower maximum visual contact with the Yard Throat and storage tracks and to minimize the lengths of train control cable required in the yard.

17.3.2.7 A maintenance and storage area shall be provide to facilitate the performance of system maintenance services.

17.3.2.8 A sufficient parking area(s) shall be provided to accommodate employee and maintenance vehicles.

17.3.2.9 An emergency repair track of eight car lengths shall be provided for emergency repair of transit cars, with provisions to remove power from the third rail.

17.3.2.10 A double ended 400-foot track or two 200-foot stub-end tracks shall be provided for storage of maintenance equipment. This track is to be equipped with a third rail and a switch to remove power.

17.3.2.11 A substation building shall be located near the throat of the yard to minimize the length of traction power cable required.

17.3.2.12 Tie breaker stations shall be located near the special trackwork as required.

17.3.2.13 A platform at car floor height shall be placed across the end of the stub-end storage tracks with fingers extending between alternate tracks. To facilitate WMATA operating requirements this platform must allow unobstructed locking / unlocking and safe entry/ exit through the full first car door opening. The finger platform shall extend a minimum length of 19'-0" beyond the bumping post. The distance from face of uncompressed bumping post to end of track is given in Section 11.10.4.

A canopy shall be constructed over the platform and the fingers. An enclosed storage facility accessible to the platform shall be provided for transit car cleaning equipment. Steps shall extend from the platform to walkways between all tracks.

17.3.2.14 An enclosed building of approximately 30 feet by 350 feet shall be provided. The building shall accommodate an exterior car washing facility and a 160 foot open inspection pit for making emergency inspections and repairs of rapid transit cars. The exterior car wash shall have access from the transfer tracks to the storage yards without requiring a reverse movement of rapid transit trains. A minimum clear lead distance of 650 feet on each end of the exterior car wash building is desirable so that the exterior washing operation will not interfere with other operations of the yard. The building shall be located on tangent track. There shall be provision to remove power from the third rail section through the building which shall be controllable from within building.

17.3.3 Service and Inspection Yards

A Service and Inspection Yard shall be made up of a Service and Inspection (S&I) Shop and a storage facility for rapid transit cars. The Service and Inspection Yard requirements are similar to those of the Storage Yard except that the building enclosing the exterior car washing facility and inspection pit and the eight-car emergency repair track are to be deleted since these operations will be performed within the S&I Shop. Equipment rooms for the Yard Control Building, listed in 2.e., may be consolidated with similar S&I Shop facilities.

Some additional requirements for an S&I Yard are as follows:

17.3.3.1 Direct access to S&I Shop entrance from the transfer tracks shall be provided so that transit cars can be moved directly into the shop for exterior washing, inspections and running repairs.

17.3.3.2 The car capacity of the shop entrance and exit lead tracks shall be as shown in Figure 17.1.

17.3.3.3 The shop exit tracks shall have access to car storage tracks and to transfer tracks without interfering with normal shop operations. This will assure an efficient flow of cars out of the S&I Shop.

17.3.3.4 A bypass track shall be provided to facilitate easy access to either end of the S&I Shop and to minimize interference of yard operation with shop operation.

17.3.3.5 Entrance to the S&I Shop from the storage yard shall be designed with a minimum of necessary reverse movements of the transit cars.

17.3.4 On-Line Emergency Storage

On-Line Emergency Storage will provide a short-term emergency storage facility for malfunctioning cars.

On-Line Emergency Storage shall be designed to mainline alignment and grade standards, with the desirable minimum capacity of eight cars per track. At terminal stations where emergency storage tracks are to be provided the storage tracks shall be located beyond the point of safe braking distance so that automatic train operation can be maintained. The emergency storage tracks shall be sloped downward from the station platform.

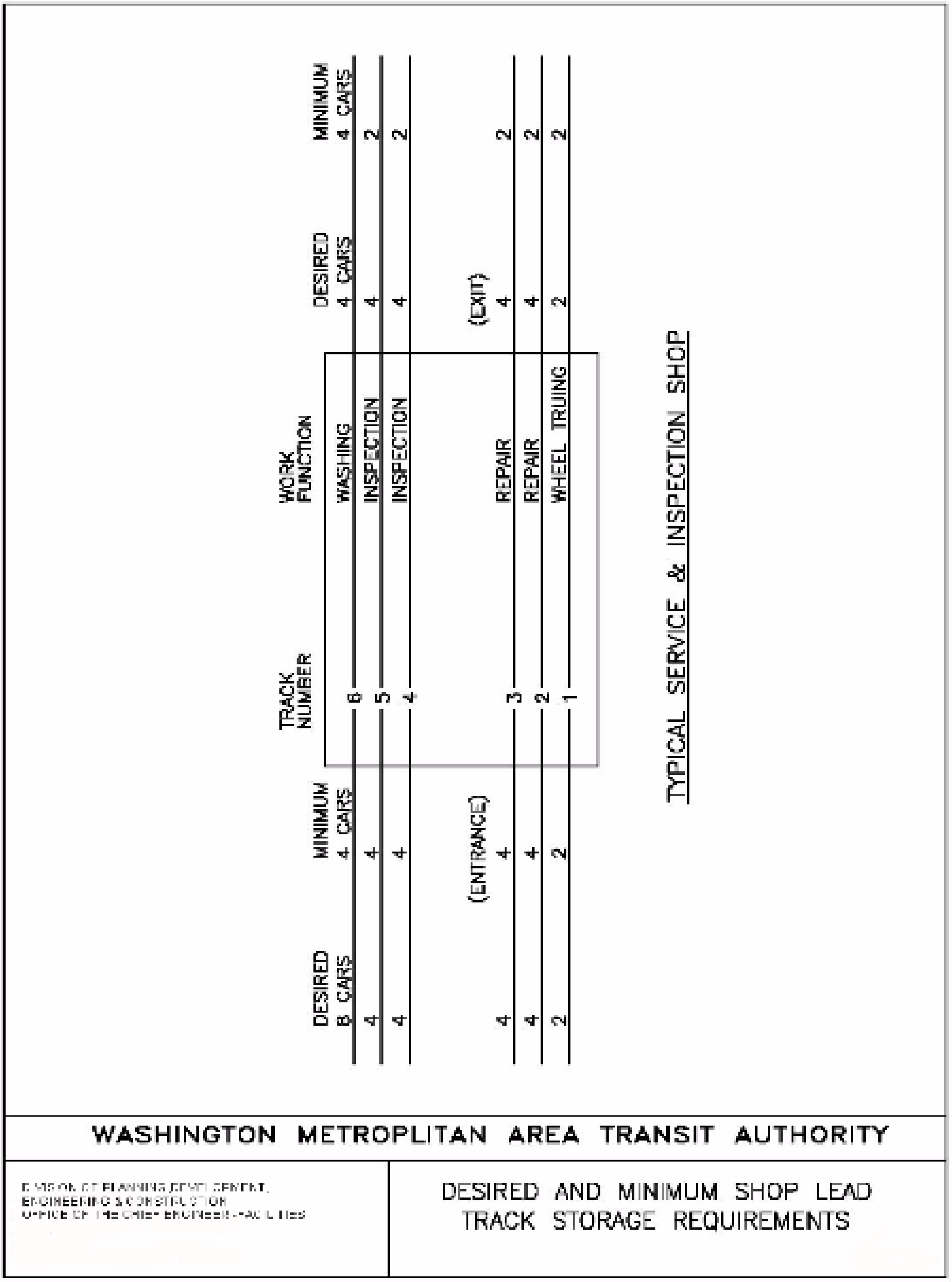

DESIRED
8 CARS
MINIMUM
4 CARS
(ENTRANCE)
TRACK
NUMBER
WORK
FUNCTION
DESIRED
4 CARS
(EXIT)
MINIMUM
4 CARS
6
5
4
3
2
1
WASHING
INSPECTION
INSPECTION
REPAIR
REPAIR
WHEEL TRUING
TYPICAL SERVICE & INSPECTION SHOP
WASHINGTON METROPLITAN AREA TRANSIT AUTHORITY
DESIRED AND MINIMUM SHOP LEAD
TRACK STORAGE REQUIREMENTS

FIGURE 17.1

SECTION 18 - BUS SERVICE AREA

18.1 GENERAL DESIGN CONSIDERATIONS

18.1.1 Bus servicing is performed as a daily routine that includes fare removal, refueling, interior and exterior cleaning and some minor maintenance/fluid checks. Smooth operation of the bus servicing facilities is one of the most important functions of the entire maintenance facility because it has a direct impact on time and schedules. Service lanes must facilitate as quick a turnaround time as possible. The location and layout of all items within the service area is critical in accomplishing this goal. The following section will provide general guidelines toward that end, with the understanding they should be customized as required by the unique aspects of the specific maintenance facility under consideration.

18.1.2 The service lanes should be flexible enough to handle all the different models and sizes of buses in the existing fleet, as well as what is anticipated for the future. It is imperative to obtain and understand this information before designing the service area.

18.1.3 The service lanes should be immediately accessible upon entering the maintenance facility. The order of operation is:

18.1.3.1 Queuing

18.1.3.2 Fare removal

18.1.3.3 Fueling and minor maintenance/fluid checks

18.1.3.4 Interior cleaning (usually done at the same time as fueling service)

18.1.3.5 Exterior cleaning

18.1.4 Since fueling and washing take approximately the same amount of time, a linear (in-line) design configuration provides the greatest efficiency of operation. In this design, buses can be refueled while the previous bus is being washed. The linear configuration is WMATA's preferred design for service lanes.

18.1.5 While WMATA's preferred standard facility houses the service lanes and maintenance area in the same building, the linear design allows for the entire servicing lane operation to be housed in a separate building from the maintenance operation if, because of site issues, that juxtaposition is deemed appropriate. Another variation used by some transit operations is to completely segregate washing from the other service lane activities. In the linear configuration, service lanes can act like wind-tunnels. Spray from washers can blow back through the servicing area, making an unpleasant working environment in cooler weather. Serious consideration should be given as to which of these variations is appropriate dependent upon wind and weather conditions, the specific site configuration and the specific operational requirements of the individual facility under design.

18.1.6 The number of service lanes required is determined by a combination of the total number of buses serviced by the facility and the amount of time allocated to this activity. To assist in this determination, it should be noted that based upon an operational average of six (6) minutes to wash a bus, ten (10) buses in one lane can be washed in one (1) hour. As a general planning rule, one (1) service lane can service one hundred (100) buses per day. Additionally, one (1) "spare" service lane shall be provided for each facility. This "spare" lane will be used for fare removal, fueling, fluid checks, and interior cleaning. The "spare" lane shall also be provided with adequate utility services to accommodate a future bus wash system.

18.1.7 Consideration should be given to providing an exterior by-pass lane that by passes the service lane when servicing is not necessary.

18.1.8 Fast actuating rollup doors should be used for service lane entrance and exit doors.

18.2 SERVICE LANE QUEUING

18.2.1 From Storage: Bus servicing can be initiated in one of two ways. The way chosen is both an operational decision and a design decision. The first way is retrieval of a bus by a hostler (facility personnel who are responsible to retrieve buses for servicing and maintenance operations and then return them to their designated parking storage locations) from a parking space where it was left by an operator at the end of his work shift. This parking space may be in the storage bays or an exterior staging area. The buses are then systematically serviced during off-peak hours. No bus awaiting service in this arrangement should extend into a street.

18.2.2 Immediate Queuing: The second way for bus servicing to be initiated is the bus operator bringing the bus directly to the maintenance facility for immediate servicing at the end of his work shift instead of to a parking area. This requires more queuing space directly on-site than retrieving buses from parking areas for servicing during off-peak hours. This space shall be exterior to the building, and should be of sufficient space to allow for peak-hour queuing. No bus awaiting service in this arrangement should extend into a street.

18.3 FARE REMOVAL

18.3.1 WMATA System: The WMATA system for fare collection is:

18.3.1.1 To have the fare removal as the first step of the service lane operation and,

18.3.1.2 To have the fare box removed from the bus and placed inside a fare box collection unit, the money is removed, the empty fare box is immediately replaced in the bus, and the bus continues on for service.

18.3.1.3 2 CCTV camera/vault.

18.3.2 Fare Box Maintenance Area (Electrical Shop): A Fare Box Maintenance Room, shall be located parallel to the fuel dispensing station. The Fare Box Maintenance Room shall be a secured minimum 20’ x 20’ space and shall be separated with a masonry wall for security reasons. All windows in the Fare Box Maintenance Room shall have bullet-resistant glass and should be alarmed. Access doors should also be alarmed for security reasons. The room shall be provided with sufficient work benches, electrical power for computers, security camera, lighting, HVAC, electrical resistance heaters and test equipment.

18.3.2.1 Fare box collection equipment will be purchased and installed per WMATA requirements as the bus maintenance facility is constructed. Adequate space, power service and data service shall be provided. Coordinate specific requirements with WMATA.

18.4 FUELING AND MAINTENANCE FLUIDS/UTILITIES

18.4.1 Fueling: Each service lane shall have it’s own diesel fuel dispensing system, which shall be connected to the fluid monitoring system.

18.4.1.1 The fuel dispenser in the service lane shall not be located further than 50 feet from the building entrance, per NFPA 30A.

18.4.1.2 Fueling Hose and Nozzle (Revenue Vehicles): A flexible 1 inch hose and fueling nozzle with swivel feature, which operates only when connected to an adapter on the vehicle, eliminating spills and reducing odors. Include hose rest hooks to accommodate extra length hose. Nozzles shall be 8 inches long.

18.4.1.3 Overhead Tramway Fueling System: This system is an overhead suspended fueling hose and post mounted support system which allows all fleet vehicles to be refueled with one nozzle within a 20’-0” fueling envelope length, and with spill-proof separation feature in the event the refueling vehicle moves away from the fuel island with the nozzle still attached. Install with 12’-0” minimum clear height and 4’-0” from edge of fueling lane, unless otherwise indicated. Included with the system shall be one (1) stainless steel 24” desk top, which is mounted on one of the support posts.

18.4.1.4 Fuel Dispensing Pump: This is a traditional mechanical registration type dispenser, and accommodates twin hoses as required by WMATA. One for revenue vehicles and one for non-revenue vehicles, which shall be fitted with a standard fueling nozzle. Include provisions for connection to fluid management system, filter and vapor recovery.

18.4.1.5 Controls: The transfer of diesel fuel from storage tanks to the dispensers shall be regulated from one of two control cabinets. The main control cabinet shall be located as directed by WMATA. A remote control cabinet shall be located in the fueling area. This cabinet shall include a “mushroom” panic button to shut down the system in case of emergency. Level indication should be here also.

18.4.1.5.1 The main control panel shall be self-contained and shall include the following:

18.4.1.5.1.1 Starters and circuit breakers

18.4.1.5.1.2 H-O-A switches for each pump

18.4.1.5.1.3 Test switches

18.4.1.5.1.4 Running lights – indicators for each pump

18.4.1.5.1.5 Required switches for the remote control panel

18.4.1.5.2 The remote control panel shall include running light indicators, selector switch and low tank level indicators.

18.4.2 Storage Tanks

18.4.2.1 Underground Storage Tanks

18.4.2.1.1 The diesel gasoline and other fluid systems shall conform to the latest requirements of the N.F.P.A., the EPA, CENF, and all state and local codes, including the District of Columbia Fire Department. All underground fuel and fluid storage tanks shall be located outside the building. While an underground location is preferable from a safety and security perspective, the environmental implications must be considered. WMATA’S facilities typically utilize underground tanks for all fuel and fluids except, where possible, above ground storage tanks are used.

18.4.2.1.2 Gasoline fuel is prohibited by N.F.P.A. from being stored or dispensed inside the building.

18.4.2.1.3 A popular storage capacity in the past was 150 – 200 gallons per bus which would be equivalent to four to six days of normal operation for buses realizing 5 miles per gallon. Economics and today’s fuel situation has altered that parameter. The following are average storage capacities for a 150 bus maintenance facility:

18.4.2.1.3.1 Diesel Fuel 2 – 20,000 Gallon Storage Tanks

18.4.2.1.3.2 Engine Oil 2 – 3,000 Gallon Storage Tanks

18.4.2.1.3.3 Automatic Transmission Fluid1 – 6,000 Gallon Storage Tank

18.4.2.1.3.4 Engine Coolant1– 6,000 Gallon Storage Tank

18.4.2.1.3.5 Gasoline (Non-Revenue Vehicles)1 – 8,000 Gallon Storage Tank

18.4.2.1.4 All fuel and fluid storage tanks shall be constructed of double-wall fiberglass in accordance with UL 1316, and shall be connected to the fluid monitoring system (See Section 18.7.). All piping shall enter the tank through a man way. Each tank shall be provided with the following:

18.4.2.1.4.1 Two watertight man ways

18.4.2.1.4.2 Mechanical high level cut-off valve

18.4.2.1.4.3 Interstitial and man way leak detection

18.4.2.1.4.4 Positive displacement flow meter.

18.4.2.1.4.5 Inventory control and high level alarm systems

18.4.2.1.4.6 Fill cap with 15 gallon, below grade catchment basin vent connections

18.4.2.1.4.7 Overfill prevention (fill limiter valve and audible alarm)

18.4.2.1.4.8 Individual service access for all functions.

18.4.2.1.5 Roadway manhole covers over the man ways shall be constructed of fiberglass and have an H-20 rating. The covers shall be configured to prevent water entry.

18.4.2.1.6 The leak detection system shall be connected to an audio visual alarm at a 24-hour manned location. The over-fill alarm shall be connected to an audio visual alarm mounted near, and in sight of, the fill box.

18.4.2.1.7 Buried tanks containing petroleum products (diesel, gasoline, oil, etc.) shall be within a structure that prevents any transfer of surface loads to the fiberglass tanks. The District of Columbia Fire Department or other authorities outside of the District shall approve the design and inspect the installation.

18.4.2.1.8 Underground storage tanks containing flammable or combustible liquids shall be buried not less than 2 feet below grade. Underground storage tanks shall be located a sufficient distance from the facility per applicable code, Fire Marshall and Insurance carrier requirements.

18.4.2.1.9 The underground storage tanks shall be vented separately to the exterior. The vent shall discharge not less than 12 feet above the adjacent ground level and terminate with a vent cap to minimize the effect of weather and air borne dirt. The vent discharge point shall not be closer than 15 feet from any operable building opening or outside air intake.

18.4.2.1.10 All underground piping shall be double-wall fiberglass, sloped toward the tank. Piping that cannot be sloped shall be provided with a point type or long line leak detection system. Fill lines shall be provided with flow meters and spill containment with a hinged roadway cover. The flow meter shall have remote readout mounted in the Superintendent’s office.

18.4.2.1.11 Underground storage tank areas shall be paved over so delivery trucks have easier access and do not block bus circulation.

18.4.2.1.12 Pumping System: One submersible pump shall be provided with each storage tank. The diesel fuel pumps shall be manifolded and shall be connected and valved so that each pump may feed any or all of the diesel fuel dispensers. A filtration system consisting of dual filters and a water separator shall be provided in each fuel dispenser line. An emergency, mushroom style, shunt-trip switch shall be located on the facility wall such that in the case of an emergency power will be cut to all underground storage systems. The emergency shut-off switch will be located not greater than 75 feet from the dispensers. The diesel pumps shall have a capacity of 50 GPM and the gasoline pump (if required) shall have a capacity of 10 GPM.

18.4.2.2 Above Ground Storage Tanks.

18.4.2.2.1 If above ground storage tanks are used for maintenance fluids (not including diesel fuel), and are located within the building, they shall be located in a 2-hour rated lubrication room. The amount of fluid stored in this room shall not exceed 10 gallons per square foot. This room shall not exceed 500 square feet in area and shall have the floor slab depressed a minimum of 4” from the surrounding floor slab. All joints in this room must be fluid-tight. In lieu of a 2-hour room, 2-hour rated tanks, UL rated 2085, may be used, if allowed or if required by the local fire Marshall and code officials.

18.4.2.2.2 All above ground fuel and fluid dispensing piping shall be schedule #40, black steel. Fitting and valve classification shall be as appropriate for the pump discharge pressure plus 25% but in no case less than class 150. All above ground fuel and fluid dispensing piping shall be painted in accordance with WMATA's standard color code. The fuel and fluid dispensing piping shall be further identified with plastic pipe markers, which will also indicate the direction of fluid flow.

18.4.2.2.3 Maintenance fluids typically stored in the building in above ground tanks would be engine coolant, automatic transmission fluid, new engine oil and used engine oil. These tanks would be connected to the overhead service reels. The remaining maintenance fluids would typically be stored in multiple 55-gallon drums on spill-pallets. These would be chassis grease, gear oil, windshield washer fluid, and wheelchair oil. These drums would be connected to the overhead service reels.

18.4.2.2.4 Used oil recovered from the buses shall be stored in an above ground used oil storage tank of minimum 2000 gallon capacity. The tank shall be double wall steel with a corrosion resistant coating and a 2 hour fire rating (UL 2085). The tank unit shall include primary tank, secondary containment chamber, leak detection system, vent, pump, suction tube, discharge hose and shall be furnished with roll collection caddys. The tank and fittings shall conform with NFPA 30, 30A and UL requirements.

18.5 OVERHEAD SERVICE REELS

18.5.1 The following maintenance fluids and utilities shall be provided by means of properly labeled overhead service reels at each fueling station in the service lane:

18.5.1.1 Engine coolant (EC)

18.5.1.2 Automatic transmission fluid (ATF)

18.5.1.3 Compressed air (CA)

18.5.1.4 Engine oil (EO)

18.5.1.5 Water

18.5.1.6 Chassis grease (CG)

18.5.1.7 Gear oil (GO)

18.5.1.8 Windshield washer fluid (WWF)

18.5.2 Overhead service reels shall be of heavy duty double pedestal frame design, spring powered and self-retracting constructed from non-sparking alloy for use in fueling environments. .

18.5.3 Hose

18.5.3.1 CA & WWF - 65' x 3/8" ID 300 psi pressure rating

18.5.3.2 GO, ATF & EC - 50' x ½" ID 2000 psi pressure rating

18.5.3.3 CG - 50' x 3/8" ID 4000 psi pressure rating

18.5.4 All piping shall be as described previously in Section 6.13.2.2 for above ground storage tanks.

18.5.5 All fluid transfer pumps for overhead service reels shall be air driven, self-priming positive displacement pneumatically operated pumps. Provide pumps capable of mounting on top of 55 gallon drums where used. Provide controls to automatically start and stop pumps when fluid is required at the overhead service reels. All pumps to operated below OSHA noise standards.

18.6 CLEANING

18.6.1 Bus Interior Cleaning

18.6.1.1 Methods / Equipment

18.6.1.1.1 In the linear (in-line) service lane design, the interior cleaning of the buses is done as part of the service lane operation. This interior cleaning is done by means of a 4” diameter hose vacuuming system, and is done at the same time the bus is being fueled.

18.6.1.1.2 Portable air blowers are used by the workman to sweep the seats and floor to dislodge dirt, papers and other debris which will be drawn into the vacuum hose and deposited into a portable dumpster. The transportation air then passes thru a secondary filter to remove particulate matter prior to its return to the building space.

18.6.1.1.3 The Vacuum shall be designed to provide for the collection of debris in dry form and discharge after compaction of same into a loading dumpster of the type presently used. Provisions shall be made for minimizing the exhaust of dust inside the building through double filtration. 100% of the air input shall be returned to the garage area.

18.6.2 Bus Exterior Cleaning

18.6.2.1 Methods and Equipment Options

18.6.2.1.1 Bus washing is the final element of the service cycle prior to parking the bus in its storage space. Preferably there is one bus washer unit per service lane. One washer unit may serve more than one service lane, but adequate space must be provided to by-pass or line up a bus for the washer. If fewer washers than service lanes are provided, the lanes without washers should be provided with piping and wiring to accommodate the addition of a future washer unit.

18.6.2.1.2 Provide the bus washer as part of the service lane operation and to provide one washer unit per individual service lane.

18.6.2.1.3 There are several alternatives available in regard to type and operation of bus washers. Minimum Automatic Washers have a rotating brush and water spray side-washing capability. Complete automatic washers have additional front and rear capability with rotating brushes that move across the front and rear as the bus progresses through the device. The roof washer is usually a wet mop, however, a rotating brush is available. Wheel washers consisting of a high pressure water spray are sometimes used.

18.6.2.1.4 There are two types of automatic bus washer systems commonly available, the Drive Thru type and the Gantry type. The Drive Thru System is the type generally used at a service island. Following fuel servicing and vacuum cleaning, the bus is driven slowly thru the washer. Upon leaving the washer, if a stripper has been made part of the system, it will dry off the bus with high velocity air prior to the bus being parked**.**

18.6.2.1.5 When a Gantry System is employed, generally for fleets with 35 buses or less, the bus is driven to the Gantry location and parked between guide rails. Adjacent to the guide rails is tracks on which the Gantry travels. Adjacent to the tracks is usually a wall on which a traveling umbilical is mounted which supplies air, electric and water to the Gantry. The Gantry contains side and top brushes. When the start button is pushed, the top brush lowers itself to a position a few inches above the floor and the machine moves toward the vehicle traveling along the tracks. The Gantry moves along the length of the vehicle with the vertical brushes cleaning the sides and the top brush cleaning the front, roof and back of the vehicle. During this cycle water and soap are sprayed on all surfaces. On its return pass the vehicle is rinsed with fresh water while the brushes counter-rotate. At the end of the rinse cycle all brushes automatically move aside to allow the vehicle to be drive away.

18.6.2.2 Drive Through Bus Washing System and Equipment: The drive thru type with a blower/dryer assembly and water reclamation system shall be as follows**:**

18.6.2.2.1 Operations: Washer components shall be automatically actuated in sequence by vehicles, primarily transit buses, driven in centered path between tire guides, at a nominal speed of 1.0 to 1.5 feet per second through wash washing stage without stopping. Entry shall be through a pumped pre-wetting/detergent application cycle, progressing through a brush washing cycle which shall effectively scrub all vertical body surfaces of front, sides and rear of vehicles including windshield and windows, using a minimum of four vertical rotary brushes, each equipped with detergent spray applicators. Effective washing of the horizontal and curved portions of the vehicle roof shall be by a full width oscillating mop augmented by a detergent spray applicator. Final rinse of the front, roof, sides, rear and wheels shall be by a canted rinse spray assembly. All equipment including piping, conduits, support devices, etc contained in this area or routed through this area to be of corrosion resistant material.

18.6.2.2.2 Major Components: Complete system shall include the following major components.

18.6.2.2.3 Automatic Controls: Vehicle actuated switch gear including prewired electric control panel and manual override controls. The bus wash shall be operated through an operator interface touch panel (HMI). The panel shall be connected to the WMATA Local Area Network for remote monitoring, alarm notification, and connectivity to the building information system. The HMI shall contain screens for diagnostic and analytical purposes to include but not limited to: all elements that automatically stop the operation of the system, pump or equipment run times for each pump, rotating brush etc., total number of successful wash cycles and number of incomplete cycles, number of successful cycles per day, gallons of water used and gallons of water discharged, gallons of detergent used, alarms or warnings for filter and backwashing status, event manager logs for every input.

18.6.2.2.4 Tire Guides: Full length, one pair min. 4" dia. tubular galvanized steel with capped ends and no breaks or edges which could damage tire sidewalls.

18.6.2.2.5 Skid Plates: One pair, flat 3/16" stainless steel mounted flush to slab. Angled entry section of tire guide shall minimize tire sidewall damage caused by resistance to lateral movement resulting from misaligned entry to vehicle washer. Plates to be nominally 3 feet wide tapering with tire guide angled to 2 feet wide at entrance to straight section of tire guides.

18.6.2.2.6 Pre-wetting/Detergent Spray Arch Assembly: Automatic, frame mounted, freestanding unit, positioned to provide optimum detergent penetration before brush wash cycle begins. Side nozzle pipe assemblies shall be canted away from approaching bus to provide sequential application of detergent starting at bottom and progressing to top of bus. Nozzle total output to be 20 gallons per minute at 40 psig and shall be of the quick disconnect type for easy removal for cleaning and replacement. Lowest point on each pipe to be fitted with valve to allow pipes to be fully drained during freezing conditions. Liquid detergent shall be stored in a 500 gal. poly tank.

18.6.2.2.7 Oscillating Mop: Roof mop assemblies shall be suspended from two separate frames supporting three mops each. Mops to be mildew resistant Ozite type carpet hung from galvanized steel frame. Each frame shall be hung by 2 pieces of Goodyear four ply conveyor belting (12000 lb combined pull strength). Sprays shall supply 20 gallons per minute at 100 psig lowest point to be fitted with valve for draining. High pressure spray at 90 gpm and 200 psig shall be angled to hit the fronts, hoods, wheels and windshields of the vehicles.

18.6.2.2.8 Vertical Brushes: Washing of bus vertical surfaces shall be by four electrically driven rotary brushes with integral detergent spray and supporting frame assembly. The brush yoke arm shall be curved to allow clearance for the extreme corners of the bus during the washing motion. All brush shaft and brush yoke bearings shall be protected from moisture. Movement of brush arm shall be by pneumatic cyclinders, brush yokes shall retract when power is off, permitting unobstructed vehicle passage through wash lane.

18.6.2.2.9 Rinse Spray Arch: Automatic frame mounted, free standing, fresh water unit.

18.6.2.2.10 Washer Equipment Miscellaneous: Brush yokes, support structure, columns, base plates, anchor bolts, pump, detergent storage tanks and detergent distribution system.

18.6.2.2.11 Radiant heated concrete floor slab from end of bus wash equipment to exit door. Exit shall be designed in order to reduce or eliminate ice buildup on slab.

18.6.2.2.12 Water Reclamation System: As follows:

18.6.2.2.12.1 Waste water run-off from the bus washer is collected in a reticulent drain, under and parallel to the bus, and is directed to a sump-well in which grit settles out of the liquid. A pump transfers this liquid to a separate adjacent storage-well through a filter that removes most of the suspended impurities. This clarified water is then pumped back to the bus washer by a separate hi-pressure pump for reuse in the wash cycle. Fresh water make-up is provided by the final rinse arch. Also, additional fresh water is added to the clarified water in the storage well to account for water lost by evaporation and carried away by the vehicle. A separate storage-well and pump system is provided for the wheel washer system. Provide closed tanks and water recirculation to control odor accumulation.

18.6.2.2.12.2 The bus washes and water reclamation system shall be controlled through a central HMI panel located in the Water Reclamation Area. Bus wash shall be part of the building monitoring system.

18.7 FLUID MONITORING SYSTEM.

18.7.1 The bus garage will be furnished with a fluid monitoring and leak detection system. The System shall monitor all storage tank levels and fluid usage. The monitoring system shall be computer based capable of providing but not limited to high and low level alarming, leak detection alarming, vehicle usage and mileage reports, vehicle bar code identification, pump/meter usage reports, product reports, time and date reports, inventory, inventory reconciliation and tank levels, and fleet reports. The system shall also be capable of providing remote access to allow the downloading of all the reports.

18.7.2 The system design shall be based on the Veeder Root TLS-PC system and supporting monitoring consoles and software. In addition to the level and metering devices the system shall be furnished with a personal computer, modem, report printer, Windows® based software and a stand-alone monitoring consoles. All of the computer related devices and software shall be the most recent technology and releases.

18.8 TYPICAL SERVICE LANE DESIGN

18.8.1 Typical Plan Layout With Critical Dimensions: Refer to Figure 18.

18.8.1.1 Design Considerations

18.8.1.1.1 Dimensional Criteria

18.8.1.1.1.1 Drive Lane Between Curbs: 12'-0" Minimum**.**

18.8.1.1.1.2 Width of island between drive lanes if only fueling equipment is located on it: 6'-0" minimum.

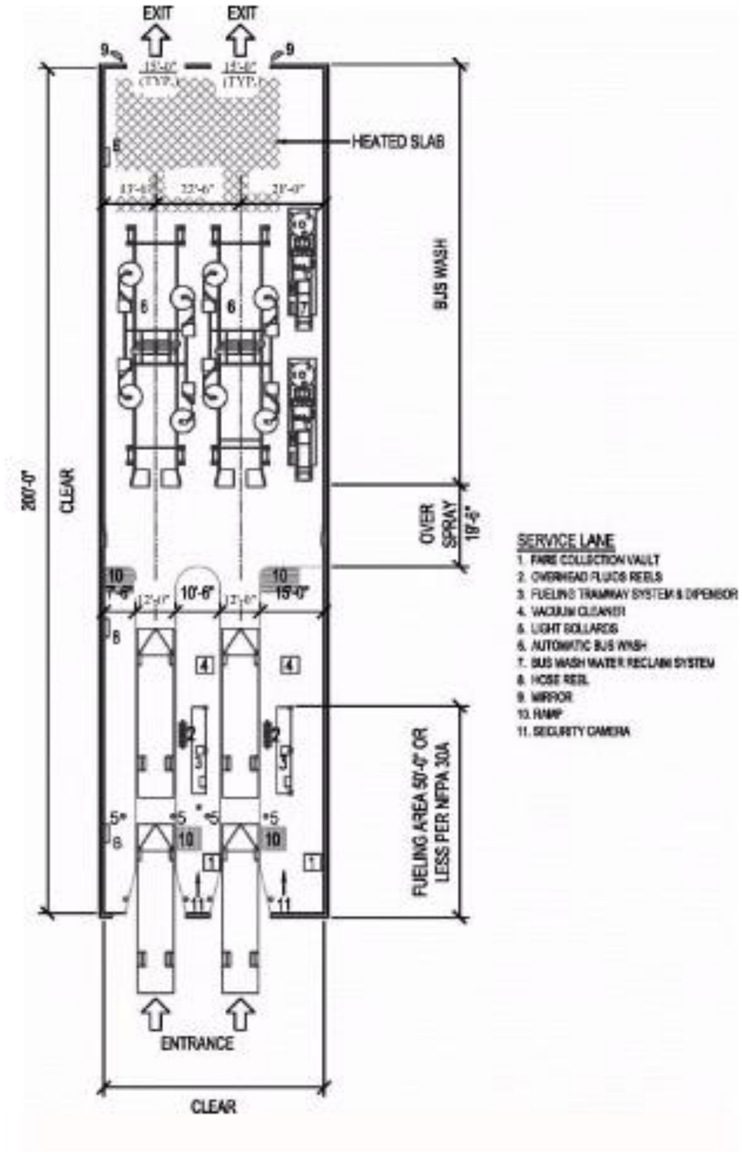
18.8.1.1.1.3 Width of island between drive lanes for fueling equipment and bus vacuuming system located on it: 8’-0” minimum.

18.8.1.1.1.4 Width of island between drive lanes if fueling equipment is located on it and each drive lane has it’s own bus wash unit: 12'-0" minimum.

18.8.1.1.1.5 Width of end island in service lane: 3'-0" minimum.

18.8.1.1.1.6 Width of entrance door into fueling area for a single drive lane: 15'-0" clear, minimum.

18.8.1.1.1.7 Width of single entrance door into fueling area for two drive lanes which share one bus wash unit: 30'-6" clear, minimum**.**


EXIT
EXIT
HEATED SLAB
BUS WASH
OVER SPRAY
18'-6"
200'-0"
CLEAR
10'-6"
FUELING AREA 50'-0" OR LESS PER NFPA 30A
ENTRANCE
CLEAR
SERVICE LANE
1. FARE COLLECTION VAULT
2. OVERHEAD FLUIDS REELS
3. FUELING TRAMWAY SYSTEM & DISPENSOR
4. VACUUM CLEANER
5. LIGHT BOLLARDS
6. AUTOMATIC BUS WASH
7. BUS WASH WATER RECLAIM SYSTEM
8. HOSE REEL
9. MIRROR
10. RAMP
11. SECURITY CAMERA

18.8.1.1.1.8 Width of entrance doors into fueling area for more than two drive lanes, each of which have it's own bus wash unit: Recommend 1 door per drive lane, each one 15'-0" clear, minimum.

18.8.1.1.1.9 Height of entrance doors: 15'-0" clear, minimum.

18.8.1.1.1.10 Minimum clear height required from the finish floor to the underside of any structure:

18.8.1.1.1.10.1 Service Lane16'-0" clear

18.8.1.1.1.10.2 Maintenance Lift Area20'-0" clear

18.8.1.1.1.10.3 Bus Storage Area (Shading)15'-0" clear

18.8.1.1.1.10.4 Bus Parts Storeroom10'-0" clear

18.8.1.1.1.10.5 Paint Booth21'-0" clear

18.8.1.1.1.10.6 Boiler Room16'-0" clear

18.8.1.1.1.10.7 Electrical Distribution Room16'-0" clear

18.8.1.1.1.10.8 Communications Equipment Room 10'-0" clear

18.8.1.1.1.10.9 Office Areas8'-0" clear

18.8.1.1.1.10.10 Repair Shops12'-0" clear

18.8.1.1.1.11 Dispensing Equipment: The fuel dispensing system in the service lane cannot be located no further than 50 feet from the building entrance.

18.8.1.1.2 Other Design Considerations

18.8.1.1.2.1 If an exterior apron is provided for exterior queuing of buses, it should be made of concrete and be sloped away from the building.

18.8.1.1.2.2 Queuing for buses in the service lanes should be planned and laid out to insure that there is no backup into a street when buses return at their peak rate.

18.8.1.1.2.3 One service lane will service approximately 100 buses per day.

18.8.1.1.2.4 If the fleet size requires only one service lane, consider providing two service lanes for fare collection, fueling and interior cleaning with a shared bus wash unit so that the fueling operation is not shut down due to equipment failure.

18.8.1.1.2.5 Consider a by-pass lane for buses not going through the wash cycle.

18.8.1.1.2.6 Consider a direct access from the service lanes to the maintenance area, located in the area between servicing and washing.

18.8.1.1.2.7 Verify that fueling hoses on a tramway are long enough to reach all filler-neck locations, especially where interior cleaning systems may fix the location of the buses front door in the service lane operation.

18.8.1.1.2.8 All fuel and fluids used in the service lane should be connected to the fluid monitoring system.

18.8.1.1.2.9 The service area should have a non-skid surface on the floor slab. Refer to Room Finish Schedule in DD Drawings (DD-ASC-003 thru DD-A-SC-007).

18.8.1.1.2.10 Service islands should be elevated at least 4" above the floor slab. This dimension needs to be coordinated with requirements for low-floor buses.

18.8.1.1.2.11 Provide pipe bollards filled with concrete for protection of all service islands and service lane equipment.

18.8.1.1.2.12 Provide pipe bollards with flood lighting mounted on top or drop lighting suspended from the structure above to illuminate the engine compartment when the bus is located in the fueling/interior cleaning position.

18.8.1.1.2.13 Equipment on the service islands should be placed so that it clears the projecting rear-view mirrors on the bus as it passes the equipment.

18.8.1.1.2.14 Depending on the exiting configuration of the service lane, consider placing mirrors on the exterior of the building to facilitate the driver's vision and provide safe exiting from the service lane.

18.8.1.1.2.15 Vacuum system could be a central unit serving multiple service lanes or individual units for each service lane.

18.8.1.1.2.16 Consider preheating exterior buses during the fueling operation in cold weather so water does not freeze on the buses during the wash cycle.

18.8.1.1.2.17 Gasoline storage or dispensing is not allowed in the building.

18.8.1.1.2.18 Entrance door operation for the service lanes shall be rollup fast actuating type.

18.8.1.1.2.19 Modify service lane design as required if articulated buses are to be serviced.

18.8.1.1.2.20 Sufficient distances between service and washing equipment should be provided to prevent water misting from the bus wash unit from drifting into the service area.

18.8.1.1.2.21 Provide a continuous trench drain from the beginning of the bus wash unit to the end of the blower dryer assembly. Connect drain to water reclamation system.

18.8.1.1.2.22 The plumbing system for the floor drainage shall include an oil/water separator as a part of the design.

18.8.1.1.2.23 Slope the slab on grade to the floor drains.

18.8.1.1.2.24 Provide a men's and women's toilet room and utility closet near the service lane for use of the service lane personnel. The toilet rooms shall be accessible. In the men's room, provide a water closet, urinal, lavatory, toilet paper dispenser, paper towel dispenser and soap dispenser. The women's room shall have two (2) water closets, a lavatory, toilet paper dispenser, paper towel dispenser and soap dispenser. The utility closet shall have a service sink and have shelving to stock toilet room supplies.

18.8.1.1.2.25 Luminaries, motors, etc. are to be water tight.

18.8.1.1.2.26 Proper lighting should be provided, both in regard to location and color-correction, in order to read the gauges of the fluid levels.

18.8.1.1.2.27 All electrical devices in the service lane area shall be specified as waterproof devices.

18.8.1.1.2.28 Provide overhead service reels in the service lane.

SECTION 19 - BUS MAINTENANCE, BUS STORAGE & ADMINISTRATIVE REQUIREMENTS

19.1 MAINTENANCE AREA

19.1.1 Introduction

This section describes circulation, spatial and equipment requirements for the maintenance area, which is the area provided for the servicing and repair of buses with specific maladies which are outside the realm of the service lanes. Such servicing and repair includes, but is not limited to tune-ups, lubrication, parts replacement, tire repair and replacement, and body repairs and painting.

19.1.2 Vehicular Traffic Pattern

19.1.2.1 Pull-In and Drive Through Service: WMATA requires that buses requiring maintenance drive forward through an entrance service door, through interior circulation space, into the required maintenance bay and then drive forward through interior circulation space to an exit service door when the required maintenance is completed. This is much easier and more efficient than a pull-in and back-out traffic pattern. Service doors remain open for a short period of time, thus conserving energy, and maintenance staff spend less time directing buses out of the maintenance area, thus providing a more efficient operation. Refer to FIGURE 19.3 below for an illustration of desired maintenance area circulation.

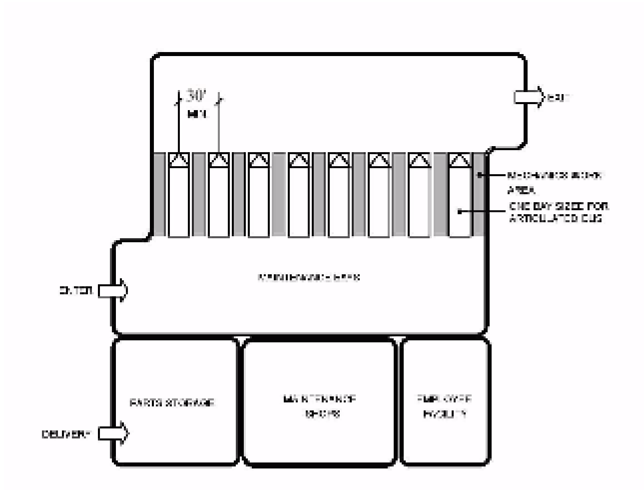


FIGURE 19.3 - Maintenance Area Diagram

19.1.2.2 Service Door Quantities: WMATA requires / desires that there be only one service door entrance and one service door exit for buses in the maintenance area. Although this arrangement requires more interior circulation space, it also conserves a great deal of energy and increases worker comfort, especially during cold weather months. Refer to DD Drawings (DD-A-SC-008 thru DD-A-SC-011) for material and design requirements for exterior service doors.

19.1.3 Maintenance Bays:

19.1.3.1 Design maintenance bays with enough space at front, rear and sides of each space for circulation and access for mechanics, as well as tool and equipment storage bins. Refer to FIGURE 19.3 above for an illustration of desired maintenance bay spacing.

19.1.3.2 Quantity and Type: Provide one maintenance bay for every 10 buses stationed at the facility. Of these bays, one bay each shall be provided for the following:

19.1.3.2.1 Steam clean bay (enclosed).

19.1.3.2.2 Tire changing bay.

19.1.3.2.3 HVAC repair bay.

19.1.3.2.4 Handicapped lift repair bay.

19.1.3.2.5 Articulated bus and intercity coach bus repair bay.

19.1.3.2.6 Paint booth and prep area for 40 ft. bus.

19.1.3.3 In addition to the quantity and types of maintenance bays above, provide two inspection bays with below-grade pits. Each below-grade pit shall be provided with two sets of stairs for exiting, a safety net and a rolling oil pan.

19.1.3.4 Provide maintenance bays with skylights for additional day lighting and with ceiling fans for additional ventilation.

19.1.3.5 Provide fall protection in every bay.

19.1.4 Vehicle Lifts:

WMATA bus facilities use three lift types; portable lifts, drive on parallelogram lifts and in-ground lifts. The distribution of lift type shall be based on optimizing the facility's current requirements and allowing for future expansion. Hydraulic lifts with in-ground plunger-cylinder units are not allowed. The following are WMATA requirements for lift types and capacities:

19.1.4.1 Portable Lifts: Hydraulic mobile lifts specifically designed to elevate large buses, 18,000 lb. capacity each, 4 lifts per bus minimum.

19.1.4.2 Drive-On Parallelogram Lifts: Heavy duty recess mounted parallelogram platform lift with non-skid surface, electro-hydraulic operation, automatic wheel chocks front and rear and a total of two rolling jacks. Platform to raise a min. of 63" above finish floor at a min. rate of 50" per minute with a min. of 10 lock stops. Safety locks will ensure a min. amount of travel in a hydraulic failure and maintain the lift at that height in this situation. Lift sizes to be 50,000 lb. capacity and 32 ft. and 75,000 lb capacity and 48 Waterproof model is to be installed in Chassis Wash Bay.

19.1.4.2.1 Adjustable Axle Lift 2 and 3 Post Modular: Lifts shall consist of two or three individual lifting assemblies in line with the longitudinal axis of the vehicle, each lifting assembly equipped to engage the axle and suspension. Lift to be housed in a totally contained environmentally safe housing, post to be equipped with shutter plate covers which move with the post to cover the trench at all times. Lift to be electro-hydraulically operated and contain a variable equalized control system. Lift locks shall be rated for same capacity as jack unit and lock in 18 positions on 3 inch increments.

19.1.4.2.2 Axle Lift 2 Post: rated for 60,000 lbs

19.1.4.2.3 Axle Lift 3 Post: rated for 90,000 lbs

19.1.4.3 In-ground Lifts:

19.1.4.3.1 In ground lifts to have integral sump and sump pump to pump out any water than accumulates in bottom of lift pit, shop floors are routinely cleaned with a water hose. Pumps to be serviceable from above the pit, entry into the pit should not be required. Pumps to be minimal emulsifying type and be capable of passing ¼" solids.

19.1.4.3.2 Lift controls shall contain Modbus RTU communication for remote monitoring and connected to the building automation system. Lifts shall not be capable of remote control. The intent is to monitor the lifts for the following conditions: lift out of service, high water level in sump, number of cycles and any other maintenance indicators.

19.1.5 Overhead Service Reels:

19.1.5.1 Provide one overhead service reel for each two maintenance bays. Construction shall be of heavy duty design, spring powered and self-retracting, with double pedestal arm design adjustable to 360 degrees. Services on reel to include water (W), engine oil (EO), electric power, automatic transmission fluid (ATF), chassis grease (CG), gear oil (GO), window wash fluid (WWF) and engine coolant (EC) . In addition, at the handicapped lift repair bay, provide separate wheelchair lift oil supply.

19.1.5.2 Refer to Section 6.26 for piping to reels and pumps to propel fluids to reels.

19.1.6 Hoists / Cranes:

19.1.6.1 Jib Cranes: Provide a one jib crane for every four lift bays. Provide bridge crane with electric chain hoist at with a 1 ton capacity and a 12 foot reach in the tire storage area. The jib crane is to swing approximately 180 degrees with stops to prevent any portion of the boom, hoist, or tagline system from coming in contact with building walls or structure.

19.1.6.2 Bridge Crane: Provide a self-supporting monorail bridge crane with electric chain hoist rated for 1 ton, in one of the articulated repair bays. Crane to run the entire length of the bay and be interlocked with the bus lift to ensure the hoist is at the end of the lift prior to the bus lift operation. This will ensure that buses are not lifted into the hoist damaging either the hoist or bus.

19.1.7 Miscellaneous Maintenance Equipment

19.1.7.1 High Pressure Hot Water Cleaner: Provide heavy duty high pressure hot water cleaner to be located outside Steam / Chassis Wash Bay. If unit is located in Bay unit to be shielded from water spray to protect against corrosion and grime/grease ruining unit. Preferred fuel is natural gas, if available. Provide heavy duty high pressure hot water cleaner with 7 to 8 gpm discharge, 3000 psi operating pressure, with adjustable spray pattern nozzle, extra hose lengths, hose reel, wand extensions, quick couples, downstream detergent injectors, rotating brush, and foam applicator.

19.1.7.2 Parts Washers: Provide a small parts washer and a large parts washer. Washers to be vented to outside of building if this is not possible than locate washers in Chassis Wash Area. If located in Chassis Wash Area ensure units are shielded from pressure washer spray in order to protect unit from corrosion and grease/grime.

19.1.7.2.1 Small Parts Washer: Provide industrial jet washer. Washer shall be top loading, hot water and detergent automatic parts washer, with floating oil removal, sludge removal, and subsequent recycling of wash water. Weight capacity shall be 500 lbs of parts.

19.1.7.2.2 Large Parts Washer: Provide industrial jet washer. Washer shall be front loading turntable type, hot water and detergent automatic washer, with two parts baskets, one removable, for extra parts cleaning capacity. Turntable diameter shall be 30 inches minimum, with weight capacity of 1500 lbs. Include filtration system to trap particles and sediment for removal, oil skimming system to remove floating oils and subsequent recycling of wash water. Include water level control and steam exhaust features.

19.1.7.3 Bearing Presses: Provide 50 ton hydraulic bearing press. Includes manually operated two speed pump, liquid filled gauge to measure ram force in pounds and tons, safety oil bypass and overload system, hand operated winch to raise / lower press bed, and self-retracting ram moving laterally on head channel.

19.1.7.4 Brake Drum Lathe: Provide heavy duty, double spindle lathe designed to cut heavy duty drums up to 16 inches deep and 24 inches in diameter, and simultaneously turn brake lining to the exact diameter of the newly refaced drum Drum spindle housing shall extend to support the largest transit dual wheel assemblies without additional support. Include lubrication system, hood enclosure, and portable chip collector. Spindle speeds shall be variable from 20 to 90 rpm.

19.1.7.5 Work Bench With Vise: Provide heavy duty work bench with vise.

19.1.7.5.1 Work Bench: Heavy duty design with heavy gauge adjustable height steel legs and maple butcher block top with protective oil finish.

19.1.7.5.2 Vise: Maximum opening 6-1/2 inches with a 6 1/4"throatdepth replacable main and pipe jaws facings, steel top jaws, built-in anvil, 360E locking swivel base, keyed round slide bar with sealed lubrication.

19.1.7.6 Large Parts Shelving & Storage:

19.1.7.6.1 Large Parts Shelving: Provide heavy duty shelving units. Provide units with minimum 14 gauge steel uprights, beams and columns; and 5/8 inch thick particle board decking. Units to have load capacity of 1650 - 3300 lbs per pair of beams and 20,000 lbs per upright assembly. Shelving shall be adjustable on 1-1/2 inch centers. For pallet storage, provide shelving units equivalent to Lyon Pallett Rack by Lyon Metal Products, with same construction as above bulk storage rack, but without particle board deck and with load capacity of 4100 - 9900 lbs per pair of beams and 17,200 30,200 lbs per upright assembly, and with shelving beams adjustable on 2 inch centers.

19.1.7.6.2 Large Parts Storage Cabinets: Provide storage cabinets. Provide units of all welded, minimum 14 gauge steel construction, with padlock hasp and heavy duty brass pin hinges on doors, 1450 lb load capacity per shelf, and shelves adjustable on 3 inch centers.

19.1.7.7 Small Parts Storage: Provide steel drawer cabinets for small parts storage. Provide units with 400 lb load capacity per drawer, variable drawer heights, and variable interior drawer layout kits as required.

19.1.7.8 Flammable Liquids Storage Cabinet: Provide heavy duty cabinets. Provide units constructed of minimum 18 gauge steel with reinforced double walls, leak-proof pan bottom, heavy gauge adjustable shelves with 350 lb load capacity, doors with built-in key lock, grounding wire connectors, dual vents with fire baffle and cap, large warning labels and adjustable leveling.

19.1.7.9 Brake Tester: Provide portable computerized electronic brake tester Unit measures vehicle speed at braking and distance traveled, brake effort, and can also be used to test acceleration. Accuracy shall be +/- 2 percent. Unit shall be completely self-contained, portable, and shall include keyboard, LCD display and printer. Unit shall display step by step instructions for each procedure, and shall be suitable for testing service and hand brakes on all types of vehicles.

19.1.7.10 Wheel Alignment Tester: Provide computerized wheel alignment tester for heavy duty vehicles. System shall include drive-on plate in floor, computer console and printer. As each axle is tested, results are displayed on the computer console and hard copy automatically printed. Capacity 30,000 lbs each single axle, 44,000 lbs each tandem axle.

19.1.7.11 Wheel Alignment Adjuster: Provide computerized wheel alignment system for heavy duty vehicles. System shall include computer console with keyboard, 27 inch color monitor and printer, and cordless sensors with self-centering wheel adapters. System provides on-screen, step-by-step instruction for sensor placement, measurement and adjustment for a wide variety of axle configurations.

19.1.7.12 Moveable / Mobile Equipment:

19.1.7.12.1 a. Forklifts / Snow Removal Equipment: Provide standard counterbalance truck type upright forklifts. Include seat deck mounted hydraulic levers, stop lights, headlights, back-up lights, strobe lights, audible back-up alarm, and rear turn signals. Provide size and capacity of forklifts to suit each facility. Provide forklift storage area and areas for snow removal equipment.

19.1.7.12.2 Floor Scrubbers: Floor scrubber to be battery powered walk behind unit designed for use on rough textured floors. Unit to have recycling system which recycles the solution allowing 3 hours of continuous runtime and leave the floor virtually dry. Brushes shall be attached using spring clip system requiring no tools for changes. Squeegee to be of parabolic breakaway design the assembly shall be free floating swing type constructed of stainless steel and aluminum with no tools required for change out. Scrubber shall have a minimum 36 inch scrubbing path, minimum aisle turn of 67 ½ inches max, squeegee width of 45 ½ inches, solution tank of 30 gallons, and a 40 gallon recovery tank. The scrubber shall have a forward speed of 0 to 3 mph. Provides storage area for floor scrubbers.

19.1.7.12.3 Parking Lot Scrubbers: Provide riding, motorized floor scrubber. Provide scrubber with minimum 54 inch wide scrub path, 60 inch wide sweep path, 100 gallon solution and recovery tanks, and power steering.

19.1.7.12.4 Wheel & Brake Dollies: Provide wheeled dollies. Provide dollies specifically designed to lift and carryall hub and drum assemblies, with lift and tilt controls and removable drip tray.

19.1.7.13 Battery Charging Bench: All-welded steel frame bench with 2" hardwood rollers on top, five rollers per bank of rollers. Capacity 200 lbs per linear foot. Acid-resistant black finish on steel.

19.1.7.14 Unit shall be capable of charging 1 to 36, 12 VDC batteries. Unit shall be provided with Bus bar set with fiberglass backboard assembly with connecting cables, insulated clamp storage bar and 10 pair of 10 gauge, 300 amp rated charging leads 36 inches long premounted at bus bar end with vinyl insulated safety clamps on other end. Three foot 4 AWG cables shall allow connection to charger or additional bus bar. Room to have ventilation, see Section 14.4.2.3 for air exchange rates. Provide dry sump, floor slope to sump to capture any spills.

19.1.7.15 Rolling Oil Pan: Provide heavy duty rolling pit drain pan designed to run on rails or angles along edge of pit

19.1.8 Dust Collection / Exhaust Collection

Refer to Section 6.26, for ventilation requirements for hood exhaust requirements at lathe, welding, cutting and grinding areas, and for tail pipe exhaust collection requirements.

19.1.9 Paint Preparation Area, Paint Booth and Paint Shop

19.1.9.1 Provide a paint preparation area large enough for an articulated bus to be cleaned, sanded, filled and otherwise prepared to receive new paint in the paint booth. Provide adequate space all around the bus for mechanics, materials, tools and equipment. Refer to Section 6.26 for ventilation and exhaust requirements.

19.1.9.2 Paint Booth: Provide a fully enclosed, prefabricated pressurized cross-draft type vehicle paint room (booth) for spray painting of buses and large trucks. Booth shall be large enough to accommodate articulated buses and shall be provided complete with fluorescent lighting, heavy duty exhaust with totally enclosed fan cooled motor, personnel access doors, product doors, manometer(draft gauge), man lift, intake and exhaust filters with grids ,and all necessary hardware. Construction shall be heavy duty, of minimum 18 gauge sheet steel panels, fabricated to provide a smooth interior surface. Refer to Section 6.26 for breathing air system and further ventilation requirements.

19.1.9.3 Provide a Paint Shop Room adjacent to the paint booth for storage, mixing and containerizing of paints. Provide a Paint Shop Room adjacent to the paint booth for storage, mixing and containerizing of paints. Room to be ventilated and heated and contain a flammable material cabinet.

19.1.10 Steam Clean / Chassis Wash Bay

Provide one fully enclosed area for steam cleaning of buses, preferably located adjacent to the lift bays and arranged for the same drive-forward-and-through-access as previously discussed. The bay shall be provided with a stainless steel parallelogram lift .Provide high pressure hot water cleaners specified above in this area. Equipment for this area to be located in adjacent area if possible in order to protected against water/corrosion. If equipment is located in bay then equipment should be shielded in order to protect it from water. This area to be provide with a hose bibb and compressed air (disconnects on wall located per detailed design). Equipment located in this area to be rated for water environment (waterproof and watertight) and constructed of corrosion resistant material. Forklift access to this area will be required.

19.1.11 Parts Storage

Parts storage shall be provided in vertical carousel part storage systems, similar to a Kardex Remstar system. This system has a large floor load ensure that the floor slab is properly rated. Provide a secure room for parts storage, for the dispensing of replacement parts for buses and for replacement parts for maintenance equipment. This room shall contain a Paint Storage System, large parts shelving, large parts storage cabinets and small parts drawer storage. Include a service door for parts deliveries.

19.1.12 Tire Storage

Provide a room for tire storage with enough height to accommodate vertical storage of tires and a jib crane and other tire handling equipment. Provide tire storage racks constructed of steel with typical construction as shown in FIGURE 19.1 below. Tire storage to be located adjacent to Tire Bay.

19.1.13 Secured Tool Storage

Provide an area room enclosed by a wire mesh partition with locking door, for secure storage of tools. Size of room shall be 15 by 25 feet minimum.

19.1.14 HVAC Repair Shop

Provide an enclosed room, temperature and humidity controlled, for repairs to HVAC equipment. Size of room shall be 15 by 25 feet minimum.

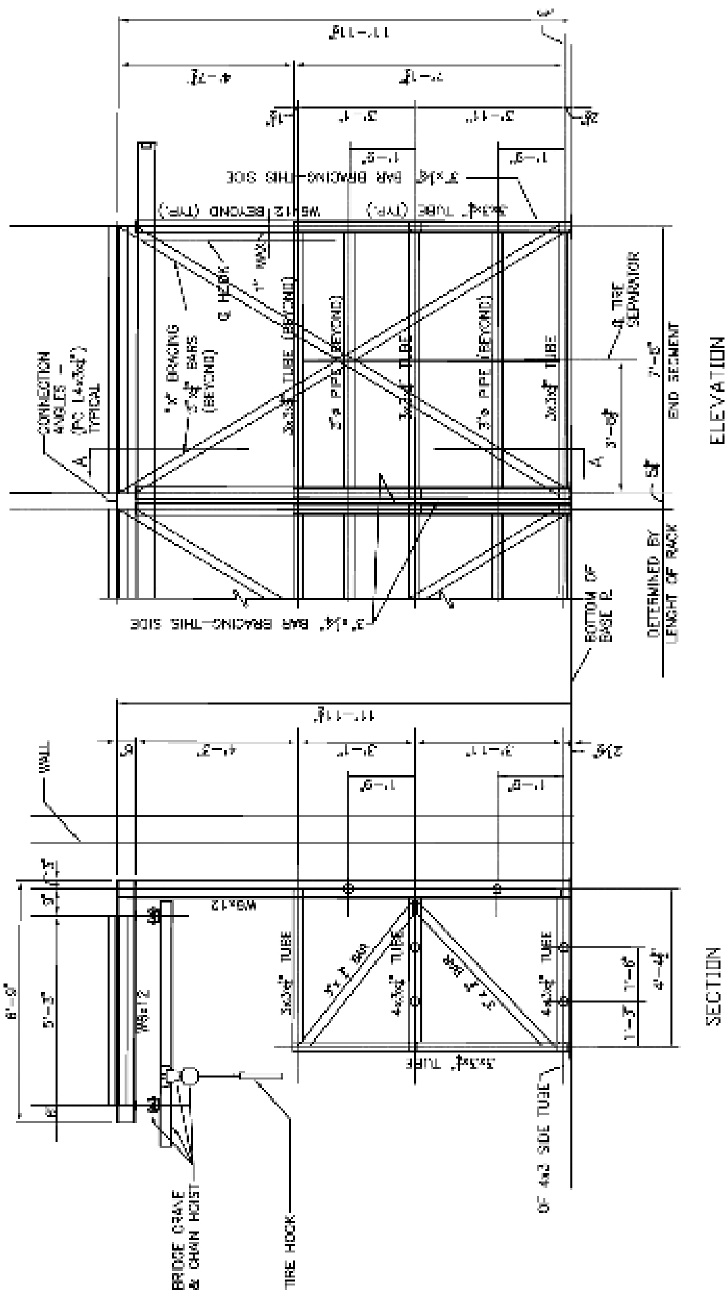


FIGURE 19.1 - Tire Storage Rack Details

19.2 BUS STORAGE

One of the principle functions of any bus maintenance facility is bus storage. Efficient bus parking configurations on a garage site are essential for smooth operations within the site.

The WMATA buses will be stored outside since there are not enough nights when the temperature is below 40 degrees F to warrant building large indoor bus storage areas. Buses will be parked such that they do not have to back up, either to enter the parking space or leave it.

19.2.1 Circulation and Parking Patterns

19.2.1.1 Access to the parking area should be as straightforward as possible with the minimum number of turns. Circulation into and through the bus storage area should be counter-clockwise, that provides for a left-hand circulation pattern. This provides the driver with an unrestricted travel view and minimizes the chance of damage to vehicles and buildings.

19.2.1.2 When planning the bus storage area, the turning radius of the buses is the most important factor. Although the area should be planned to house the buses used in that particular fleet, there should be some part of the area that could handle larger, intercity and articulated buses, even if they are not part of the existing fleet.

19.2.1.3 There are several parking configurations that can be used, depending on the size of the site and the transit operations. Refer to Figure 19.2. The first is parking the buses head to tail in rows, double rows or in-line (stacked) patterns. This is the most efficient in terms of land use but it means that the first bus in line must always be the first to leave and all others must follow in order.

19.2.1.4 The second configuration is the single pull-through, usually in an angled or double angled pattern. A herringbone pattern is another option, but requires backing out. This configuration is WMATA's preference as it offers the maximum flexibility for bus pull out as any bus can enter or leave independently. These patterns consume much more space as there needs to be an aisle wide enough for the bus to turn into a parking stall. This aisle is shared by the row behind as an exit row. A double row is a variation of the single row, with resulting loss of some flexibility.

19.2.1.5 The choice of parking pattern for a particular application is influenced by site and circulation constraints. Conventional stacked parking is only selected when the site is small. If possible, modern facilities are constructed on sites large enough to permit parking patterns that allows access to every vehicle at all times. Direct access greatly simplifies maintenance access, pull-outs and pull-ins.

19.2.2 Paving

19.2.2.1 The bus areas are to be paved with concrete in order to withstand the constant starting, stopping and turning of heavy vehicles. Refer to Section 2 and Section12 for concrete pavement design requirements. The storage area should be sloped a minimum of 1/4" per foot to drain well, but should not exceed a 4% slope, except in rare cases.

19.2.2.2 Automobile parking areas are to be paved with asphalt, referto Sections 2 and 12 for design requirements.

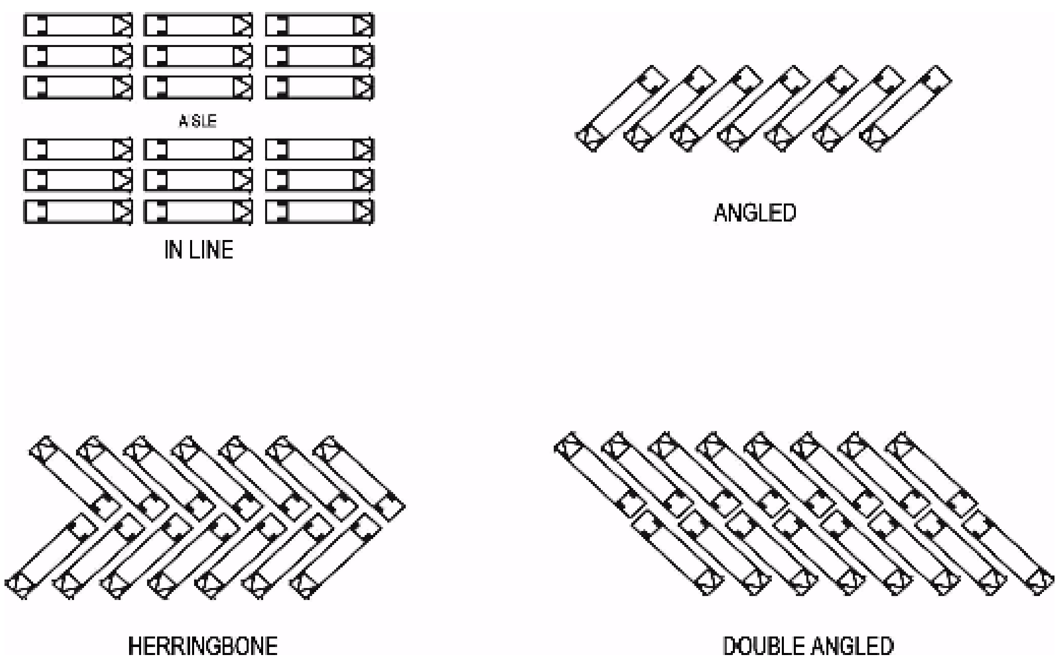


FIGURE 19.2 - Bus Storage Parking Patterns

19.2.3 Services

A canopy for shading the buses reduces the build-up of heat in the bus and the consequent time needed to let the bus air conditioning run to cool it down. This saves not only on fuel, but also on time that the bus is running but not in service earning revenue. There is also a reduction in air pollution. Canopies also reduce snow accumulation on buses, reducing time for snow removal. Canopies shall be included as an optional design element for cost comparison.

19.2.3.1 Site lighting is required for driver safety but it is important that the light is directed onto the site without spillover onto neighboring properties. Canopies can provide shielding for light patterns, where lighting is mounted under canopy roofs. Electrical and compressed air outlets should be located on light standards or canopy columns and shall be spaced throughout the parking area. Depending on the size of the parking area, a dedicated air compressor may be used, but, in any case, air drying is important to prevent line freezes in cold weather.

19.2.4 Security

19.2.4.1 Land use, zoning, and neighborhood characteristics must all be considered when designing perimeter security. Controlled access to the facility is necessary, not only for protection of vehicles and equipment, but for protection of personnel. There are two types of facilities to secure; those built to the property line and those that are set back. Lot line structures can usually be secured through prudent location of windows and doors, minimizing street level access. The setback facility involves more complex issues. While wire mesh fencing with razor ribbon will deter most intruders, it may not be compatible with the community. Concealment of razor ribbon and other obstacles is prohibited.

19.2.4.2 Building security shall involve control of unauthorized access to the facility as well as internal property protection. Supervisors shall have clear views of work and storage areas for safety as well as security. Where this is not possible, electronic surveillance, including closed circuit television (CCTV), shall be provided. See Section 27 for electrical and electronic security system requirements.

19.2.4.3 Security Booth

19.2.4.3.1 An insulated, weatherproof, minimum 8'-0" by 12'-0" booth shall be provided for 24-hour direct and remote monitoring of site access, revenue areas and fire alarms. The booth shall be located at the main security gate for setback facilities, or at the service lane entrance for lot-line structures. The booth may be elevated above grade, where prudent, to enhance surveillance, but shall allow observation of vehicle occupants from inside.

19.2.4.3.2 The unit shall be shipped completely assembled and ready to set in place on foundations on the site. Fluorescent luminaries shall be ceiling mounted. In addition, required wiring, duplex outlets, electrical heater (including thermostat), air conditioner, exhaust fan and circuit breaker box shall be provided.

19.2.4.3.3 Wall assembly shall be welded, galvanized steel construction with 14 gauge steel panels and tubing on the exterior and 18 gauge panels on the interior. Floor shall be constructed of 12 gauge galvanized steel, 4-way safety plate. All exposed interior and exterior steel surfaces shall be electrostatically painted. Walls and roof to be fully insulated.

19.2.4.3.4 Door shall be weather stripped, of hollow metal steel construction and provided with a vision panel. Sliding windows shall be aluminum frame construction with glass and screens included. Clear, tempered safety glass (1/8" minimum thickness) shall be used for door glazed vision panel and windows.

19.2.4.3.5 Unit to be furnished with personnel lockers (48"high), writing counter, one standard desk chair and one small filing cabinet. An exterior writing stand with light shall be provided on the facility entrance side of the booth.

19.2.4.3.6 The booth security equipment shall include:

19.2.4.3.6.1 An Alarm Monitoring System for security and fire.

19.2.4.3.6.2 Monitors for Closed Circuit Television System and Video Motion Detectors.

19.2.4.3.7 Yard Lighting: All yards shall be illuminated per design requirements in Sections 4 and 13.

19.2.4.3.8 Fencing: Front, rear and side yards shall be secured with eight-foot high chain link fencing. The fence shall be constructed of a 9 gauge, 1" x 1" galvanized steel mesh fabric. Fence posts shall be set in concrete footings and shall be spaced in a maximum of 8 feet apart. The top of the fence shall be capped with 3 strands of barbed wire. Refer to WMATA's standard Fence Detail Drawings.

19.3 ADMINISTRATIVE AND OPERATIONS REQUIREMENTS

19.3.1 General Description

19.3.1.1 The Administrative & Operations Area consists of functions required for the smooth day to day operations of the facility. These include offices for administrators and facilities for bus operators and their supervisory personnel. This area is separated from the maintenance area, with particular attention given to relationships between dispatchers, bus driver's day room, bus parking, employee parking and locker room facilities.

19.3.2 Functional Space Descriptions

19.3.2.1 Space requirements for this area are dependent on the fleet size and level of management at the particular facility. Refer to Section 18 for further elaboration in this regard. In general adequate space for the following shall be provided:

19.3.2.1.1 Dispatcher: The daily routines of the bus system are conducted by the dispatcher. These include the dispatching of bus drivers, route schedules and record keeping. The dispatch room shall have direct visual contact with buses entering / leaving the facility and the bus storage area.

19.3.2.1.2 Day Room: This Room is the place where the bus drivers report for duty, spend off time between runs, prepare necessary reports and have meals. Typically it is divided between an active area and a more quiet space. Allocation of 15 SF per person for this area is adequate. In addition, space for kitchenette and vending machines shall be planned. The Day Room is adjacent to the dispatcher, separated by a pass thru window. The dispatcher should also be able to view the entire space. There should be easy access from employee parking, bus parking, locker and toilet facilities.

19.3.2.1.3 Supervisors: Shall be located convenient to their area of supervision and their office shall include some degree of privacy for consultation purposes.

19.3.2.1.4 Lockers and Toilet Facilities: Separate facilities for male and female management and male and female hourly employees are required. Female facilities shall be designed for expandability to a 50/50 male/female ratio, where initial requirements are for less than this ratio.

19.3.2.1.5 Training / Conference: These spaces may or may not be combined depending on the facility size, larger facilities tending to have separate spaces. The rooms should be sized at 15 SF per person. Acoustical and climate control within the room shall be carefully considered and acoustical separation from adjoining rooms is essential. Lighting of the room shall be designed to function for the type of presentations intended. Within the training room considerations for bus simulation equipment may be necessary.

19.3.2.1.6 Facility Manager's Office: Shall be adequately sized for the necessary furnishings. Should provide for closed door private conversations. Offices for general managers shall be designed to provide space for small meetings within the room.

19.3.2.1.7 General Office: This space is sized according to the level of management of the facility. The Administrative and Clerical Personnel are the space users and should be located conveniently to all upper management.

19.3.2.1.8 Storage: Rooms and areas for storage shall be carefully considered for size and conveniently located according to need.

19.3.3 Furniture Requirements

The following chart represents the types of furnishings that are normally found in the different types of spaces. Quantities and specific types need to be decided during program development of the specific facility.

	SPACE TYPE										
Equipment	Manager Office	General Office	Dispatcher	Day Room	Supervisor	Conference Room	Training Room	Storage	Drivers Locker Room	Management Locker Room	Remarks
Staff Desks											
Desk Chair ..		..	..		..						
Side Chairs ..		..			..	..	..				
File Cabinets ..		..	..		..						
Shelving ..						..	..	..			May be fixed or movable
Wastebasket ..		..	..	..	..	..	..		..		..
Large Lockers					..						
1/ 2 Height Lockers									..		..
Benches									..		..
Lunch Tables				..							
Café Seating				..							
Tackboards ..		..	..	..	..	..	..		..		..
Chalkboards			..			..	..				
Projection Screen						..	..				

Figure 19.4 - Furniture Requirements

SECTION 20 (NOT USED)

SECTION 21 Moved to Section 6.26

SECTION 22 – LIGHT RAIL (FUTURE)

SECTION 23 - TRACTION POWER

23.1 GENERAL

These design criteria include functional and design requirements for the supply and supervision of all electrical power to the Washington Metropolitan Area Rapid Rail Transit System. Where applicable or noted this Design Criteria will be read concurrent with Section 13 and Section 28.

The Electrical System shall supply power to all transit facilities to provide safe, efficient and continuous operation of the entire system. Design of the Electrical System shall be coordinated with the requirements of the individual power companies in D.C., Maryland and Virginia providing primary power to the system.

23.1.1 Clearance to Installations

A minimum of 2"is required between any fixed installation (e.g., pipes, pipe hangers, pipe supports, signals, luminaries, etc.) and the design vehicle dynamic outline. This is defined by the clearance envelope. However, installations shall be so dimensioned and located that maximal distances are obtained between these and the clearance envelope along tangent and curved alignments.

23.1.2 Scope

The Design Criteria covers the Traction Power System Scope of work:

23.1.2.1 Traction Power System providing for propulsion requirements including technical requirements for the contact rail, running rails and traction power cable.

23.1.2.2 Spacing requirements for locating Traction Power Substations and structure size to accommodate the TPSS equipment.

23.1.2.3 Auxiliary AC Electrical Systems (Refer to Section 13)

23.1.2.4 Lighting systems for illumination (Refer to Section 13)

23.1.2.5 Supervisory Control and Data Acquisition (SCADA) system described in Design criteria, Section 28.

23.2 TRACTION POWER

23.2.1 General

WMATA is a heavy rail transit system. The transit cars shall be propelled by electric traction motors driving steel wheels through appropriate gearing. Electric traction power shall be supplied to the cars by means of a contact rail installed parallel to the running rails, upon which one or more collector shoes attached to each car will maintain sliding contact.

Running rails of both inbound and outbound tracks shall be used as negative return conductors for the traction power system, except at crossover locations and in service and inspection yards where only one running rail provides the negative return.

The entire conductor system including the contact rail, the running rails, and associated cable connections shall be capable of supporting voltages to the transit cars within the limits set forth below.

Direct current traction power shall be provided by rectifiers with rated voltage output of 700 volts at one hundred percent (100%) load. Maximum voltage output at one percent load at the substation bus shall not exceed 742 volts. Substation regulation shall not exceed six percent (6%) from one percent to one hundred percent of rated transformer/rectifier capacity and shall be approximately linear to four hundred fifty percent.

23.2.2 Maximum Voltage Drops and Negative Rail Potentials

23.2.2.1 In order to sustain high traction motor performance, the design voltage drop from rated voltage output of 700 volts shall not exceed 175 volts at any train, under normal operating condition. Negative rail potential shall not exceed 70 volts for normal operation, 100 volts for heavy service demand (Operation under Emergency Conditions) and 120 volts for abnormal.

23.2.2.2 Normal operating condition is defined as a rail system operating with eight car-trains at 120 second head way, and with all transformer-rectifier units within all traction power substations in service.

23.2.2.3 As part of the normal operating conditions, under heavy service demands (Emergency Conditions) such as train bunching, special event services, etc., and a substation with only one transformer-rectifier unit in out of service, a voltage drop of 225 volts at the train shall be permitted. Reduced train performances under these voltage condition shall not be allowed.

23.2.2.4 Under abnormal traction power configuration with a total loss of AC power at anyone substation, the traction power system shall be designed to restrict the voltage drop to a maximum of 250 volts. Reduced train performance characteristics under these low voltage conditions would be allowed.

23.2.3 Cable

23.2.3.1 All direct current traction power feeder cables shall be stranded, shielded (for positive), non-shielded (for negative), tinned copper conductors, and shall have low smoke, zero halogen generation characteristics.

23.2.3.2 All cables shall be flame retardant and shall be rated 90 degree centigrade in dry and wet locations.

23.2.3.3 The number and size of traction power cables connecting the DC feeder breakers to the contact rail, and from the running rails to the negative bus shall be bused upon the maximum RMS current obtained under various operational scenario with a temperature rise not to exceed safe insulation design limits of the cables and based on a minimum insulation life of 30 years.

23.2.3.4 The positive power cable shall be monitored on a continuous basis to avoid fire hazard, ground fault, and risk of arcing and fire due to cable insulation deterioration through cable insulation monitor device installed in substation/TBS facilities

23.2.3.5 The traction power cables shall be 1000 KCMIL and be rated 2 kV. Standard duty, ASTM class D, stranded, shielded cables shall be used for positive traction power feeders from DC Switchgear to points adjacent to the contact rails. Extra flexible, ASTM class G stranded, non-shielded cable shall be connected to each Class D cable with bolted type connectors at points adjacent to the contact rail and extended to the contact rail. The cable shall be connected to the contact rail as indicated in the design drawings. The negative traction power cables shall be class D stranded non shielded cables.

23.2.3.6 The traction power DC cables in substations and tie-breaker stations shall be run in fiberglass cable trays. Where traction power cables are to be installed in shaft ways they shall be installed exposed with insulated clamps, unless the shaft way is an emergency exit, in which case the cable shall be run in concrete encased duct banks with FRE conduit. Where the cables are run in vertical shafts in the duct banks, pull boxes shall be inserted at the required intervals with approved insulating support, to prevent the weight of the conductor from damaging insulation or placing strain on termination point. At the end of the conduit approved type of sealant shall be used to prevent moisture and spread of fire.

23.2.3.7 The positive traction power cables feeding to contact rails on aerial trackway structures shall be routed external to (not through) the aerial sturcture. The cables shall be separated from and electrically insulated from all structural steel and concrete.

23.2.3.8 At all locations where cables are exposed, the positive and negative return cables shall be installed in separate raceways /cable trays.

23.2.3.9 FRE conduit size for 1000 KCMIL cables shall be 4" IPS Standard (one cable per FRE conduit). Minimum conduit quantities (including spares) for various rail connections for feeders of less than 250 feet in length shall be as follows:

23.2.3.9.1 Substation positive feeder for a full section of contact rail: eight conduits.

23.2.3.9.2 Substation positive feeder for a short rail section at an acceleration sectionalizing gap: five conduits.

23.2.3.9.3 Tie breaker station feeder for a full section of contact rail: seven conduits.

23.2.3.9.4 Tie breaker station feeder for a short rail section at an acceleration sectionalizing gap: five conduits.

23.2.3.9.5 Substation negative return: twelve conduits to each track.

23.2.3.9.6 Surface trenching: is not recommended. In special conditions high density polymer concrete (HDPC), Plastibeton or equal for above ground installations shall be used. Cables to be installed with HDPC separators between individual cables.

23.2.3.10 Feeders in excess of 250 feet in length may require additional conduits to satisfy voltage drop requirements. Cable derating shall be provided for the duct bank configuration. To the extent possible, two high ducts (2 rows high) shall be provided to reduce the derating.

23.2.3.11 Typical details of conduits and cable installations are shown on the Electrical Design Drawings.

23.2.3.12 Conduit ends shall be sealed after installation of cable, and spare conduits shall be plugged or capped with best qualified conduit sealing bushings as shown on Electrical Design Drawing (DD-E-081).

23.2.4 Cable Supports

23.2.4.1 Traction power positive cables from the DC switchgear and negative cables from the negative switchboard shall be laid in cable trays, with adequate cross-sectional area to permit a neat alignment of the cables and avoid crossing or twisting which may damage the cable insulation.

23.2.4.2 Supporting arms or racks shall be spaced to avoid exceeding the raceway load bearing capacity of the raceway. The cables shall be arranged in one layer. Raceways for positive and negative cables shall be physically separated, and insulated from ground. The minimum vertical clearance for cable trays shall not be less than 11 inches apart.

23.2.4.3 Communication cables from Traction Power Substation and Tie Breaker switchgears and equipment shall be laid or run in separate fiberglass cable trays.

23.2.5 Positive Contact Rail

23.2.5.1 Positive contact rail will be a composite steel/aluminum rail (or aluminum rail if economically justifiable) on main line tracks and in yard areas. Contact rail connections will be as indicated.

23.2.5.2 Composite contact rail shall have a resistance at 20EC of not more than 0.0020 ohms per 1000 ft. Voltage drop calculations shall be based on contact rail resistance adjusted for 40EC ambient and 50EC rise in temperature due to a total of 90ºC.

23.2.5.3 The relative position of the contact rail to the running rails, the type of support, insulator, cover board bracket, and the supporting hardware are shown on the Electrical Design Drawings.

23.2.5.4 Mechanical continuity shall be provided in the contact rail from substation to substation except for locations at contact rail transitions, Tie Breaker stations and special track-work. At these locations and at the substations the rail continuity shall be broken to provide definite power sections. The system shall be designed to permit isolation of each power section. For each Route, the electrical continuity of the contact rail is maintained between power sections at all times for rail operation.

23.2.5.5 Where separations of contact rail are necessary, such as at crossovers, emergency exits and other obstructions, electrical continuity shall be maintained by the use of jumper cables. End approaches shall be provided at each separation to facilitate contact shoe return to the contact rail. The jumper cable shall be installed in conduit or covered raceways for protection from physical damage.

23.2.5.6 At TPSS and TBS locations a gap-segment-gap arrangement shall be installed and dimensioned to prevent simultaneous bridging of both gaps by one a pair of cars.

23.2.5.7 Contact rail through passenger stations shall be located at trackside opposite the platform. Contact rail at-grade shall be located in the area between tracks, except at special trackwork and center platform stations. Contact rail on aerial structures shall be located in accordance with the General Plans and Design Drawings.

23.2.5.8 In sections of contact rail of 1800 feet or less, a contact rail anchor shall be provided at midpoint. In sections of contact rail exceeding 1800 feet, rail anchors shall be provided at maximum 1000 foot intervals, together with expansion joints at midpoint between rail anchors. Spacing of anchors shall be adjusted to provide an anchor near the middle of curved sections, with expansion joints in tangent sections. Typical rail anchor locations and details are shown in the Electrical Design Drawings and General Plans.

23.2.5.9 At all locations where jumper cables or bonding are used to provide electrical continuity, such as around expansion joints, such bonding or cabling shall provide conductivity which will not reduce the circuit capability. Jumper cables shall be installed in conduits.

23.2.6 Running Rails

23.2.6.1 The running rails for mainline operation shall be 115 pounds per yard RE section, AREA Specifications. Each new single rail shall not have a resistance of more than 0.003486 ohms per 1000 ft. at 20ºC. Voltage drop calculations shall be based on a single rail resistance of .01 ohms per1000 ft. at 20ºC and adjusted for 50ºC rise at 40ºC ambient for a total of 90. Generally, rails shall be welded in continuous lengths. Where rails are furnished with uninsulated "glued" joints electrical continuity shall be enhanced by using jumper cables. At locations requiring insulated joints, the electrical continuity of running rails shall be maintained by use of impedance bonds.

23.2.6.2 Between substations negative rails shall be cross-bonded for traction power equalization, through impedance bonds at maximum intervals of 2000 feet. Cross bonding shall also be provided at tie breaker stations, to facilitate connection of cable for negative polarity reference. A negative rail polarity reference, number 6 AWG wire in conduit, shall be provided from each track through impedance bonds at the tie-breaker station. Where train control impedance bonds occur within the spacing interval, these bonds may be utilized for traction power cross-bonding.

23.2.7 Mainline Sectioning

23.2.7.1 Main line traction system is divided into power zone that is the contact rail. Located between TPSS to TPSS and power section that is the contact rail between a TPSS and TBS. These power sections and zones are controlled through DC track feeder breakers. .

23.2.7.2 Blue light Emergency Trip Stations (ETS), combined with emergency telephone stations, shall be located at intervals not exceeding 800 feet throughout the rapid transit system and at each end of each passenger station platform. Additional trip stations shall be provided at special trackwork such as crossovers and at emergency access and exit locations and as required by code (NFPA 130).

23.2.8 Contact Rail De-icing System

23.2.8.1 The contact rail de-icing system shall be designed to remove ice from the head of the contact rail and consists of a flexible, electrically insulated, conductive heating element mounted under the head or on the web of the contact rail. The heating element will be attached to the contact rail with steel attachment clips. The De-Icing System shall be electrically insulated from the contact rail.

23.2.8.2 The heating element shall be of a constant wattage type design. Microprocessor based Zone controller shall be provided in Traction

Power Substations to interface with Trackside heater controller for remote control and indication by SCADA. Provision shall be made for local controls specified through SCADA systems.

23.2.8.3 The rated nominal output shall be 30 watts per foot at 750 volts DC when mounted on a 32EF substrate.

23.2.8.4 750 volts shall be supplied to the heating element by tapping off the contact rail though a fuse box disconnect switch mounted adjacent to the contact rail. The negative side of the heating element shall be connected to the running rail negative return system through a trackside heater control panel. Each trackside heater control panel shall provide control and indication to two 400 foot sections of heater element on the outbound or inbound track.

23.2.8.5 The supervisory control and indication functions shall be provided by microprocessor based controllers of a zone control panel located in the traction power facility serving the traction power section/zone that the heater elements are installed on. Control cables shall be installed in the mainline duct bank.

23.2.8.6 Control power for the zone control panel shall be supplied from the local DC distribution panel. Control power for the wayside heater control panel shall be derived from 750 volts DC.

23.2.8.7 Outbound or inbound heater elements shall be turned on or off individually by the zone controller. Individual indication from trackside controller shall be provided to SCADA.

23.2.8.8 Storage track isolation switch shall provide isolation for the heater tape.

23.2.8.9 Details of the contact rail heater system are shown on the Electrical Design Drawings.

23.3 TRACTION POWER SUBSTATIONS

23.3.1 Substation Spacing and Capacity

23.3.1.1 The spacing and capacity of traction power substations shall be based on supplying power to the trains as demanded by the operating schedule, during maximum traffic periods, within the limits of the permissible voltage drops, and equipment ratings. It will also include the loads imposed by Contact Rail Deicing System and the Switch Heaters.

23.3.1.2 Substation buildings will be designed to accommodate three rectifier/transformer units, each rated at 3000 kW.

23.3.1.3 Each traction power substation rectifier unit and rectifier transformer shall be capable of withstanding the loading cycle defined in NEMA RI-9 for "Extra Heavy Traction".

23.3.1.4 The following shall constitute the basis of traction power calculations:

AW2 = 110,750 pounds per car

Worn wheels-25 inches

AW0 = 84,500 pounds per car.

Max. car speed - 75 mph. Max. Car speed -75 mph with worn wheels

Max rate of acceleration (P5) - 3.0 mphps

Traction motors per car- 4

New wheel diameter- 28 inches

Gear ratio (assumed) - 5.414 to 1

Speed- tractive effort from traction motor efficiency curves assumed in initial calculations are shown in Fig. 23.1

Auxiliary power - 90.0 kW per vehicle.

Nominal voltage 700 VDC

Maximum voltage 860 VDC

Minimum voltage 450 VDC

23.3.1.5 Preliminary calculations to determine optimal substation locations and spacings will be based on the traction power system simulation study. Locations shall be indicated on the General Plans.

23.3.1.6 For maximum substation reliability, at least two rectifier units of 3000 kW capacity shall be installed. Alternate unit ratings at selected substations may be permitted as directed by the Authority.

23.3.2 System Simulation

23.3.2.1 The design of the traction power systems shall be based on load flow simulations. Operation of 8 car-trains along the appropriate alignment shall be simulated to calculate all necessary parameters for the traction power system design. 8 car-trains shall be simulated to operate on the system at the minimum projected headways as specified by the authority, under normal and individual substation outage conditions, with the cars loaded to AW2. Under these operating conditions the traction power system design shall be shown to operate successfully within the required design parameters and the voltage at the trains shall not exceed the requirements in Section 23.2.2.

23.3.3 Substation Power Supply

23.3.3.1 In 13.8 kV incoming service areas, the Power Company will deliver to each substation within its territorial boundaries two dedicated underground, 13.8 kV, 3-phase, 60 hertz power circuits as primary service. The same feeders may also supply power to the AC switchboard rooms in the adjoining passenger station. Each of these 13.8 kV power services will be furnished from separate Utility Company substations, or from separate buses of "high reliability" substations as an alternate. The same utility substation will not supply power to at least two adjacent traction power substations. At each substation and passenger station, the 13.8 kV incoming service feeders will be metered. The Designer shall coordinate with the Utility Company for minimum clearance at the front and rear of the 13.8 kV incoming service switchgear and for clearance in front of the Utility Company's metering cabinet.

23.3.3.2 In 34.5 kV incoming service area, the Power Company will deliver to each substation within its territorial boundaries two dedicated underground, 34.5 kV, 3 phase, 60 hertz power circuits as primary services. Each of these 34.5 kV primary services will be furnished from separate Utility Company substations or from separate buses of "high reliability" substations.

23.3.3.3 Utility Company shall provide 34.5 KV distribution plan for Authority review and approval.

23.3.3.4 As approved, multipole disconnect switches shall be installed to provide means to isolate substation utility feeder from the distribution circuit.

23.3.3.5 The capacity of each power company's circuit shall be sufficient to support the total connected load of all traction substation and passenger station including the overload capacity of traction power transformers, maintaining voltage to the transformer within plus or minus 5% of normal rating.

23.3.4 Traction Power Equipment

Provision shall be made in each substation for one additional transformer rectifier unit to allow a total of 3 units.

23.3.4.1 Traction power equipment shall be designed to operate unattended. Controls shall be provided to operate all switchgear from the Operation Control Center (OCC) or from local control switches in the equipment, as well as from a HMI control panel remotely located in the Traction Power Substation.

23.3.4.2 A one line diagram for a typical traction power substation is shown for reference in the Electrical Design Drawings.

23.3.4.3 New rectifier transformers shall be 12 pulse, rectifier connected per ANSI circuit No. 31, and shall be design so that the maximum overall regulation rate is not greater than 6% +/_ 0.5% between 1% rated load and 450% rated load with temperatures rise limits in accordance with the latest ANSI/IEEE standards. All outdoor transformers shall comply with the latest EPA requirements. The transformer-rectifier design and component selection shall minimize harmonic distortion and shall comply with IEEE 519. The traction power substation rectifier shall be silicon diode type, self-cooled by natural ventilation.

23.3.4.4 Thyristor or controlled rectifiers will be considered where necessary to provide improved voltage regulation or reduce overall costs. It shall consist of full wave bridges providing 12-pulse rectification capable of withstanding the loading cycle defined in NEMA RI-9 for “EXTRA HEAVY TRACTION” without exceeding the manufacturer’s allowable diode junction temperature and without damage to any component. The rectifier shall also be capable of withstanding the maximum theoretical short circuit current on the rectifier until cleared by the protective devices.

23.3.4.5 In the service and inspection shop substation, rectifier transformer unit shall be capable of withstanding the loading cycle defined in NEMA RI-9 for “ HEAVY TRACTION” without exceeding the manufacturer’s allowable diode junction temperature and without damage to any component.

23.3.4.6 For an operational traction power system in addition to the traction power equipment, auxiliary equipment shall include interconnecting buswork, control battery and UPS; provision for stray current corrosion control drain cables and stray current remote monitoring systems, provision for supervisory control and monitoring of the equipment through the (SCADA) system.

23.3.4.7 All substation interconnecting buses shall be copper. Buses shall be sized on the basis of maximum current density of 800 amperes per square inch of cross sectional area. Temperature rise shall be within the permitted ANSI/NEMA standards. All buses shall be adequately supported to withstand available short circuit currents, and isolated for the appropriate voltage level.

23.3.4.8 The overall dimensions of major equipment are shown on the Standard Drawings including the minimum clearances. Section Designers during final design of substation equipment shall ensure that these clearances are maintained. Particular attention should be paid to design of structural floor in view of small base design of transformers.

23.3.4.9 In 13.8 KV service area, the primary service cables from the Utility Company will be extended into the substation and terminated in the appropriate cubicles by the power company. Four 5 inch FRE conduits shall be provided for 13.5 kV incoming primary service cables. Four 8 inch, unless otherwise indicated, PVC conduits shall be provided for 34.5 kV Utility Company primary service cables at substations by the power company.

23.3.4.10 Micro-processor based solid state protective relaying of the incoming line breakers, as well as relay control of the primary bus tie breaker, shall be in accordance with the standards of the power company. The design drawings illustrate typical single line diagrams and supervisory control for traction power substations. Designer shall perform a complete short circuit study for frame and trip sizes of breakers, cable withstand duty, protective relay coordination, etc.

23.3.4.11 Utility grade Power Quality Meter (PQM) shall be installed in each incoming line, feeder breaker and auxiliary transformer feeder breaker cubicles. Each DPM shall be connected to the automatic energy management system (AEMS) for remote monitoring.

23.3.5 Equipment Arrangement

23.3.5.1 Substation structures shall have adequate floor area and loading capabilities to permit placement of electrical equipment and ancillary components of any manufacturer in the general arrangements shown on the Electrical General Plans and Design Drawings. Relative spacing and positioning of each transformer and rectifier unit shall permit the removal, replacement, or maintenance of such unit without the necessity of moving other units. The arrangement of the equipment shall permit doors to be opened, panels to be removed, and circuit breakers to be withdrawn.

23.3.5.2 Rectifier unit and the DC switch gear line up along with all connecting bus work and positive cable trays shall be insulated from ground. An additional three feet of floor insulation all around the equipment shall be provided to prevent accidental contact with grounded structures. DC switch geer shall have 4'-6" of floor insulation in front and 3'-0"on all other sides. Design shall provide for all uninsulated walls, columns, ducts, ground bus, fixtures, other grounded equipment or structures to be located at least three feet away from the insulated equipment.

23.3.5.3 Ceiling heights, vertical clearance below ceiling hung equipment, and structural openings shall permit entry and removal of the largest components which will be installed in the structure.

23.3.5.4 Substations located below grade shall be constructed with equipment hatches, not located directly over any electrical equipment to permit the removal of equipment from the substation to the street level above. Below grade substations shall be designed to allow personnel carrying large test equipment safe access into facilities. All electrical rooms which are below grade shall be waterproofed. All entering conduit through which surface or subsurface water may seep, shall be provided with water seal fittings for conduits and cables on both ends. Water seal fitting shall also be provided for all manholes. Conduit through substation ceiling shall be prohibited. Drip loop shall be provided for all cable entering through walls. Where waterproofing is not feasible, electrical equipment shall be compatible with the environment, and facilities for drainage or pumping shall be provided. No mechanical or drainage piping shall be permitted in electrical rooms.

23.3.6 Grounding

23.3.6.1 Stray Current and Cathodic Protection

23.3.6.1.1 Measures to mulitgate stray current control shall reduce or limit the level of stray currents at the source, under normal operating conditions. Traction power substations shall be spaced at interval such that maximum track-to earth potentials do not exceed 70 volts DC during normal operations. Running rail and contact rail shall be isolated from ground.

23.3.6.1.2 Metallic tunnel liners and structural reinforcing steel for underground concrete structures, including wire mesh reinforcing for shotcrete tunnel lining, shall be bonded or welded to provide electrical continuity as shown on Structural Standard Drawings ST-S-007,ST-S-021 thru ST-S-023. The metallic reinforcing of floating slabs shall be bonded to adjacent invert reinforcing at each corner of the floating slab to maintain slab-to-track potential at the same level as in normal invert construction.

23.3.6.1.3 Reinforcing steel in concrete retaining walls, abutments, aerial structures, and other similar structures shall be made electrically continuous. To allow for stray current tests, one No. 2 AWG insulated wire shall be exothermic welded to the reinforcing and terminated in a flush mounted junction box for periodic testing. The junction box spacing shall not exceed 500 feet in continuous structures.

23.3.6.1.4 At each traction power substation associated with underground Metro structures, provisions shall be made to connect the electrically continuous tunnel lining or reinforcing via cable to the traction power substation negative bus through stray current drainage system.

23.3.6.1.5 The stray current and drainage equipment will be furnished as part of traction power equipment. Each design section incorporating a traction power substation shall include termination connections to the reinforcing steel or liner, as well as all embedded conduits and cables into the substation, as required on the standard drawings.

23.3.6.1.6 The stray current remote monitoring/test facility located in the substation negative switchboard shall allow for continuous remote monitoring of stray current to identify changing conditions associated with track-to-earth resistance. Substation shall be provided with remote monitoring systems to record the negative bus to earth potential, the stray current returning through the shunt. The remote monitoring system shall consist of a standalone data acquisition module connected to SCADA.

23.3.6.1.7 Provisions shall be included to monitor track-to-earth potentials on a continuous basis. Monitoring facilities shall be located at traction power substations. Provision shall be made for future installation of Negative Grounding Devices (NGD).

23.3.6.1.8 At each fan and vent shaft, provision shall be made for stray current test boxes. Conduits, junction boxes, cables, and waterproof sleeves shall be installed as shown on the ST and DD drawings.

23.3.6.1.9 Ferrous piping for Metro facilities, buried in contact with earth, shall be coated and provided with cathodic protection where required by soil conditions, as defined by corrosion surveys. Recommended types of coating and details of the design of the cathodic protection system will be furnished by the Authority to the Section Designer. The Section Designer is expected to review corrosion survey reports and to submit request for development of required details to the Authority, covering those elements of his design requiring corrosion protection.

23.3.6.1.10 Permanent ferrous metal foundation piling directly above or immediately adjacent to underground subway structures shall be bonded and provided with stray current drain cables to a traction power substation, when adjacent to the substation. Metal piling remote from a substation shall be provided with stray current drain cables into the subway structure for test purposes. To assist in shielding stray currents, soldier piles to be left in place shall be bonded for continuity and provided with drainage connections. Bonding of soldier piles shall be accomplished by using No. 4/0 AWG insulated cable, thermite welded between piles. Soldier piles so bonded and drained to traction substations shall not be used for current ground purposes.

23.3.6.1.11 Underground metallic structures of other jurisdictions such as gas lines, metal water mains, etc., in the vicinity of traction power substations may require connection to substation negative buses. These connections will be based on stray current tests performed jointly by the Utility Company and WMATA. To permit such future connections, at least four 3-inch conduits shall be stubbed-out and capped, approximately 30 inches below grade, and at a distance of 3 feet outside of each traction substation. These conduits shall be brought into the substation and turned up at a wall adjacent to the negative switchboard.

23.3.7 Substation and Tie Breaker Station Grounding

23.3.7.1 Each substation and tie breaker station room shall be equipped with a 1/4" x 2"copperground bus on the inside periphery, mounted at the wall as indicated on the typical installation drawings and connected to a ground grid. Each substation ground bus shall have a maximum resistance to ground of 2 ohms.

23.3.7.2 Each tie breaker station ground bus shall have a maximum resistance to ground of 5 ohms.

23.3.7.3 Equipment enclosures and raceways for alternating current equipment, including AC switch gear and rectifier transformers, shall be firmly grounded to the ground bus. Structural metalwork where exposed within the substation, supervisory control cabinets, and ventilation equipment or ductwork shall be grounded to the ground bus.

23.3.7.4 Where metallic enclosures inter connect grounded and ungrounded equipment (e.g., the anode bus enclosure between rectifier transformer and rectifier), adequate insulation methods shall be employed to provide high resistance to ground.

23.3.7.5 Design and installation of ground grid where required shall be per Section 13.

23.4 LIGHTING SYSTEMS (Refer To Section 4 and 13)

23.5 Substation Starting Sequence

23.5.1 The following depicts the starting sequence for a typical rectifier substation from the Electrical Supervisory Control Console.

23.5.1.1 Select substation zone. Master control relay for selected zone (Device No. 4) automatically closes and is indicated by zone identification light illuminating on operator's console.

23.5.1.2 Select incoming line breaker (Device No. 52L1 or 52L2).

23.5.1.3 Verify non-lockout status of incoming line breaker.

23.5.1.4 Close incoming line breaker.

23.5.1.5 Select Rectifier Transformer AC feeder breaker (Device No. 52R).

23.5.1.6 Verify non-lockout status of rectifier transformer unit.

23.5.1.7 Close Rectifier-Transformer AC feeder breaker.

23.5.1.8 DC associated cathode breaker (Device No. 72) automatically closes.

23.5.1.9 Select DC feeder breaker (Device No. 172).

23.5.1.10 Close DC feeder breaker.

23.5.2 Conditions Preventing Start

23.5.2.1 The conditions which will prevent starting of a rectifier substation remotely through Supervisory Control shall include, but are not limited to:

23.5.2.1.1 Failure of master control relay in zone unit.

23.5.2.1.2 Failure of AC rectifier transformer feeder breaker to close.

23.5.2.1.3 Failure of air flow device where applicable to actuate.

23.5.2.1.4 Equipment LOCAL-REMOTE switch in LOCAL position.

23.5.2.1.5 Loss of control voltage.

23.5.2.1.6 Hand reset lockout relay not reset.

23.5.3 Substation Shutdown Sequence

23.5.3.1 The following steps sequence the procedure for shutdown of a rectifier substation from the Electrical Supervisory Control Console at the Operations Control Center.

23.5.3.1.1 Select substation zone. Master control relay for selected zone (Device No. 4 automatically closes and is indicated by zone identification light illuminating on operator's console.

23.5.3.1.2 Select rectifier transformer AC feeder breaker (Device No. 52R).

23.5.3.1.3 Trip rectifier transformer AC feeder breaker (Device No. 52R).

23.5.3.1.4 The associated DC cathode breaker will automatically open.

23.5.3.1.5 AC Incoming Line Breaker will remain closed unless tripped from operator's console.

23.5.3.1.6 DC feeder breakers will remain closed unless tripped from operator's console. DC feeder breakers maybe required to function as "tie" feeders thereby remaining closed.

23.5.3.1.7 All shutdown breaker operations shall prevail, regardless of position of the "LOCAL-REMOTE" switch on any breaker.

23.5.4 Transformer-Rectifier Lockout

23.5.4.1 The following devices shall operate the Transformer-Rectifier AC Feeder Lockout relay (Device No. 86) and cause shutdown unit it is hand reset. One alarm shall be transmitted to Central Control to indicate the transformer lockout. The specific device that caused the lockout shall be annunciated on the local annunciator panel in the substation.

23.5.4.1.1 Transformer winding over-temperature device, second step (49 T2)

23.5.4.1.2 Transformer oil over-temperature device, second step (26 T2)

23.5.4.1.3 Transformer sudden pressure device (63 SP)

23.5.4.1.4 Transformer explosion diaphragm device (63 MR)

23.5.4.1.5 Rectifier over-temperature, device, second step(26 RT2)

23.5.4.1.6 Rectifier ground relay, hot structure (64C)

23.5.4.1.7 AC overcurrent phase relay, time (51A)

23.5.4.1.8 AC overcurrent phase relay, instantaneous and time (50/51)

23.5.4.1.9 AC overcurrent residual ground relay, instantaneous and time (50N/51N)

23.5.4.1.10 Rectifier diode failure second stage

23.5.5 DC Switchgear Lockout

23.5.5.1 The DC switchgear hot structure ground relay (Device 64D) shall trip the DC switchgear lockout relay (Device 86) and annunciate its operation on the local annunciator panel in the substation. Device 86 shall trip and lock out all cathode breakers and DC feeder breakers in the substation until it is hand reset.

23.5.6 Safety Devices

23.5.6.1 The following safety devices shall be annunciated continuously on the Electrical Console at the Control Center until the trouble is acknowledged or corrected. These devices shall all illuminate an annunciator panel provided in the substation:

23.5.6.1.1 Transformer winding over-temperature, first stage (49T1)

23.5.6.1.2 Transformer oil over-temperature, first stage (26T1)

23.5.6.1.3 Rectifier over-temperature, first stage (26 RT1)

23.5.6.1.4 UPS transfer switch position (83b)

23.5.6.1.5 Battery "charge" relay indicating "no charge"

23.5.6.1.6 UPS Inverter output failure

23.5.6.1.7 DC control power failure

23.5.6.1.8 Rectifier diode failure (95)

23.5.6.1.9 Cable failure

23.5.6.2 The following safety devices shall illuminate an annunciator panel provided in the substation.

23.5.6.2.1 Rectifier ground relay, grounded structure (64X)

23.5.6.2.2 [4]DC Switchgear, grounded structure (64Y)

23.5.6.2.3 [1]DC Switchgear, hot structure (64D)

23.5.6.2.4 Transformer low oil level (63 QL)

23.5.6.2.5 Rectifier diode failure (95)

23.5.6.2.6 Transformer sudden pressure relay (63SP)

23.5.6.2.7 Cable failure

23.6 MAINTAINABILITY AND CONSTRUCTIBILITY

23.6.1 The design of the electrical system comprising equipment, raceways, fixtures, devices, wires and cables shall be coordinated with structural, mechanical architectural and other disciplines for the purposes of providing adequate space, clearances and structural support, and to ensure non-interference with other trades during construction. It shall take into account the ease of maintainability of the electrical equipment installed. Maintenance operations include inspection, adjustments, cleaning, trouble shooting, servicing, repairs and replacement of electrical equipment. The equipment selected should be subject to minimal system component failure.

23.6.1.1 Space

23.6.1.1.1 Sufficient working space and adequate access shall be provided for the maintenance and replacement of electrical equipment. Adequate space around electrical equipment shall be provided and maintained to allow for heat dissipation and cooling. This requirement shall include adequate space for movement of equipment during initial installation, and during subsequent scheduled maintenance involving removal and replacement of failed equipment.

23.6.1.2 Accessibility

23.6.1.2.1 All electrical system switching and overcurrent protection devices shall be accessible to authorized persons only. Access to cables or conduits installed in return air plenums under station platforms shall be provided through manhole covers at appropriate locations.

23.6.1.2.2 Adequate means, such as lifting eyes and/or I beams with a running hoist, shall be provided for raising, lowering, shifting, removal or replacement of heavy electrical equipment. Pulling eyes shall be provided for the pulling of cables at the following locations:

23.6.1.2.2.1 Traction Power Substations

23.6.1.2.2.2 Tie Breaker Stations

23.6.1.2.2.3 Cable shafts

23.6.1.2.2.4 Manholes

23.6.1.2.2.5 Other locations where considered necessary

23.6.1.3 Equipment Protection Against Water and Moisture:

23.6.1.3.1 Each substation building and electrical room shall be designed to preclude any entry of water. Seals shall be provided on raceway and cable penetrating a building wall, floor or ceiling at a point. No exposed water or sewage piping shall be installed inside substation and electrical equipment rooms. No pipe or mechanical duct that could cause moisture or condensation to fall on the electrical equipment shall be located above any major electrical equipment. Manholes shall be sealed to prevent water pressure to break cable conduit seals in the facilities.

23.6.1.4 Embedded Conduits, Conduit Sleeves and Channel Inserts:

23.6.1.4.1 Embedded conduits can be installed in the space available between rebars. Where a slab has to carry a large number of conduits, steps shall be taken to ensure that it will be feasible to install all the conduits without compromising the structural integrity of the concrete structure. Adequate cross sections shall be shown on the drawings to indicate how the raceways and other embedded items will be installed and cross each other where applicable. Where embedded FRE conduit emerges from a concrete slab or a wall, a FRE to galvanized rigid steel conduit adapter shall be provided, except traction power conduit.

23.6.1.4.2 Where conduits are not provided as raceways, channel inserts shall be installed for supporting multiple conductor cables located under platforms, and in manholes. Spare conduit and sleeves shall be provided in concrete walls, floors or ceiling slabs of the AC Switchboard Rooms, Electrical Rooms, Traction Power Substation, Tie Breaker Stations, Mechanical Rooms, ductbanks and other areas as required for possible future requirements.

23.6.1.5 Electrical Plans, Details and Schedules:

23.6.1.5.1 Plans and details showing physical arrangement and elevation with dimensions shall be provided on the drawings for all major electrical and mechanical equipment, raceways, junction boxes, fixtures and other items so that the design and construction can be coordinated with mechanical, structural and other disciplines.

23.6.1.5.2 Schedules of all major electrical equipment including switchgear, switchboards, panelboards, transformers, disconnect switches, conduits, and cables shall be provided on the drawings. These schedules shall be complete and consistent with plans on associated electrical and mechanical drawings.

23.6.1.6 Lighting System (Refer to SECTION 4)

23.6.1.7 Operation and Maintenance Manual:

23.6.1.7.1 Operation and Maintenance Manual shall be provided for major electrical equipment. It shall include manufacturer's operation and maintenance instructions, Preventive maintenance inspection, wiring diagram, control and power elementary diagrams, list of spare parts and recommended stock quantities for one year routine maintenance and repair. A copy of approved shop drawing of equipment and other items shall be included.

23.7 SERVICE AND INSPECTION YARDS

23.7.1 Introduction

The service and Inspection Yards, referred as S&I yards on WMATA facilities, serve the functions of storing rail cars during non- revenue hour, provide for the inspection and maintenance of the cars and replacement and repair of bulky car equipment in Major Repair Shops. The propulsion power for the movement of rail cars to and from the yard, to support rail car auxiliaries of the stored cars in the yard, contact rail deicing and switch heaters is provided by the Traction Power facilities located within the Yard area.

23.7.2 Traction Power Design

The steel running rails in the yard are installed insulated from the ground in the same manner as the running rails for the main line revenue tracks, but because of its overall lower resistance to ground, due to the track lengths and configuration, the yard tracks are isolated from the mainline track through the insulated joints.

23.7.2.1 At the main line tracks and yard track isolation, the yard contact rail shall also be electrically isolated from the main line contact rail, therefore effectively isolating the yard traction power system from the main line traction power system. Physical separation between the mainline contact rail and yard contact rail shall be more than 52 feet. However means shall be provided to defeat electrical isolation of the mainline and yard traction system, should the rectifiers supplying the yard traction power fail.

23.7.2.1.1 At locations where vehicular access is required in the yard areas, contact rail shall be physically isolated by a distance exceeding 52 feet. The traction power jumper cable, supplementing contact rail current density shall be installed in the fiber glass conduits encased duct banks, to maintain yard contact rail electrical continuity.

23.7.2.2 Yard Traction power facilities shall be sized to accommodate up to four, three megawatt, transformer rectifier units and for reliability reason minimum of two units shall be installed in the traction power substation regardless of the load calculations. The yard load calculations shall include the following loads:

23.7.2.2.1 Auxiliary load of maximum number of rail that can be accommodated on the yard and storage tracks.

23.7.2.2.2 Constant wattage heater tape loads for all contact rails installed in the yard including yard track up the Mainline/Yard isolation point.

23.7.2.2.3 Load of the switch heaters.

23.7.2.2.4 Load to support house power for the S&I shop.

23.7.2.2.5 Loads to support movement of one 8 car train moving in and one moving out of the yard simultaneously.

23.7.2.2.6 Where yard TPSS is also supplying the house power to the S&I shop through a dedicated transformer rectifier unit, a positive and negative bus tie breakers shall be installed in the yard TPSS to supply shop through the Yard traction power equipment in case transformer rectifier unit supplying the shop fails. Under this scenario, as required under section 23.7.6 of the design criteria, backup traction supply to the S&I shop from the yard traction power distribution system shall not be necessary.

23.7.2.3 Yard rectifiers shall support100% of the calculated loads without utilizing over load capabilities of the rectifiers. The overload capabilities of the yard rectifiers shall be considered only during the movement of the eight car train in and out of the yard with yard in addition to supplying 100% of the designed loads.

23.7.2.4 Yard Contact Rail (YCR) shall be of composite rail design similar to the one utilized for the main line. The end approaches in the yard contact rail shall be 5.6 feet standard unless otherwise noted. The electrical characteristics of the contact rail and the running rail, are covered in other sections of Manual of Design Criteria.

23.7.2.5 Circuit breakers shall be provide to supply power to the yard YCR.

23.7.2.5.1 The yard traction power system shall be so designed that the yard lead YCR are supplied through dedicated feeder breakers.

23.7.2.5.2 Tie Breaker Stations shall support double crossovers installed at locations determined critical, based upon yard's failure mode analysis, to maintain yard operations during emergency.

23.7.2.5.2.1 Where more than one TPSS supply yard YCR, the YCR shall receive a double end power supply.

23.7.2.5.2.2 The YCR supplying car storage tracks and other tracks where cars can be stored shall have either double end power supply or means to be supplied through the other YCR through a Tie Breaker Station.

23.7.2.5.2.3 Electrically interlocked, Positive and negative bus tie breakers shall provide mainline/yard isolation as well as DC power to the S&I shop where applicable.

23.7.3 Traction Power Cable

Traction power positive cable shall be LSZH, standard duty, 127 strands, 1000 KCMIL, or 169 strands, 1500KCMIL, 2KV insulated shielded cable and shall be connected to the composite contact rail as shown. Cable connecting the contact rail to the feeder cable and the jumper or transitional cable shall be LSZH, 1000KCMIL or 1500 KCMIL, 2KV, extra-flex, 427 strand, non-shielded cable.

23.7.3.1 Traction power negative cable will LSZH, standard duty, 127 strands, 1000KCMIL or 169 strands, 1500KCMIL, 2KV insulated cable.

23.7.3.1.1 The negative cable shall be connected to only one of the running rail (Power Rail) per track and shall be utilizing C-Clamps as shown. The other rail of the track (Signal Rail) shall be for the ATC signaling purposes and shall not be electrically connected to the Power Rail.

23.7.3.2 The power rails in the yard shall be cross-bonded to equalize traction power return current. Additional cross-bonding cable shall be installed to compensate loss for cross-bonding cable as a backup means for the traction current return.

23.7.3.3 At special track work, where the power rail and the signal rail reverse sides, adequate number of power bond cable shall be installed to maintain electrical resistance of the Power Rail.

23.7.3.3.1 Installation of the negative return and cross bonding cable to the Power Rail shall be coordinated with the ATC discipline.

23.7.4 Traction Power Equipment:

23.7.4.1 Technical requirements of the traction power equipment shall be the same as those of the main line with the following exceptions

23.7.4.1.1 The remote control of the yard traction power equipment shall be from the yard control panel through the Yard SCADA System. HMI installed in the Yard Control Tower shall display equipment arrangement, its status and alarms Information.

23.7.4.1.2 The MPR providing protection to the DC feeder breakers shall be inhibited for the load measuring and automatic reclosing of the circuit breakers.

23.7.4.1.3 The setting of the protection relay shall be based upon an approved short circuit/ coordination study.

23.7.4.1.4 Provision shall be made to supply S&I house power from the traction power substation distribution system, in case transformer rectifier unit supplying the S&I house power fails. Key interlocks shall be provided to avoid duel supply to the S&I shop.

23.7.4.2 The traction power equipment shall communicate with the yard control tower through the SCADA equipment for control, alarm and status indications. Yard control tower shall be equipped with means to de-energize the entire yard with one command (Emergency OFF)

23.7.4.3 Where the yard contact rails have a duel end feed, trip command from the yard control tower shall trip both breaker supplying the same tracks simultaneously. The closing of the feeder breakers shall however be independent of this requirement.

23.7.5 Yard Storage Tracks:

Adequately sized no load make/break Isolation Switches with a minimum rating of 2000A shall be install for each storage track to isolate the storage track for maintenance/ repair purposes.

The Isolation Switches shall be enclosed in a fiberglass enclosure suitable for pad mounting in horizontal position.

The isolation switches shall have enough number of auxiliary contacts to transmit its status to the yard control tower and provide means to isolate both power buses of the heater cable install on the storage tracks.

At the isolation switch locations, a minimum of 52 feet gap shall be maintained between the storage track and main yard track contact rails (YCR).

Cross-bonding between the power return rail of storage tracks shall be installed for the purpose of traction power return current equalizing.

23.7.6 Service and Inspection Shop:

23.7.6.1 750 VDC House power required for the movement of the cars in and out of the S&I shop and during testing and inspection of the rail cars, is provided through a dedicated TPSS located in the S&I. This TPSS design shall have provisions to receive backup power from the Yard traction power distribution system in case failure of its transformer rectifier units. Key interlock scheme shall inhibit simultaneous duel feed to the shop traction system. This house power is isolated from the yard traction power distribution system.

23.7.6.2 DC switchboard located in the TPSS (DC Power Substation) shall supply power to the car wash and S&I shop's overhead stinger system. The stinger system enable rail car movement in and out of the shop.

23.7.6.2.1 The stinger system shall be so designed to permit only one of the stingers to be energized at a time.

23.7.6.3 Energization of any of the stinger system or of the car wash contact rail shall follow an audio and visual warnings.

23.7.6.3.1 The DC switchboard shall also supply power to the pedestal and wall mounted contactor. These pedestals and wall mounted contactor shall supply power to the rail car during inspection and testing.

23.7.6.4 S&I shop and the car wash tracks shall be electrically isolated from the yard tracks and shall be encased in an insulating epoxy to provide isolation from the S&I shop floor's reinforcement.

23.7.6.5 S&I shop and car wash tracks shall be firmly grounded to the substation grounding system.

23.7.7 Contact Rail Heater:

23.7.7.1 Constant wattage heater shall be installed on all yard contact rails, including the contact rail in the storage tracks.

23.7.7.2 Both buses of the contact rail heaters shall be extended from the main YCR heater to the storage track heater through the auxiliary switches included with the associated Isolation Switch to isolate the storage area heater tape from the source when the Isolation Switch is open.

23.7.7.3 The YCR and storage track heaters shall be associated by zones with provision for local control to control individual zones or all zones simultaneously from the Yard Control Tower with a single command.

23.7.7.4 Micro Process based Master Heater control panel shall be located in the yard Traction Power Substation and shall receive the control power from the TPSS 125 volts DC distribution Panel. Master control panel control the way side Heater Control panels and receives heater tape status indication for transmission through SCADA system to the Yard Control Tower. Yard contact rail heater are remotely controlled from the Yard Control Tower under normal operation.

23.7.7.4.1 Control power for the wayside heater control panels shall be derived from 750volts dc traction power distribution system.

23.7.8 Yard Control Tower:

23.7.8.1 With TPSS and the Yard Master Control Panel selector switches in remote Yard Control Tower through HMI shall communicate to the equipment through its DIO for control and status. The equipment status and equipment arrangement and that of the yard YCR is displayed on large screen monitor as detailed in manual of SCADA design criteria.

23.7.8.2 The yard traction power equipment and SCADA design shall provide for the de-energization of the entire yard traction system with a single command from the Yard Control Tower.

23.8 STANDARDS AND CODES

23.8.1 Where applicable, Traction Power, AC Power and lighting system design shall conform to the following standards and codes:

23.8.1.1 National Electrical Code (NEC)

23.8.1.2 National Electrical Safety Code (NESC)

23.8.1.3 Electrical Codes of the District of Columbia and Counties of Maryland and Virginia through which the Transit System will operate

23.8.1.4 American National Standards Institute (ANSI)

23.8.1.5 National Electrical Manufacturers Associations (NEMA)

23.8.1.6 Institute of Electrical and Electronic Engineers (IEEE)

23.8.1.7 Insulated Cable Engineers Association (ICEA)

23.8.1.8 Underwriters Laboratories, Inc. (UL)

23.8.1.9 Intertek Testing Services (ITS)

23.8.1.10 Occupational Safety & Health Administration (OSHA)

23.9 GLOSSARY

23.9.1 Standard Terminology

23.9.1.1 In general, definitions applied to Traction Power, AC Power, and Supervisory Control Functions shall conform to definitions listed in ANSI/IEEE C37.100 of the American National Standards Institute and the Institute of Electrical and Electronics Engineers.

23.9.1.2 Basic electrical terminologies used in these criteria, which are not defined in the ANSI/IEEE reference or in the following Special Terminology, are to be interpreted in their normal usage.

23.9.2 Special Terminology

23.9.2.1 The following definitions of special terms shall apply. Terminology more pertinent to Train Control may also be used in the Electrical Criteria.

23.9.2.1.1 Anode Bus:

23.9.2.1.1.1 An assembly of rigid conductors with associated connections, joints and insulating supports connecting the AC output of a rectifier transformer to a rectifier.

23.9.2.1.2 Cathode Breaker (Rectifier Main Breaker):

23.9.2.1.2.1 A direct current circuit breaker protecting the positive output side of a rectifier.

23.9.2.1.3 Cathode Bus:

23.9.2.1.3.1 An assembly of rigid conductors with associated connections, joints and insulating supports carrying positive direct current from the output side of a rectifier to a cathode breaker.

23.9.2.1.4 Contact Rail Anchor:

23.9.2.1.4.1 An insulated assembly attached to contact rail and invert or ties, which restrains the rail against thermal movement parallel to the tracks.

23.9.2.1.5 Contact Rail Assembly:

23.9.2.1.5.1 The bus bar at trackside which carries electric energy for the propulsion of trains; the assembly includes supports, insulation and protective covering.

23.9.2.1.6 DC Feeder Breaker:

23.9.2.1.6.1 A direct current circuit breaker with associated load sensing devices, the purpose of which is to provide energization to, or remove energization from, a section of contact rail. The feeder breaker may operate as a tie feeder or as a radial feeder, or both.

23.9.2.1.7 End Approach:

23.9.2.1.7.1 Segment of contact rail graduated from minimum height to full height, to permit car shoes to ride up onto the contact rail or leave it at a contact rail gap.

23.9.2.1.8 Interface:

23.9.2.1.8.1 The junction between two systems or subsystems. A point where the two systems or subsystems are common.

23.9.2.1.9 Rectifier - Transformer AC Feeder Breaker:

23.9.2.1.9.1 A primary voltage alternating current circuit breaker in the line side of a rectifier transformer.

23.9.2.1.9.2 TPSS and Tie Breakers will be identified by number i.e., TPSS/TBS C01, 1402 etc.

23.9.2.1.9.2.1 TPSS and TBS track feeder breakers will have supervisory control identification as follows:

23.9.2.1.9.2.1.1 TPSS - Breaker 31, 32 supplying in-bound side of control pail and breaker 33, 34 supply out-bound side of control rail

23.9.2.1.9.2.1.2 TBS - Breaker 41, 42 supply in-bound side of contact rail and breaker 43, 44 supply out-bound side of contract rail

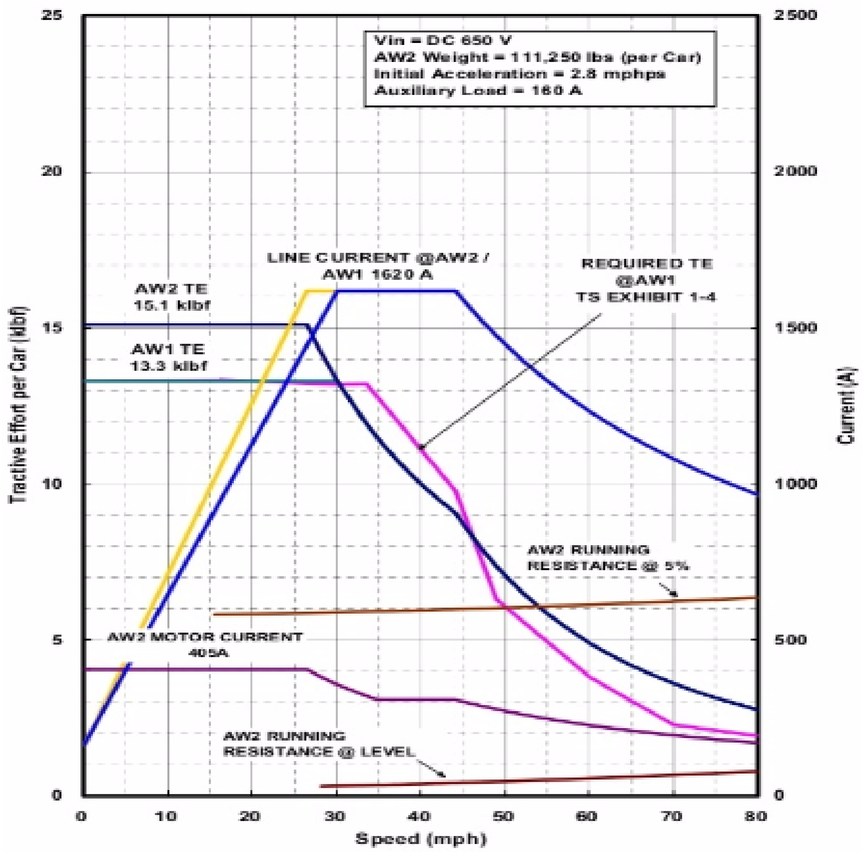


FIGURE 23.1

Railcar Electrical **Performance Characteristics**

SECTION 24 - AUTOMATIC FARE COLLECTION (AFC)

24.1 GENERAL (FUTURE)

24.2 Central Computer Systems (Future)

24.3 Bus Garage/Shop Facilities (Future)

24.4 Bus Farebox24.4

24.5 Light Rail (Future)

24.6 Heavy Rail Station

24.6.1 Mezzanine Layouts and Locations (Future)

24.6.1.1 Walker Ducts (Future)

24.6.1.2 Conduits (Future)

24.6.1.3 Wire and Cable (Future)

24.6.1.4 Faregate Aisles

The required number of standard faregate aisles is calculated by dividing the projected faregate transactions of the peak minute by the average transactions per minute for one aisle. The calculation employs two important factors: peak load and platform clearance. The peak load concept, or peaking factor, accounts for the uneven distribution of disembarking passenger loads during the peak hour. With respect to platform clearance, it is WMATA policy that platforms be cleared in half the scheduled headway time of the peak train service. Clearance of the platform allows for headway fluctuations, which may occur during peak periods, and assures that the disembarking passenger load will have unimpeded flow to and through the faregate aisles, without the danger of passenger back-up. The platform clearance factor is assigned only to the number of disembarking passengers.

Spare aisles, a service gate, and at least one ADA accessible faregate aisle are added to the number of standard faregate aisles to establish the total faregate aisle program.

24.6.1.5 Faregate Aisle Queue:

The queue length is calculated if the number of standard faregate aisles is less than the program requirement. The calculation determines the maximum queue volume, and employs a peak queue factor and interpersonal spacing for Level of Service C pedestrian flow. If the number of standard faregate aisles satisfies the program requirement, then the minimum queue length may be applied.

24.6.1.6 Farecard Vendors:

The required number of farecard vendors is calculated by dividing the projected farecard vendor transactions of the peak minute by the average transactions per minute for one vendor. The calculation employs two factors: peak load and a percentage factor for the number of peak-hour boarding passengers using the vendors. The peak load concept, or peaking factor, accounts for the uneven distribution of passenger loads during the peak hour. Spare vendors are added to the number of farecard vendors to establish the total farecard vendor program. One accessible farecard vendor and one accessible exit fare vendor are required.

The percentage factor varies among the stations, and is highest for those stations that serve passengers unfamiliar with the automatic fare collection system, e.g. tourists and convention attendees.

24.6.1.7 Farecard Vendor Queue:

Calculate the queue length if the number of farecard vendors is less than the program requirement. The calculation determines the maximum queue volume, and employs a peak queue factor and interpersonal spacing for level of service C per pedestrian flow criteria. If the number of farecard vendors satisfies the program requirement, then the minimum queue lengths may be applied.

24.6.2 Power Requirements (Future)

24.6.3 Data Communication Network (Future)

24.6.4 SMADS (Future)

24.6.5 Vending Equipment (Future)

24.6.6 Faregates (Future)

24.6.7 Performance and Reliability (Future)

24.6.8 Fire and Intrusion (Future)

24.6.9 Signage and Equipment Appearance (Future)

24.6.10 Mezzanine Railing (Future)

24.7 PARKING FACILITIES (FUTURE)

24.8 ADMINISTRATION AND REGIONAL FACILITIES

SECTION 25 - AUTOMATIC TRAIN CONTROL (ATC)

25.1 GENERAL

25.1.1 Criteria Coverage

25.1.1.1 Scope

These Criteria include all functional and design criteria for Train Control Systems for the Washington Metropolitan Area Transit Authority (WMATA) METRORAIL Transit System. This includes criteria for the Automatic Train Control (ATC) System for the mainline Revenue Service portion of the METRORAIL System, and for the Signal Control and Interlocking Systems applicable to the yards and other non-revenue service portions of the METRORAIL System. These Train Control Criteria (Section 3) do not include criteria for the WMATA Operations Control Center (OCC). See Section 26.2.1 for an overview of the Computer Systems portion of the criteria.

25.1.1.2 Intent

The intent of these Criteria is to prescribe conditions which must be specified, designed, properly implemented, tested, and documented, to result in WMATA Train Control Systems and equipment which shall control the movement and certain operations of trains in a safe and expeditious manner, and in complete compatibility with the current Train Control Systems in use on the WMATA METRORAIL System.

25.1.1.3 Standards

The design of WMATA Train Control Systems must be coordinated with the design standards of current and new transit car equipment, propulsion power equipment, and communications equipment, and with the current WMATA Train Control Systems.

25.1.1.3.1 Organizational Standards

25.1.1.3.1.1 The design and implementation of WMATA Train Control Systems shall be guided by the requirements of:

25.1.1.3.1.2 Part 236-Rules, Standards, and instructions governing The Installation, Inspection, Maintenance, and Repair of Signal and Control Systems, Devices and Appliances, of the: Rules and Regulations Governing Railroad Signal and Control Systems, as prescribed by the Department of Transportation -Federal Railroad Administration - Office of Safety;

25.1.1.3.1.3 National Electrical Code and all applicable local codes.

WMATA Train Control Systems shall conform to the recommendations of applicable Parts of the Signal Section Manual of the Association of American Railroads/American Railway Engineering and Maintenance-of-Way Association (AAR/AREMA Signal Manual of Recommended Practice) unless otherwise specified.

25.1.1.3.2 WMATA Standards and Practices

25.1.1.3.2.1 The design and implementation of WMATA Train Control Systems shall comply with the requirements of:

- Current WMATA METRORAIL clearance standards;
- Current WMATA METRORAIL Standard Operating Procedures;
- Current WMATA METRORAIL wayside signal aspects, names, and indications;
- Current WMATA METRORAIL nomenclature, terminology and definitions of terms.

25.1.2 Current Wayside METRORAIL System Configurations

25.1.2.1 Current METRORAIL "Routes," "Lines" and Yards

25.1.2.1.1 Routes

The various geographical METRORAIL "Routes" are designated by a letter of the alphabet and a geographical destination name, usually the outer terminus of the Route as follows:

"A" Route/Shady Grove Route:

Metro Center (Upper) to Shady Grove;

"B" Route/Glenmont Route:

Metro Center (Upper) to Glenmont;

"C" Route/Huntington Route:

Metro Center (Lower) to Huntington;

"D" Route/New Carrollton Route:

Metro Center (Lower) to New Carrollton;

"E" Route/Greenbelt Route:

Gallery Place (Lower) to Greenbelt;

“F” Route/Branch Ave. Route:

Gallery Place (Lower) to Branch Ave.

“G” Route/Addison Road Route:

D-G Junction to Largo Town Center;

“J” Rte/Franconia/Springfield Rte.:

C-J Jct. to Franconia/Springfield;

“K” Route/Vienna Route:

Rosslyn to Vienna;

"L” Route/Potomac River Crossing:

L’Enfant Plaza (Upper) to Pentagon.

“N” Route / Wiehle Ave Route:

East Falls Church to Wiehle Ave.

25.1.2.1.2 Lines

There are five color-coded Revenue Service “Lines” normally operated by the Authority, as follows:

Line	From	To	Routes Used
Red	Shady Grove	Glenmont	A & B
Orange	Vienna	New Carrollton	K, C &D
Blue	Franconia/ Springfield	Largo Town Center	J, C, D & G
Yellow	Huntington	Fort Totton	C, L, F & E
Green	Greenbelt	Branch Ave.	E & F
Silver	East Falls Church	Dulles	N

25.1.2.1.3 Yards

There are eight Yards on the METRORAIL System, as follows:

Yard Name **Type**

Brentwood	Heavy Repair/S&I
Greenbelt	Heavy Repair/S&I
Alexandria	S&I
New Carrollton	S&I
Shady Grove	S&I
West Falls Church	S&I
Glenmont	Storage
Branch Avenue	S&I
Dulles	S&I

25.1.2.2 Current Wayside Train Control System Configurations

25.1.2.2.1 Mainline Automatic Train Control

Systems shall conform to current WMATA practices as follows:

25.1.2.2.1.1 The mainline, revenue service Automatic Train Control (ATC) System shall be controlled primarily from wayside Train Control Rooms located at Passenger Stations and certain intermediate locations. The vital, fail-safe relay and microprocessor-based control equipment comprising the wayside portion of the Automatic Train Protection (ATP) subsystem shall be located in these TCRs, along with non-vital control and indication equipment used in the wayside portion of the Automatic Train Operation (ATO) and Automatic Train Supervision (ATS) subsystems.

25.1.2.2.1.2 The equipment in the TCRs shall be hard-wired to the various Train ATC Control track circuits, switch machines, signals, loops, marker coils, pushbuttons, snowmelters and other trackside train control equipment.

25.1.2.2.1.3 For supervisory purposes, the ATC equipment shall be hard wired to a Remote Terminal Unit (RTU) in each mainline TCR in a prescribed sequence as shown on pre-approved RTU Scan Sheets. The RTU shall in turn be wired to a TC/COMM interface junction box in an adjoining Communications Equipment Room. The Communications

System (by others) provides the link between the field RTUs and the ATS Operations Control Centers (OCC) in downtown Washington, DC and Landover, MD. See Section 26.2.1 for an overview of the Computer Systems portion of the criteria.

25.1.2.2.2 Yard Signal Control and Interlocking Systems shall conform to current WMATA Yard Train Control System practices as follows:

25.1.2.2.2.1 Yard Signal Control and Interlocking Systems shall be controlled by vital and non-vital Train Control (TC) equipment installed in Train Control Rooms located at strategic points in the Yard.

25.1.2.2.2.2 The TC equipment in the TCRs shall be hard-wired to the various switch machines, signals, snowmelters, dragging equipment detectors and other trackside train control equipment in accordance with WMATA standard practices and in a manner approved by the Authority.

25.1.2.2.2.3 A Yard (Interlocking) Control Panel shall be provided in the Yard Control Room to enable WMATA Interlocking Operators to supervise the movement and routing of transit cars and railborne maintenance/ service equipment within the limits of the yards.

25.1.2.2.2.4 Control of a portion of the yard lead tracks adjacent to a mainline passenger station may have to be made transferable between the Yard Interlocking Operator and Central Control.

25.1.2.3 Train Control Room Configuration

25.1.2.3.1 Racks and Cable Trays

Cable trays and 19-inch equipment racks for Train Control equipment, power supplies, and cable entrance terminations, shall be installed in rows in the TCRs in compliance with WMATA standard spacing requirements and in coordination with lighting, power source, grounding and HVAC equipment installed by others.

25.1.2.3.2 Train Control Power

Automatic power transfer and bypass-isolation equipment, room prime ground bus bars, and, where applicable, large interlocking control panels, shall be wall-mounted in the TCRs at locations pre-approved by the Authority.

25.1.2.3.3 Maintenance Furniture and Equipment

Maintenance furniture and equipment, as specified, shall be provided at appropriate locations in each TCR.

25.1.3 Basic Train Control Functions, Principles and Requirements

25.1.3.1 Train Location Detection

Determination of train location on the WMATA METRORAIL System shall be accomplished by means of the shunting of track circuits by the wheel-and-axle sets of the transit cars.

25.1.3.1.1 Vital Track Circuits

25.1.3.1.1.1 Vital Audio Frequency (AF) track circuits (of the type described in Section 25.2.2.1.1.1, shall be used for “train detection” purposes on mainline tracks in the revenue service areas and on certain yard lead tracks.

25.1.3.1.1.2 Vital, single-rail, AC power frequency track circuits (of the type described in Section 25.1.6.1), shall be used for train detection purposes on mainline interlocking tracks and on yard interlocking, yard lead, and yard running tracks, and as otherwise specified.

25.1.3.1.2 Non-vital Track Circuits

Non-vital, series-type, alternating current (60 Hz) track circuits (of the type described in Section 25.3), shall be used for train detection purposes on yard storage, wash track, and shop lead tracks.

25.1.3.2 Train Separation

25.1.3.2.1 Block Design

The Block Design shall perform three basic functions:

25.1.3.2.1.1 Provide track blocks and speed determination for safe train operation, i.e. provide safe-braking distance (SBD)train separation for both “ideal” and “worst case” trains at all times.

25.1.3.2.1.2 Provide the required operational headways (in both directions);

25.1.3.2.1.3 Allow trains to travel as fast as safely possible.

25.1.3.2.1.4 In addition, the Block Design shall provide such track circuit boundaries as are necessary for:

- crossbonding and negative propulsion return requirements;
- safe definition of interlocking boundaries;
- proper operation of program station stopping;
- automatic train routing and automatic terminal operation.
- The methods, procedures and formulae used to determine Safe Braking Distance and intermediate block boundaries shall be as specified in the latest WMATA Automatic Train Control Contract Specifications.

25.1.3.2.2 Speed Control

Appropriate mainline speed limit “commands” shall be generated by the wayside Automatic Train Protection (ATP) System as determined by the Block Design, based upon trackwork characteristics, transit vehicle characteristics, train routing, passenger comfort considerations, and train occupancy of the various track blocks. These speed commands shall be transmitted by the wayside ATP system to the Audio Frequency track and loop circuits where they will be detected and acted upon by the carborne Automatic Train Control systems to safely control the acceleration, speed, and braking of the transit car trains.

The WMATA Automatic Train Control uses stepped code speeds for operating vehicles on the main line tracks. The code speeds are: 15, 22, 28, 35, 40, 45, 50, 55, and 65, and 75. The design of a curve for a faster speed than one of the coded speeds will result in the ATC operating the train through the curve and spirals at code speed which is below the rated design speed of the curve/spiral. For example a curve designed for 44.5 miles per hour will be limited to 40.0 mph in Metrorail operation. The determination of maximum design speed through a curve for areas of limited space should recognize this limitation in design flexibility in the design of actual curve super elevation.

25.1.3.2.3 Traffic Control

25.1.3.2.3.1 Vital traffic circuits shall be provided to prevent opposing moves of trains between interlockings on mainline tracks and on certain yard lead tracks. These vital traffic circuits shall be integrated with non-vital, automatic traffic initiation circuits, and configured and implemented in the same manner as the vital traffic circuits currently in use on the WMATA METRORAIL System.

25.1.3.2.3.2 Yard running tracks shall be equipped with non-vital traffic and traffic initiation circuits configured and implemented in the same manner as those currently in use on WMATA Yard running tracks.

25.1.3.3 Train Routing

Route initiation shall be accomplished by identifying the desired route in terms of the entering signal and exiting signal.

25.1.3.3.1 Manual Route Initiation from Central or Local Interlocking Control Panel Manual route requests at an interlocking shall be initiated and selected as follows:

25.1.3.3.1.1 The desired entrance point (home signal) control device shall first be activated. Once this has been done, the Entrance-Exit system circuits (logic) shall determine the "status" of all possible routes emanating from the chosen entrance point, based upon conditions in the field, and shall indicate which of these possible route exit points are "available," i.e., can safely accept a train exit movement from the interlocking without conflicting with any other route previously granted or requested. (A route request originating a tan intermediate or hold-out signal has only one possible route "exit." The "availability" of this route will depend upon the current availability of the desired "traffic" direction on the applicable exit track.)

25.1.3.3.1.2 The desired route through the interlocking shall be "selected" by activating the control device at the "available exit" point desired.

25.1.3.3.2 Automatic Route Initiation

Facilities shall be provided at designated locations for train routing to be automatically initiated in one of three ways, as applicable:

25.1.3.3.2.1 By track occupancy in approach to a converging switch (first-come, first-served);

25.1.3.3.2.2 By recognition of train destination code by the TWC System (in approach to one or more diverging switches);

25.1.3.3.2.3 By terminal mode selection in approach to a terminal interlocking.

25.1.3.3.3 Wayside PB Route Initiation

Facilities shall be provided to enable train operators to initiate their own desired routes at certain designated locations, by means of wayside pushbuttons.

25.1.3.3.4 Initiation Coordination

The methods of route initiation described above shall be coordinated to protect against misrouting and lockups.

25.1.3.3.4.1 Coordination shall include:

- local-remote control to prevent both local control and central control from being active at the same time;
- lockout control to prevent any active initiation method from functioning while another method is being used to initiate a route, and;
- time-out control to cancel an unidentified entering signal if an exit is not identified in a predetermined time.

25.1.3.3.5 Route Completion

After the route initiation is completed by identifying both the entering signal (PBS relay energized) and the exiting signal (XS relay energized), the route completion circuits (logic) shall complete the route by requesting the proper switch positions, de-energizing the unselected “available exit” (EX) relays, making a preliminary check of the route integrity, initiating the vital locking, and initiating the request for signal clearing. Route completion shall be accomplished as described in the latest WMATA Train Control Specifications.

25.1.3.3.6 Time Released Approach Locking

Approach locking with timed release shall be provided for all controlled signals. One such locking circuit shall be provided for each signal or group of converging-route signals. This form of locking shall be initiated when the Route Check (RC) relay becomes energized and shall remain in effect until released by one of the following:

- The signal is accepted by the train (two track release).
- The signal is set to stop and no train is within the approach limits.

- The signal is set to stop and a predetermined “approach” time has expired.

The approach locking (AS) relay circuits shall be arranged such that a momentary interruption of track circuit energy will not release the locking. This shall be accomplished by using “two track release,” (the last track circuit within the interlocking, and the first, “exit” track circuit beyond the interlocking). The two track circuits shall be driven from different branch fuses, and the AS relays shall be cross checked so that, if opposing AS relays are both de-energized, as would be the case with a dc bus failure, time must be run to release the locking.

25.1.3.3.7 Route Locking

25.1.3.3.7.1 Route locking shall be provided to maintain security of the route ahead of the train as it progresses through the interlocking. Route locking shall be initiated by the initiation of approach locking and shall be released when approach locking is released and there are no occupancies in the route. In some cases the route shall be divided into contiguous sections for route locking purposes and locking of the section(s) of the route behind the train shall be released (sectional route release) as the train progresses through the route.

25.1.3.3.7.2 Route Locking shall be performed by Route Stick (RS) relays.

25.1.3.3.8 Detector Locking

Detector locking shall be established by the track relay(s) for the track circuit(s) in which each switch (or crossover) in the route is located and shall prevent switches from being thrown under a train. At interlockings, loss of shunt protection shall be provided by requiring track relays to be energized for a predetermined time before locking is released.

25.1.3.3.9 Switch Control and Indication

25.1.3.3.9.1 The switch control relays (NWZ and RWZ)shall be driven from the switch call relays (lever repeaters NLP and RLP) in the route completion network. The switch control relays shall be circuited to provide storage of the switch call, provide premature indication prevention, and prevent preconditioning.

25.1.3.3.9.2 The mainline switch control repeater relays shall be vital relays, primarily for maintenance convenience.

25.1.3.3.9.3 The mainline switch control repeater relays shall control pole changed energy to the switch operating relays (NWR and RWR) through lock stick relay (LSR) contacts. The lock stick relay contacts shall be wired to provide a short circuit across the switch operating relays when the LSR is de-energized.

25.1.3.3.9.4 A lock stick relay (LSR) shall be used to provide mainline switch stroke completion in the event that the lock relay becomes de-energized prior to completion of the switch stroke.

25.1.3.3.9.5 Overload protection of mainline switch machine motor circuits shall be provided by an overload stick relay (OR), which has one coil in series with the motor circuit. The second coil shall be used as a stick coil and shall be energized (through contacts of the same relay) from the drive circuit for the switch operating relays.

25.1.3.3.9.6 Mainline switch machine motor circuits shall be two-wire, pole changed circuits controlled by magnetic blow-out contacts on the switch operating relays.

25.1.3.3.9.7 Mainline switch position indication shall be controlled by a set of switch circuit controller contacts within the switch machine which are part of a two wire, pole changed circuit, driving a pair of biased switch repeater relays (NWPR and RWPR). Where two switch machines are operated as one, such as at a crossover, the indication circuit shall be controlled by the switch circuit controllers in both switch machines connected to one another by way of the Train Control Room to drive a single set of switch repeater relays.

25.1.3.3.9.8 Switch correspondence relays shall be provided to verify that the switch repeater relays are indicating that the switch is in the position required by the switch control and switch operating relays.

25.1.3.3.9.9 NOT USED

25.1.3.3.9.10 Signal Control

Signals shall be controlled by home signal (HG) relays which are energized by route check (RC) network relays. The following checks shall be included in these networks:

- Approach locking is in effect.

- Route locking is in effect.
- Traffic locking beyond the exit signal is in effect.
- Lock (and mainline Lock Stick) relays are de-energized.
- Switches are in proper correspondence.
- Route is not occupied.
- Timers associated with release of locking are at zero time.
- There has not been an overrun of a red signal controlling a conflicting route at the interlocking.

Where a number of control lines extend past a mainline facing point signal location, route sensitive signal repeater relays shall be provided for use in the speed circuits.

25.1.3.3.9.11 Signal Clearing

Once the desired route has been aligned and checked, locking activated, and, where applicable, suitable traffic direction established, the ATP system shall:

25.1.3.3.9.11.1 Cause the applicable wayside signal to display the appropriate “clear” aspect. Signal lighting energy shall be controlled through front and back contacts of the home signal (HG) relays. (The two red lenses of the STOP aspect shall be independently lighted from separate energy buses.)

25.1.3.3.9.11.2 Where applicable, cause the appropriate speed commands to be transmitted (in the proper sequence).

25.1.3.3.9.11.3 The ATS System shall then indicate the route aligned and locked, and the cleared signal, to Central and to the local control panel(s).

25.1.3.3.9.12 Speed Command Loop Control

Mainline speed command loop control and selection circuits shall be provided to sequence the transmission of speed commands through interlockings. The circuits and sequencing shall be such that a speed command never appears behind a train and only one loop is energized downstream of the track circuit occupied by the train.

25.1.3.3.9.12.1 Loop control circuits shall be organized to require that the appropriate home signal be clear and a train be on the first track circuit in the approach before the sequence can begin.

25.1.3.3.9.12.2 Overrun protection shall be provided to interrupt the sequence and stop the transmission of all speed commands within the interlocking in the event of an overrun of a red signal controlling a conflicting route.

25.1.3.4 Rail/Impedance Bond Circuit Connections

25.1.3.4.1 Negative Propulsion Return Current Connections

The yard and mainline Train Control Systems shall include all running rail and impedance bond connections of the types and sizes required by the applicable Specifications for negative-return rail transposition purposes, for current equalizing purposes, and for the return of propulsion current from the trains, through the running rail(s), to the substation-return conductors (furnished by others). This shall include compression cone type, compression eyelet type, compression-bolted type, and base-of-rail-clamped type bonds, as specified.

25.1.3.4.2 Track Circuit/Rail Connections

25.1.3.4.2.1 All power-frequency track circuit leads and bonding shall be provided.

25.1.3.4.2.2 Power frequency track circuit leads shall be connected to the running rails by means of rail-web, pin-type connectors of the specified type and size.

25.1.3.4.2.3 Signal rails shall be bonded by means of exothermically connected rail-head bonds of the specified type wherever possible, and by rail-web, pin-type bonds where necessary.

25.1.3.4.3 Snowmelter Related Rail Connections

25.1.3.4.3.1 All rail connections necessary for the safe operation of switch point snowmelters and switch rod heater units shall be provided in the specified manner. This shall include:

25.1.3.4.3.1.1 Exothermic connection of snowmelter and rod heater unit negative return leads to the center of the web of the proper negative return rail(s).

25.1.3.4.3.1.2 Exothermic connection of snowmelter case-heater negative return leads to the proper negative-return rail, or bolted connection to appropriate impedance bond center tap.

25.1.3.4.3.1.3 Base-of-rail exothermic connection of the snowmelter fuse box positive energy lead to the appropriate third rail.

25.1.3.5 Basic Criteria for TC Circuits and Equipment

25.1.3.5.1 Clearances

All wayside Train Control equipment shall be designed and installed to provide 4-inch clearance for the dynamic outline of the METRO transit cars wherever possible. This shall include allowances for the end and center overhang of transit cars on curved track (and when passing through crossovers and diverging turnouts), and for the tilting of the transit cars on superelevated track. In all cases where a 4-inch transit car clearance envelope cannot be maintained, an absolute minimum 2-inch clearance envelope shall be maintained. See, Figure 25 - TC2.

25.1.3.5.2 Maintainability

All Train Control equipment shall be designed and installed in such a manner that it will be easy to maintain and replace.

25.1.3.5.3 Track Circuit Length

The running rail portion of every track circuit (or contiguous portion thereof) shall be at least 50 feet in length (to avoid the possibility of being straddled by the transit car wheelbase).

25.1.3.5.4 Cross-Bonding

Negative propulsion return cross-bonding of mainline tracks shall be provided at intervals of approximately2000 feet wherever practicable, i.e., where cross bonding conduit has been furnished in place by others. Under no circumstances shall both ends of an AF track circuit be cross-bonded nor shall any AF track circuit exceed in length 55% of the distance between a cross-bond to which it is connected and the next cross-bond. Note that a substation return location shall be considered to be a cross-bonding location.

25.1.3.5.5 Environmental Requirements

25.1.3.5.5.1 Physical

25.1.3.5.5.1.1 All Train Control equipment provided shall function normally throughout the applicable temperature and humidity ranges prescribed in the applicable WMATA METRORAIL Train Control Specifications.

25.1.3.5.5.1.2 All Train Control equipment provided shall function normally while being vibrated under the conditions prescribed in the applicable WMATAMETRORAIL Train Control Specifications.

25.1.3.5.5.2 Electrical

All Train Control equipment and systems provided shall function properly in the unfavorable electrical environment of the WMATA METRORAIL Rapid Transit System, which will tend to cause electro-static, electromagnetic, inductive, conductive and radiated interference.

25.1.3.5.5.2.1 Examples of electrical interference sources:

- Alternating current 60 Hz systems
- Direct current traction power systems
- Propulsion power contact shoe and third-rail arcing
- Rotating machinery
- Lightning discharges
- Public and private communications systems
- Wayside and carborne ATC equipment
- Highway traffic and traffic control systems
- Rail Car Chopper Harmonics under all possible load conditions (minimum and maximum)

25.1.3.5.6 Cable and Wiring

25.1.3.5.6.1 All Train Control cable and wiring provided shall meet all the requirements specified for such cable and wiring in the latest applicable WMATA METRORAIL yard or mainline Train Control Specifications.

25.1.3.5.6.2 All TC cable and wiring conductors shall be sized to provide equipment-rated current and voltage, within specified tolerances, at each piece of TC equipment supplied under full load conditions.

25.1.3.5.6.3 The types of cable, insulation, and number of conductors provided for each type of application shall be in accordance with the requirements of the latest applicable WMATA

METRORAIL Train Control Specifications.

25.1.4 Support Systems

25.1.4.1 Data Transmission System (DTS)

All Data Transmission System extensions shall consist of microprocessor based Remote Terminal Units (or their equivalent) located in mainline Train Control Rooms and other data transmission media to accurately transmit non vital Train Control information between the Communications Carrier Transmission System (CTS)and the various wayside Train Control equipment.

25.1.4.1.1 Remote Terminal Units

A Remote Terminal Unit (RTU) (or acceptable alternative) shall be provided for each major mainline wayside control site, which shall include a main TCR at each passenger station. These RTUs shall be appropriately sized individually to serve the applicable number of non-vital Train Control “control” and “status” data points necessary at each “control location,” plus a 20 percent spare capacity. Data points shall be assigned and wired in a WMATA-prescribed sequence as indicated on Authority approved “RTU Scan Sheets.” The RTUs provided shall operate in complete harmony with the current METRORAIL Data Transmission System (DTS) parameters, and shall interface properly with the current METRO RAIL Communications “Carrier Trans-mission System” (CTS).

25.1.4.1.2 Train Control System Functions

The DTS Remote Terminal Units shall be connected to the applicable wayside Communications Equipment Room using appropriate cable (s).

25.1.4.1.3 DTS Interfacing

25.1.4.1.3.1 Remote Terminal Units

The various TC and ancillary control and indication data points shall be connected to the Remote Terminal Units (or equivalent) in the mainline TCRs using appropriate cable(s). This interface wiring shall be kept separate from internal RTU (or equivalent) wiring circuitry. Most of the Train Operation function wiring will be within the Train Control Rooms.

25.1.4.1.3.2 Communications Systems

25.1.4.1.3.2.1 The DTS Remote Terminal Units shall be connected to the applicable wayside Communications Equipment Room using appropriate cable(s).

25.1.4.1.3.3 Yards

Appropriate non-vital hard wiring and/or fiber optic interface systems shall be provided to connect certain non-vital yard Train Control functions to the RTU (or equivalent) in the terminal station Train Control Room.

25.1.4.2 TC Power Distribution Systems

25.1.4.2.1 Description

A complete Train Control Power Distribution System shall be provided inside each Train Control Room and Train Control Equipment Room. Each of these Power Distribution Systems shall include all transfer and bypass equipment, power supplies, transformers, buses, feeders and mains necessary to accept electrical energy from the power sources furnished by others, modify it as necessary, and distribute it at proper voltages to the various pieces of Train Control equipment mounted in the TCR in compliance with Authority standards.

25.1.4.2.2 Load Balance and Power Factor

Each TC Power Distribution System shall be designed to achieve the best load balance and power factor practicable.

25.1.4.2.3 Power Failure Alarm

Each TC Power Distribution System shall include a power failure and over current alarm system circuited in compliance with Authority standards. Where a Remote Terminal Unit (RTU) is located in the TCR, this alarm system shall include a check of the internal power supply of the RTU.

25.1.4.2.4 Protective Devices

Each TC Power Distribution System shall include an array of monitoring, isolation and protective facilities in compliance with Authority standards.

25.1.4.2.5 Voltage and Capacity

All TC Power Distribution Systems, regardless of rated system voltage, current or frequency, shall deliver the system voltage to the TC modules, de-ices, or appliances connected to that system at not less than 95 percent, or more than 105 percent of the nominal voltage rating of the modules, devices, or appliances, and with sufficient capacity for continuous operation of the applicable equipment.

25.1.4.2.6 Configuration

Each TC Power Distribution System shall be configured in compliance with all applicable Authority standards and practices, and shall be compatible with the commercial power sources furnished by others.

25.1.4.2.7 Supplementary Power Sources

For those TCRs or TCERs not furnished with commercial power sources by others, the TC Power Distribution System shall also include provision of necessary power sources from the nearest TCR having one or more commercial power sources.

25.1.4.3 Lightning/Surge Protection and Grounding Systems

25.1.4.3.1 Lightning/Surge Protection

25.1.4.3.1.1 A complete, coordinated system to protect the Train Control circuits and equipment from lightning and other electrical surges shall be included in the Train Control system. This lightning/surge protection system shall include:

25.1.4.3.1.1.1 Segregation of high voltage wiring from low voltage wiring;

25.1.4.3.1.1.2 Segregation of Train control wiring from power/operating wiring and communications wiring;

25.1.4.3.1.1.3 Provision of short, direct, low resistance conductor paths for the grounding of equipment and protective devices;

25.1.4.3.1.1.4 Provision of initial lightning protection and surge protection by means of low resistance (15 ohms) earth grounds for outside Train Control equipment, and at the point where TC cables and wiring first enter the buildings housing the Train Control Rooms;

25.1.4.3.1.1.5 Provision of primary, high-current-capacity, properly grounded arresters of characteristics and type(s) appropriate to the application(s);

25.1.4.3.1.1.6 Provision of three-stage secondary surge protection, which shall consist of:

25.1.4.3.1.1.6.1 Stage 1 - Dual over voltage devices, each containing a gas-filled surge arrester, a varistor type over voltage protection module, and zener type suppression diodes;

25.1.4.3.1.1.6.2 Stage 2 - Fast-blow fuses rated at the maximum current capable of being delivered by the device(s) being protected, and;

25.1.4.3.1.1.6.3 Stage 3 - a duplication of Stage 1, circuited as shown on Drawing TC-23 of the Technical Appendix.

25.1.4.3.2 Grounding

25.1.4.3.2.1 Low resistance grounding shall be provided for all TC circuits and metallic equipment and racks in Train Control Rooms, and for all metallic outdoor TC equipment.

25.1.4.3.2.2 Ground connection to the track rails or use of the neutral conductors of the power company or any signal power supply system will not be permitted.

25.1.4.3.2.3 All ground connections in each TCR shall be made to a room prime ground bus bar (provided by others) in the manner prescribed by the latest applicable WMATA METRORAIL Train Control Specifications.

25.1.4.3.2.4 The grounding of each piece of metallic outdoor TC equipment shall be provided by means of an individual connection to a driven copper ground rod, or rods driven in series, one on top of the other. The resistance of the connection from each piece of equipment to earth ground shall not exceed 15 ohms.

25.1.4.4 Microprocessor Support Systems(MPS) and Drawing Editor Systems

25.1.4.4.1 Microprocessor Support Systems

25.1.4.4.1.1 A WMATA prescribed number of microprocessor-based service systems capable of supporting the programming, maintenance and modification of all other microprocessor systems in the Train Control System shall be provided as part of each Train Control System. Each of these MPS Systems shall include:

25.1.4.4.1.1.1 All of the applicable contract-prescribed equipment, fixtures, software and instructional information necessary to program, reprogram, and maintain all of the other microprocessor systems, as prescribed in the applicable Train Control Specifications;

25.1.4.4.1.1.2 A simulator/diagnostic program for each type of microprocessor-based system included in the Train Control System, and;

25.1.4.4.1.1.3 All cables, connections and interface facilities necessary to allow the MPS System to be used in conjunction with Train Control Test Fixtures for all the related operating microprocessor systems in the Train Control System.

25.1.5 Miscellaneous TC Functions

25.1.5.1 Platform Edge Light Control

TC non-vital control circuitry shall be provided from the passenger station TCR to the appropriate station AC Service Room(s) to control, the illumination of platform edge lights on each passenger platform.

25.1.5.2 NEXT TRAIN Sign Control

A three position (Track 1/Automatic/ Track 2) control switch shall be provided on the Dispatcher's Control Panel at tail-track terminal stations. This switch and its associated control circuitry shall enable the Dispatcher to control the illumination of the passenger NEXT TRAIN signs (by others) at such terminal stations. The "Automatic" setting shall result in NEXT TRAIN sign illumination based upon "First-in/First-out logic.

25.1.5.3 Train Arrival Bus Indication Lights (TABIL)

Circuitry shall be provided to control the illumination of Train Arrival Bus Indication Lights (TABIL) (by others) at Rail/Bus transfer stations. This circuitry shall detect the close approach of outbound trains to the applicable passenger stations during evening rush hours and close a contact in the station AC Service Room which shall in turn cause the illumination of a "train arrival warning light"(by others)in the bus pickup area for an adjustable length of time.

25.1.5.4 Snow and Ice Buildup Prevention

All power operated track switches on the WMATA METRORAIL System which are exposed to the weather shall be provided with special snow melter layouts to prevent buildup of snow and/or ice in the area of the switch points and rods. These snow-melter layouts shall consist of two types of heaters (one type for the switch points and a second type for the switch rods); a wayside control case to control the application of propulsion power to these heaters, and; all necessary associated control and indication circuitry and installation hardware, all in conformance with current WMATA practices.

25.1.5.5 Right-of-Way Intrusion Detection Warning (IDW) System

Wherever the WMATA METRORAIL tracks closely parallel a railroad or major highway, a system shall be provided to detect an intrusion through the barrier of intervening segments of the WMATA property boundary , and to automatically turn off all ATP speed commands in the METRORAIL track areas opposite or in approach to the detected intrusion location, all in conformance with current WMATA practices.

25.1.5.6 Dragging Equipment Detection

A system shall be provided to detect equipment or cabling protruding from the underside of the transit cars to a distance below the tops of the running rails (at locations designated by the Authority), and to indicate such a condition to the train operators and as an alarm condition to Central and local control points.

25.1.5.7 Automatic Train Approach Warning System (ATAWS)

A system shall be provided to produce and direct an audible alarm downstream ahead of an approaching train, on both tracks at a specified Automatic Train Approach Warning System (ATAWS) track location. The purpose of the alarm is to warn wayside personnel, within two hundred feet of the protected area, of the approaching train when the train reaches the predetermined ATAWS trigger location.

The system shall produce a strobe light indication for the train operator, only during the period of the alarm sound, to indicate that the ATAWS audible alarm, is properly functioning. The ATAWS strobe light location shall be three hundred feet downstream from the ATAWS trigger location for the direction of travel and on the same track as the approaching train. The audible alarm and strobe light indicator will operate for a minimum of four seconds beginning when the train reaches the trigger locations. The ATAWS trigger location shall be at least six hundred feet, but not farther than the next track circuit boundary, upstream from the protected ATAWS location.

25.1.6 Basic Wayside Equipment Criteria

25.1.6.1 Power Frequency Track Circuits

Power Frequency (60 Hz) AC Track Circuits shall be of the single rail, balancing impedance type using AC vane-type vital relays. This type of track circuit shall be used for train detection purposes on mainline interlocking tracks, and on yard interlocking, yard lead, and yard running tracks, and as otherwise specified.

25.1.6.2 Wayside Signal Layouts

Controlled and marker signal layouts provided shall be complete with:

- signal heads having three lamp compartments;
- appropriate signal-head lamp adjusting transformers
- appropriate lamps, adjustable lamp holders, lenses, blanking plates, terminal blocks; and, for outdoor signals, lens hoods.
- appropriate masts and bases;
- appropriate signal number plates;
- appropriate foundations for all ballast-mounted signals;
- appropriate ladders or climbing steps; all fabricated, assembled and mounted in the WMATA prescribed manner.

25.1.6.3 Cases and Junction Boxes

Appropriately equipped cases and junction boxes, complete with applicable foundations or pedestals, shall be provided for all yard wayside train control equipment. These housings shall be so located and constructed that they meet all transit vehicle clearance criteria. All metallic cases shall be made of stainless steel, and shall be equipped for proper grounding. All cases and junction boxes shall be suitably equipped for waterproof closure and, where applicable, lockable.

25.1.6.4 Maintenance Furniture and Equipment

25.1.6.4.1 Appropriate tables, storage cabinets, lockers, ladders, and other maintenance furniture and equipment shall be provided in each TCR, as specified.

25.1.6.4.2 Appropriately sized and constructed Gang Boxes (for storage of tools and equipment) shall be provided in the field at interlocking locations as specified.

25.2 MAINLINE OPERATION - AUTOMATIC TRAIN CONTROL

25.2.1 General

25.2.1.1 Mainline Operating Principles

25.2.1.1.1 Operating Modes

The WMATA METRORAIL trains operate in one of three modes:

25.2.1.1.1.1 AUTOMATIC:

Movement controlled automatically by ATP and ATO commands;

25.2.1.1.1.2 MANUAL OPERATION WITH OVER-SPEED PROTECTION:

Movement controlled manually by train operator, subject to speed limits imposed by ATP speed commands. If no ATP speed command is received, the train will be forced to stop, and then will be permitted to proceed at no more than 15 MPH (Stop and Proceed Mode) until such time that an ATP speed command above 15 MPH is received, whereupon the train may be operated up to the received speed command;

25.2.1.1.1.3 ATP Cutout:

All ATP control is bypassed when in this mode. The train operator must obtain permission from Central Control to enter this mode of manual operation.

25.2.1.1.2 Direction of Traffic

Normal running on the Revenue Service portion of the WMATA METRORAIL System is “forward on the right hand track,” i.e., right-hand running. However the ATC System shall permit safe operation in either the “Normal” or the “Reverse” direction on all mainline tracks. These tracks shall be protected by vital “Traffic Circuits” between interlockings.

25.2.1.1.3 Station Stopping

Automatic station stopping to within plus or minus five feet of the desired location at the station platform shall be provided by programmed braking following a predetermined deceleration profile. This programmed braking shall be initiated and updated by electronic signals caused by the interaction of coils on the transit cars with wayside marker coils located between the running rails at fixed distances from the center of the station platform track. The wayside inductive coils shall indicate to the trains:

- the direction of travel for which the information applies (where necessary), and;

- the type of programmed stop to be made (or skipped):
- Type "A" (Long) Stop: Head of train to far end of station platform;
- Type "B" (Short) Stop: Head of train to middle of station platform;
- Type "C" (Center) Stop: Center of train to center of station platform.
- No stop to be made.

25.2.1.1.4 Terminal and Turnback Moves

25.2.1.1.4.1 Trains approaching a terminal double-crossover interlocking from the mainline shall be automatically routed to the appropriate tail track in accordance with the "Mode" of automatic terminal operation selected by Central or by operation of the local Dispatcher or Inter-locking Control Panel, as follows:

- Mode 1: Route to track 1
- Mode 2: Route to track 2
- Mode 3: Route to first available (unoccupied) tail track, with preference to the "inbound" track if both tail tracks are unoccupied.

25.2.1.1.4.2 Tail track selection may also be controlled manually by either Central Control or from the local Dispatcher or Interlocking Control Panel, or by means of wayside pushbuttons operated by the Train Operator.

25.2.1.1.4.3 Trains turning back at a pocket-track interlocking shall be automatically routed into the turn back pocket track based upon the destination code carried by the train, or they may be manually routed into the pocket track by Central or by operation of the local Interlocking Control Panel.

25.2.1.1.4.4 Provision shall be made for turning trains back at: emergency double-crossover interlockings; the converging end of junction interlockings; and the mainline converging ends of pocket track interlockings, by providing one or more "turn back blocks" on the mainline tracks at the end(s) of such interlockings.

25.2.1.1.5 Dispatching

25.2.1.1.5.1 Transit trains will normally be dispatched from terminal passenger station platform tracks, but may also be dispatched in a similar manner from pocket tracks, non-revenue service connecting tracks, or other locations specially equipped with TWC impedance bonds.

25.2.1.1.5.2 The departure routing of a train from a terminal interlocking (or other train dispatching inter-locking or turn back point location) shall not be initiated until the train has been assigned “Identity” and the train operator has sent a “Train Ready” indication through the Train-to-Wayside (TWC) System. The departure routing shall be initiated manually by Central, or by operation of a local Dispatcher or Interlocking Control Panel. In an emergency situation, at certain locations, the train operator may be able to initiate a route from wayside pushbuttons.

25.2.1.1.6 Headway

25.2.1.1.6.1 The ATC System provided shall enable the METRORAIL System trains to operate at 90 second headways in either direction on either mainline track, unless otherwise specified.

25.2.1.1.6.2 The ATC System shall, wherever economically practical, enable the METRORAIL System trains to operate with a sustained 10minute headway in each direction during single track, run-around service between successive interlockings made necessary by maintenance or emergency conditions.

25.2.1.2 Special Mainline Wayside Equipment Criteria

25.2.1.2.1 Audio-Frequency Track Circuits

Audio Frequency track circuits shall consist of:

- Vital AF transmitter units capable of generating the proper coded ATP train detection and/or speed and door command signals, and, where applicable, TWC signals;
- Vital AF receiver units capable of detecting the various coded train detection signals and driving vital track relays;
- Track impedance bonds of proper negative-propulsion-return ampacity capable of properly interfacing the various train detection, speed/door command and, where applicable, TWC signals to the running rails, and of defining the boundaries of the track circuits within acceptable tolerances in accordance with WMATA standard practice;

- All interconnecting wiring, relays, adjusting devices and miscellaneous mounting hardware.

25.2.1.2.2 Audio Frequency Speed Command Loops

Audio Frequency Speed Command loop circuits shall be used in conjunction with vital power frequency track circuits to transmit speed commands to trains in track crossover areas. They shall consist of:

- AF transmitter units capable of generating the proper coded ATP speed command signals;
- Wire loops installed in an appropriate, workable configuration in the cross-over tracks;
- All interconnecting wiring and mounting devices.

25.2.1.2.3 Switch-and-Lock-Movement Type Track Switch Layouts

25.2.1.2.3.1 All mainline track switches and (certain yard lead switches designated by the Authority) shall be equipped with Track Switch Operating Layouts which shall consist of:

- A Switch-and-Lock Movement
- An arrangement of rods and hardware to connect the Switch and-Lock Movement to the switch points for throwing, locking and point detection purposes.

25.2.1.2.3.2 The switch machines (S&L movements) shall be equipped with/for the following:

- Integral point detection.
- Manual operation by hand crank.
- No less than 1000 lbs. closing force on the switch points.
- Operation (throw time) within the limits shown in Figure TC-8.

25.2.1.2.4 Marker Coil Layouts

25.2.1.2.4.1 Inductive Marker coil layouts of the functional types currently used on the WMATA METRORAIL System shall be provided at certain fixed distances from the center of each passenger station platform track to convey to the approaching trains their distance from the platform centers and, where applicable, the type of ATO stop (if any) to be made.

25.2.1.2.4.2 Inert, distance-only marker coil layouts shall consist of a single, fixed-frequency effect coil unit, or a pair of fixed-frequency effect coil units.

25.2.1.2.4.3 “Variable frequency” marker coil units, used to indicate both station center distance and type of stop to be made, shall consist of two individual marker coil units, one of fixed frequency effect and the other having a variable frequency effect controlled remotely from a Train Control Room.

25.2.1.2.4.4 The various types of Marker Coil Layouts shall be fabricated, located and installed in compliance with current WMATA practice. See. Figure 25 - TC-6.

25.2.1.3 Interface with Yards

25.2.1.3.1 Vital traffic circuits shall be provided on Yard Lead tracks between the mainline station tracks and the area of the yard normally controlled exclusively by the Yard Interlocking Operator.

25.2.1.3.2 Train movements between yards and terminal station platforms will be made in the manual Stop and Proceed Mode of operation. No speed commands shall be provided for such moves.

25.2.2 ATC Subsystems

25.2.2.1 Automatic Train Protection (ATP) System

The Automatic Train Protection (ATP) System is that part of the ATC System which provides protection against collisions and over speed conditions. The ATP System also provides control of interlockings, route security through interlockings, and control of train door operation. Principal functions of the ATP System are Train Detection, Speed Command Selection, Speed Command Transmission, Interlocking Control and Security, Train Door Control, and all related car-borne equipment to receive, decode, and safely act upon the ATP commands.

25.2.2.1.1 Train Detection

25.2.2.1.1.1 AF Track Circuits

Mainline train detection shall be provided by joint less audio frequency track circuits except in certain areas of special trackwork. These track circuits shall have the tuning unit and impedance bond mounted between the rails at the block boundary. Audio frequency track circuits in special trackwork areas shall use an inductive loop to inject the signal into the rails and an impedance bond to couple the signal from the rails to the receiver in a center-receive configuration. Balancing-impedance-type, 60 Hz track circuits shall be used in the diamond of double crossovers and in the crossover track of single crossovers.

25.2.2.1.1.2 Train Detection Frequencies

25.2.2.1.1.2.1 The audio frequency track circuits shall use eight frequencies (two sets of four) for train detection purposes. The frequencies to be used are:

Set 1	Set 2
(for Tks 1 & 3)	(for Tk 2)
F1 - 2100 Hz	F2 - 2320 Hz
F3 - 2580 Hz	F4 - 2820 Hz
F5 - 3100 Hz	F6 - 3370 Hz
F7 - 3660 Hz	F8 - 3900 Hz

25.2.2.1.1.2.2 Only one set of the above frequencies shall be used on a given track and the same set shall not normally be used on adjacent tracks.

25.2.2.1.1.3 Adjustment

Audio frequency track circuits which have both the transmitter and receiver in the same room shall be adjusted for a shunting sensitivity of 0.1 ohm. Track circuits which have the transmitter and receiver in separate rooms shall be adjusted for a shunting sensitivity of 0.2 ohms.

25.2.2.1.2 Speed Command Selection

Speed command selection shall be via vital relay contacts or processor equivalent. The selection contacts shall represent the following:

- Traffic locking
- Occupancy of track circuit for which the speed command transmitter is effective
- Occupancy of track circuits downstream of the speed command transmitter

- Occupancy of track circuits upstream of the speed command transmitter if these circuits are within a more restrictive civil speed zone and the more restrictive civil speed limit is less than 2200 feet upstream of the speed command transmitter
- Position of switches down-stream of the speed command transmitter
- Status of signal clearing networks downstream of the speed command transmitter
- Position of switches upstream of the speed command transmitter, when the position of such switches can create a more restrictive civil speed limit
- Condition of temporary speed restriction control
- Additional conditions as required to provide safe train separation, speed, and door control, and to provide schedule control at station platforms and dispatching locations.
- Where track circuit occupancy and signal clearing network status must be transferred from one train control room to another for speed command selection purposes, such information transfer shall be accomplished via polar direct current line circuits or fiber optic communication link.

25.2.2.1.3 Speed Command Transmission

Speed command transmission shall be via one of two audio frequency carriers, 4550 Hz and 5525 Hz, ON/OFF AM modulated at one of five discrete frequency code rates. One additional code rate shall be used for the transmission of door opening commands. The command code chart is as follows:

Modulation Code Rate		Audio Frequency Carrier		
		F9	F10	F9 + F10
No.	Frequency	(4550 Hz)	(5525 Hz)	
1	3.0 Hz	Open Doors Left (when Stopped)	Open Doors Right (when stopped)	Stop
2	4.5 Hz	15 MPH	45 MPH	Stop

3	6.83 Hz	22 MPH	50 MPH	Stop
4	10.1 Hz	28 MPH	55 MPH	Stop
5	15.3 Hz	35 MPH	65 MPH	Stop
6	21.5 Hz	40 MPH	65 MPH	Stop
None of the above	Stop	Stop	Stop	Stop

25.2.2.1.3.1 The speed selection network shall select a code rate generator output to drive the modulator, and energize a carrier generator, in accordance with the above code chart, to cause the appropriate command to be transmitted.

25.2.2.1.3.2 In all areas, except special trackwork areas, speed command transmission shall be via the same transmitter as the train detection frequency. The transmitting equipment shall be shared between the train detection frequency and the selected speed command frequency on a time division multiplexing basis. The multiplexing shall be controlled by the selected code rate which shall alternately key the train detection and speed command frequencies.

25.2.2.1.3.3 Special Trackwork Speed Command Transmission

In special trackwork areas two speed command transmission methods shall be used, as follows:

- inductive loop transmission shall be via the same equipment as the train detection frequency.
- At receive/receive locations and for the loops through 60 Hz track circuits, transmission shall be via an independent speed command transmitter, the output of which shall be directed through loop selection networks to energize the proper inductive loop for the routing and position of the train.

25.2.2.1.4 Interlocking Control and Security

For purposes of this description, interlocking control and security is divided into the following categories and shall be accomplished as described in Section 25.1.3.3 Train Routing:

- Route Initiation

- Route Completion
- Time Released Approach Locking
- Route Locking
- Detector Locking
- Switch Control and Indication
- Signal Control
- Loop Control

25.2.2.1.5 Train Door Control

25.2.2.1.5.1 Train doors shall be controlled by commands transmitted via the vital, wayside-to-train command transmission system used for speed commands. Two commands shall be used; OPEN RIGHT DOORS and OPEN LEFTDOORS. The absence of either of these commands shall be interpreted as CLOSE DOORS.

25.2.2.1.5.2 Door control commands shall be transmitted only at block boundaries associated with platform ends. Block boundaries associated with side platform stations shall be equipped to transmit the OPEN RIGHT DOORS command at the normal traffic-leaving end and the OPEN LEFT DOORS command at the normal traffic entering end. Block boundaries associated with center platform stations shall be equipped to transmit the OPEN LEFT DOORS command at the normal traffic-leaving end and the OPEN RIGHT DOORS command at the normal traffic-entering end.

25.2.2.1.5.3 Car-borne ATP equipment shall compensate for direction of travel of the controlling "A" car and ensure that it is safe to open the train doors prior to acting upon the commands. One of the safety checks which shall be made is the verification that the train is at a passenger station. This check shall be accomplished by cycling a bit back and forth between the train and the station via the TWC system. The cycling of the TWC bit shall be used to keep a vital relay (PSCR) on the train energized as long as the train is in TWC communications with a passenger station.

25.2.2.1.5.4 The application of the door control commands shall be under control of the station dwell control circuits.

25.2.2.2 Automatic Train Operation (ATO) System

The Automatic Train Operation (ATO) System is that part of the ATC System which provides automatic train stopping and starting at passenger station platforms and provides speed control compensation for varying conditions of grade and curvature. Description of the Car-borne portion is in the Vehicles Criteria Manual.

25.2.2.2.1 Wayside Portion

The wayside portion of the ATO system shall consist of station stopping markers which shall provide the distance-to-centerline information as well as the type of stop (long, short, center, or skip) information.

The marker units shall be tuned circuits, the inductance of which is an air core coil with an inside diameterofapproximately11 inches. The coil shall be the coupling element to the car-borne equipment and shall be located between the running rails with its axis vertical. The top edge of the coil shall be between 1/4 and 3/4 inches below the top of rail. The relationship between the coil center and the track centerline shall be as follows:

RADIUS OF CURVE	OFFSET FROM CENTERLINE
Greater than 8500'	0"
8500' - 2900'	1"
2900' - 1750'	2"
1750' - 1250'	3"
1250' - 975'	4"
975' - 800'	5"
800' - 700'	6"
Less than 700'	7"

Offset from centerline of track shall be toward the outside of the curve. See the Figure 25-TC-6, "Marker Coil Offset vs. Curve Radius."

Each marker layout (except the single-unit 160 ft. marker) shall consist of two independent tuned circuit units. This configuration is used to provide for double direction running and to provide the required amount of data with fewer frequencies.

25.2.2.3 Automatic Train Supervision (ATS) System

The Automatic Train Supervision (ATS) System is that part of the ATC System which provides centralized monitoring and supervision capabilities and certain automatic ATC supervision facilities at wayside. The ATS system consists of a computer system and central control consoles located at the Operations Control Center (OCC) in the Carmen Turner Facility and Jackson Graham Building, Remote Terminal Units (RTUs) or equivalent processor located at wayside Train Control Rooms (TCRs), and a Data Transmission System (DTS) linking the equipment at the OCC with that in the TCRs. A Train-To-Wayside Communications system (TWC) is also included to provide a two-way link between the TCR equipment and trains at stations. The RTUs are hard-wired remote control devices dedicated to the monitoring and supervision of certain wayside ATC functions and devices as well as the electrical and support facilities at the location.

25.2.2.3.1 Central Control Facility

See Section 26 for an overview of the Computer Systems portion of the ATS system.

25.2.2.3.2 Wayside Portions

The following portions of the ATS System shall be located on the wayside, primarily in the Train Control Rooms at passenger stations:

- Door and dwell controls
- Train-to-wayside communications (TWC)
- Performance level translators
- Data Transmission System (DTS)

25.2.2.3.2.1 Door and Dwell Controls

Door and dwell control modules shall provide the local hardware to implement the controls generated by central control or automatically by normal train operations. This hardware shall be configured to provide a backup means of door and dwell control in the event that control from central is interrupted. The configuration shall be such that the local backup provisions are exercised on each train movement to make failures self-evident. The sequence of operation shall be as follows:

- When an arriving train completes its station stop a TRAIN BERTHED signal shall be transmitted to the station via the

TWC system. Receipt of this signal shall cause the speed commands to be removed from the platform block and the block downstream of the platform, the door open commands to be applied at both ends of the platform after a 2 second delay, and energy to be applied to the local dwell timer. The TRAIN BERTHED signal shall then be transmitted to central control via the DTS.

- Upon expiration of the preset time of the dwell timer, the door open commands shall be removed and speed commands restored unless override controls are received from central control.
- The dwell shall be permitted to terminate prior to the expiration of the preset time upon receipt of the TERMINATE DWELL control from central control, or by the manual closing the train doors.
- The dwell shall be permitted to extend beyond the preset time with the doors held open upon receipt of the HOLD WITH DOORS OPEN control from central control.
- The dwell shall be permitted to extend beyond the preset time with the doors closed upon receipt of the HOLD WITH DOORS CLOSED control from central control. In this case the door open commands shall be removed but the speed commands shall not be restored until the HOLD WITH DOORS CLOSED control is no longer received.

25.2.2.3.2.2 Train-to-Wayside Communications (TWC) System

The TWC system shall provide the communications link for the following ATS functions between revenue trains and the wayside:

Train-To-Wayside	Wayside-To-Train
Train Destination	Train Destination
Train Number	Train Number
Manual Push button Right (Tk 1 & 2)	Passenger Station Check
Manual Push button Left (Tk 1 & 2)	ATS Acceleration
Doors Closed	ATS Speed Limit

Right (Tk 1 & 2)	
Doors Closed Left (Tk 1 & 2)	Hold With Doors Closed
Train-To-Wayside	Train-To-Wayside
PSS Active (Tk 1 & 2)	Hold with Doors Open
Train-To-Wayside	Train-To-Wayside
ATP in Effect (Tk 1 & 2)	Terminate Dwell
Train in ATO (TK 1 & 2)	Door Close Warning, Platform 1
Passenger Station Check	Door Close Warning, Platform 2
Train Ready	
All Doors Closed	
Train Berthed	
Motion Detection	
Train Length	

25.2.2.3.2.2.1 The TWC System shall function in the same manner as the current continuous-scanning, time-division multiplex transmission system in which communications transmitted to wayside and received from wayside are time-share

25.2.2.3.2.2.2 The car-borne TWC System shall be inductively coupled to the wayside TWC System via coils on the cars. At wayside receiver locations other than flyby locations, the area of effective two-way communications shall be at least 600 feet long.

25.2.2.3.2.2.3 The following message formats shall be transmitted by the train and received by the wayside:

SHORT MESSAGE FORMAT

Bit No.

1-3	Message Prefix
4-7	Word 1 (ATS Speed Limit)
8	Parity, Word 1
9-11	Message Suffix

LONG MESSAGE FORMAT

Bit No.	
1-3	Message Prefix
4-11	Word 1 (Train Destination)
12	Parity, Word 1
13-24	Word 2 (Train Number)
25	Parity, Word 2
26-37	Word 3 (Spare)
38	Parity, Word 3
39	Passenger Station Check
40	ATS Acceleration
41-42	Spare
43	Parity, Word 4
44-47	Word 5 (ATS Speed Limit)
48	Parity, Word 5
49-51	Message Suffix

25.2.2.3.2.2.4 The prefix bit configuration for the short message mode is MARK-SPACE-MARK. The prefix bit configuration for the long message mode is MARK-MARK-MARK. The suffix bit configuration for both long and short message modes is MARK-MARK-MARK.

25.2.2.3.2.2.5 The message structure is a non-synchronous, return-to-zero, serial code at a bit rate of 100 bps. There shall be a 100 millisecond pause between successive message transmissions from the trains. The message shall start

60 ms after the transmitter is keyed. The TWC carrier frequency is 9800 Hz.

25.2.2.3.2.2.6 A frequency of 9950 Hz is interpreted as a "MARK." A frequency of 9650 Hz is interpreted as a "SPACE." Parity is "ODD."

25.2.2.3.2.2.7 The existing impedance bonds which are tuned to transmit and receive the TWC signals exhibit an impedance of approximately1.0 ohms at 9800 Hz. With this impedance, the TWC system will work reliably with a receiving bond current of .016A rms to 0.3A rms. The transmit rail current produced by the bond is approximately1.5A rms with a train adjacent to the bond. Input to the TWC receiver shall be 400 mV p'p'.

25.2.2.3.2.2.8 The following message formats shall be transmitted to the trains depending upon the location of the transmitter:

SHORT MESSAGE FORMAT

Bit No.	
1-3	Message Prefix
4-7	Word 1 (ATS Speed Limit)
8	Parity, Word 1
9-11	Message Suffix

LONG MESSAGE FORMAT

Bit No.	
1-3	Message Prefix
4-11	Word 1 (Train Destination)
12	Parity, Word 1
13-24	Word 2 (Train Number)
25	Parity, Word 2
26-37	Word 3 (Spare)
38	Parity, Word 3

39	Passenger Station Check
40	ATS Acceleration
41-42	Spare
43	Parity, Word 4
44-47	Word 5 (ATS Speed Limit)
48	Parity, Word 5
49-51	Message Suffix

25.2.2.3.2.2.9 Long messages are transmitted to trains in response to a received message from the train at all locations other than flyby locations. Short messages are transmitted to trains in response to a received message at flyby transmitter locations.

25.2.2.3.2.2.10 Performance Level Translators

25.2.2.3.2.2.10.1 Performance Level Translators shall convert the two bit performance level control received from Central Control into a four bit binary code, which shall identify the ATS speed limit required to achieve the desired performance level.

25.2.2.3.2.2.10.2 The ATS speed limit code produced by the performance level translator for a given performance level code input shall be determined by the wiring of a programming plug. The correlation between performance level and ATS speed limit (programming plug wiring) for a given station-to-station run shall be based on computer simulations of station-to-station runs with each of the ATS speed limits.

25.2.2.3.2.2.10.3 The performance level translator shall be a part of the TWC transmitter module. The ATS speed limit code produced by the translator shall be transmitted to the train via the TWC system. The trains shall interpret the ATS speed limit code as follows:

ATS CODE	SPEED LIMIT (mph)	ATS CODE	SPEED LIMIT (mph)
0000	79	1000	44
0001	79	1001	49
0010	14	1010	54
0011	19	1011	59
0100	24	1100	64
0101	29	1101	69
0110	34	1110	74
0111	39	1111	79

25.2.2.3.2.3 Data Transmission System (DTS)

The Data Transmission System shall be as described in Section 25.1.4.1.

25.2.2.4 Rail Operations Control Center (OCC) Overview

The overall supervisory control of WMATA METRORAIL operations is conducted by specially trained WMATA personnel at a central control facility known as the Operations Control Center (OCC), located in the Carmen Turner Facility (CTF) in suburban Maryland. This central control facility, part of the ATC Automatic Train Supervision (ATS) System, contains: a control computer; a hot backup computer, and; a computer for software development, which also serves as the ultimate backup computer.

The control computer receives and transmits messages between the operations control center and station locations via the Data Transmission System (DTS). It communicates with the central control operator by providing displays on a large scale screen and on individual video monitors, and by accepting operator input from the computer control consoles. The control computer performs schedule adjustments by changing station dwell times and train performance levels. These changes are sent to the applicable station Remote Terminal Units (RTUs) via the DTS.

The METRORAIL system can operate as a stand-alone entity without the computer complex at the OCC. However, without the capabilities provided by the ATS software in the central control computer, the display system, and the DTS, the job of monitoring and supervising the METRO operations, especially to maintain schedules, would be more difficult. This is especially true when an abnormal condition (e.g., a malfunctioning train) is encountered.

The general Train Control and ancillary functions provided to aid the central control operators are:

25.2.2.4.1 Display System

- Train System Displays
- Train and Interlocking Detail Displays
- Train Information Displays
- Electrical System Displays
- Train and Electrical System Alarm Displays
- Geographic Displays

25.2.2.4.2 Traffic Regulation Monitoring

- Schedule Control
- Schedule Adjustment Strategies
- Schedule linkage of train put-ins

25.2.2.4.3 Supervisory Capability

- Train Control requests to wayside ATP system
- Interlocking requests to wayside ATP system
- Commands to wayside ATS equipment
- Commands to wayside support system devices
- Status Monitoring and Alarm Processing

25.2.2.5 Automatic Train Supervision Software

The software for the central computer has been designed in a building block approach and provides the primary functions of Traffic Regulation, and Control and Display.

25.2.2.6 Traffic Regulation

All trains in the METRO system under central computer supervision enter revenue service, run, and terminate revenue service according to times provided by predetermined train schedules. These train schedules are the basis for Traffic Regulation Control. A train schedule is defined as a set of arrival and departure times at successive locations which completely dictates a train's intended movement from entry into revenue service until layup. A train schedule defines, among other things, the scheduled arrival time and the scheduled dwell time at every station traversed by a given train. A unique schedule is defined for each train that is in revenue service or is about to enter revenue service. The system schedules are selected by the central control operators at the start of revenue service on a particular day.

Traffic Regulation automatically maintains the scheduled headways between all of the trains operating in the territory and regulates train movements for time schedule adherence, proper merging of trains at rail line junction points, and optimum utilization of terminal locations. This is achieved by control of both station dwell time, and train performance (speed) and acceleration levels which govern the inter-station running time.

The four main components of the Traffic Regulation software are Put-in Processing, the Line Algorithm, the Terminal Algorithm, and Strategy Selection. Also, statistics of the actual performance of trains are gathered for off-line analysis.

25.2.2.7 Put-in Processing

The Put-in Processing software initiates train entry into revenue service either from a storage point, such as a yard or a pocket track, or from a terminal station after a train reversal. The primary function of the Put-in Processing software is to construct a schedule for the next terminal-to-terminal run of the train so that the Terminal Algorithm and the Line Algorithm can control it. Another function performed is the lighting of warning lamps at yards prior to the scheduled dispatch of a train so that the yard personnel can prepare a train for revenue service.

25.2.2.8 Line Algorithm

The primary function of the Line Algorithm is to attenuate delays due to minor line disturbances as quickly as possible and prior to the arrival of trains in areas where the probability of such delays is high. Line disturbances are events or conditions which cause a train to be early or late with respect to its schedule. Such events cause the Line Algorithm to affect the dwell time of a train at a station and the performance of a train departing from a station. The Line Algorithm minimizes or eliminates the effects of delays by adjusting the dwell and performance level of a train such that the departure schedule error at a station and the arrival schedule error at the next station are both minimized.

There are four performance levels. Performance Level 1 (PL1) requests the train to run at the maximum safe inter-station speed, resulting in the minimum safe inter-station run time. The normal schedule for a train is based on PL2, which is approximately 10 percent slower than PL1. This gives traffic regulation a catch-up capability by allowing it to requestPL1 to reduce a train's lateness. PL3 and PL4 are approximately 10 percent and 20 percent slower than PL2 and are used when trains are ahead of schedule.

Each of the four performance levels maybe combined with a request for either full or half acceleration, thus providing eight different inter-station run times. For each station platform the program can select either a normal dwell time or another value which lies within the range of minimum and maximum dwell times for that platform. Dwell times available for some platforms can be varied with the time of day.

25.2.2.9 Terminal Algorithm

A special case handled by a part of Traffic Regulation called the Terminal Algorithm is used to avoid conflicts between trains at terminals having a crossover interlocking located between the terminal station and the penultimate station. Since these interlockings are used to reverse trains, conflicts in the use of the interlockings can be generated by trains arriving at and departing from a terminal station at close headways. A route conflict exists whenever two trains attempt to traverse conflicting routes through an interlocking at the same time.

25.2.2.10 Strategy Selection

The central control operators have the capability of providing corrective strategies through the Strategy Selection program whenever required. The control philosophy employed here is that the operator is the best judge of what corrective action is most suitable in any given situation and the computer is most useful as a device to display the options available and to implement the selected option. The Strategy Selection programs include Replace Train, Delete Train, Add Train, Eliminate Gap, Create Gap, Offset Schedule, Tilt Schedule and Skip Stop. All act to either modify or maintain the existing schedule.

25.2.2.11 Control and Display Software

The Control and Display software drives the displays and alarm printers and responds to central control operator inputs through the console trackballs and keyboards. The Control and Display software responds to field changes or when requested by an operator input to update train displays. It examines the data returned from the field and marked as changed by the Data Base Processor software. It then updates displays and alarm messages for the central operator as required.

The Control and Display software provides the processing of all operator inputs and coordinates execution of the software required by those inputs. These commands allow the central control operators to manually supervise system operation and to request specific displays.

25.2.2.12 OCC System Hardware

The system hardware is used to perform the required Automatic Train Supervision functions and backup functions. The individual components are integrated to provide the means by which the various software components perform their functions.

25.2.2.13 General Purpose Computer Subsystem

Three interconnected computers comprise this subsystem. Each computer consists of a central processor with byte addressing, floating point and memory protection instructions, a priority interrupt system, and a power monitoring circuit.

The computer systems are networked to each other and to the peripheral devices through a dual Ethernet network.

25.2.2.14 Communications Subsystem

To handle the specialized data transmission, the central computers are connected to two Front End Processors which are connected to a bank of modems. The modems are connected through the DTS to the various field devices and permit the transfer of data to and from the central control computer. The FEPs receive the raw data from the field and forward change information to the central processors.

25.2.2.15 Control and Display Subsystem

The Control and Display subsystem, used by the central control operators in controlling the system, has as its main functions; the presentation of system status, operational data and alarms to the central operator, and the execution of system commands from the console trackball and keyboard.

25.2.2.16 Video Monitors

Video monitors provide the display facility: "Close-up" views of the interlockings; System alarms (Train and E&S Alarm); Performance statistics (Train Information); Electrification system (Traction Power); and the state of mechanical support equipment at a station selected by the operator (Support Station). In the event that a video monitor malfunctions, the central control operators have the capability of reconfiguring the displays so that a desired display can be moved to a working video monitor.

25.2.2.17 Large Scale Display

A Large Scale Display System provides an overview display of the METRO System and can also be used to display any of the System's local or special displays.

All alarm conditions on the METRO System, whether the result of train control indications, calculations, traction power and support system indications or computer indications, are displayed in tabular form on the appropriate alarm display and can be output to a printer. Alarms are also displayed in the alarm area (bottom three lines) of the video monitor. Each message is accompanied by an audible alarm. The alarm area contains up to three of the most current unacknowledged alarm messages. There is an indication if there are more than three currently unacknowledged alarms.

25.3 YARD TRAIN CONTROL OPERATION

25.3.1 General

25.3.1.1 Yard Definition and Purpose

A Yard is primarily a system of tracks, buildings, and special facilities provided for the inspection, washing, cleaning, maintenance, storage and/or repair of transit cars, and for the make-up of transit car trains.

25.3.1.2 Yard Configurations

There are three basic types of yards in the WMATA METRORAIL System:

25.3.1.2.1 “Storage Yards” provide washing, cleaning, inspection and storage facilities for transit cars, and storage facilities for maintenance equipment.

25.3.1.2.2 “Service & Inspection” (S&I) Yards are essentially Storage Yards having a shop Building added for the maintenance and minor repair of transit cars.

25.3.1.2.3 “Major Repair Yards” contain facilities for the major repair and overhaul of transit cars.

25.3.2 Yard Control Facilities

25.3.2.1 Yard Train Control Rooms

25.3.2.1.1 Train Control Rooms (TCRs) (by others) are furnished at certain strategic locations within the yard for the installation of Yard Signal Control and Interlocking System equipment. Additional prefabricated TCRs shall be provided where necessary.

25.3.2.1.2 Yard TCRs shall be equipped with applicable vital and non-vital Train Control equipment necessary to implement the Yard Signal Control and Interlocking System.

25.3.2.2 Yard Control Room

Each Yard contains a Yard Control Room which contains facilities for the Yard Interlocking Operators to control propulsion power and train movements within the Yard, and to communicate within the yard and with the WMATA Operations Control Center.

25.3.2.3 Yard Control Machine

A Yard Control Machine shall be provided in the Yard Control Room for the monitoring and control of train movements within the yard, and between the yard and the main line. This Yard Control Machine shall be located, wherever possible, in an area which provides the operator with visual oversight of the yard area.

25.3.2.3.1 Control Panel Configuration

25.3.2.3.1.1 The Yard Control Machine shall consist of one or more consoles which support control and indication panels which display a diagram of all tracks and interlockings within the yard limits and the associated mainline station platform.

25.3.2.3.1.2 Right-hand track switches (in the field) shall be displayed as right hand switches on the control panel, and left hand switches (in the field) shall be displayed as left-hand switches on the control panel. A small “dot” shall be displayed on the panel next to the applicable diverging track indicator for each power switch layout to indicate the arbitrarily designated “NORMAL” alignment for that switch.

25.3.2.3.1.3 The control panel shall provide and interface to initiate safe routes for trains, manually control track switches for test and maintenance purposes, interface with Central Control, and monitor train movements, dragging equipment detectors, snowmelters, and various alarm conditions. Audible alarm devices shall be mounted within the control machine console.

25.3.2.3.2 Control Panel Controls

25.3.2.3.2.1 A Key Switch shall be provided to control activation of the control panel.

25.3.2.3.2.2 Train routing shall be initiated by a non-vital Entrance/Exit system.

25.3.2.3.2.3 Appropriate interface shall be provided to request routes for train movement and signal fleeting.

25.3.2.3.2.4 Individual control point interface shall be provided for the independent operation of track switches and crossovers.

25.3.2.3.2.5 Interface shall be provided to cause the display of the current alignment of all electrically powered switches in the yard.

25.3.2.3.2.6 Appropriate interface shall be provided for Transfer of Control of the mainline interface portion of the yard to and from Central Control.

25.3.2.3.2.7 An interface shall be provided to acknowledge alarm conditions and silence audible alarms.

25.3.2.3.2.8 A interface shall be provided for the control of yard snowmelter layouts.

25.3.2.3.3 Control Panel Indications

25.3.2.3.3.1 The control panel interface shall provide for all visual indications, to include:

- Track Occupancy
- Track Vital Traffic Direction
- Track Route Locked
- Track Switch Locked
- Track Switch Position

- Track Available Exit Points
- Track Wayside Signal Status and Fleeting
- Track Snowmelter Status
- Track Blown Fuse
- Track Power Status
- Track Grounding Status
- Track Microprocessor Status
- Track Dragging Equipment Status
- Track Individual Snowmelter Failure
- Track Next Train Needed
- Track Central/Local Control
- Track Dispatch Warning

25.3.2.3.3.2 Audible indications shall be provided as follows:

25.3.2.3.3.2.1 A single-stroke bell tone to indicate a change in status of certain normal operational features.

25.3.2.3.3.2.2 An acknowledgeable (cancelable) bell or buzzer to indicate alarm conditions.

25.3.2.3.4 Control Machine Furniture

An appropriate armchair and a file cabinet, both on casters, shall be provided for the Yard Interlocking Operator in the Yard Control Room.

25.3.2.4 Computerized Yard Control System

25.3.2.4.1 Non-vital functions

Non-vital functions of the Yard Signal Control and Inter-locking System shall be performed by solid-state, electronic processors unless otherwise specified. These processors shall be configured in a manner approved by the Authority and shall meet the Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR) requirements shown in the Train Control Figures for Basic

Design Information. (Figure 25-TC-1 thru Figure 25-TC-31)

25.3.2.4.2 Quality

The logic and operation of the computerized system shall be at least equivalent in safety and speed of operation as the best operation achievable by a system implemented with non-vital relays and discrete component circuitry.

25.3.2.4.3 Documentation

Complete documentation shall be furnished for all software and hardware to be included in the Yard Control System. This shall include both conventional relay logic drawings and computer equivalent circuit drawings (or equivalent software logic statements)for all of the non-vital functions which are to be performed by the processors in the Yard Control System, and a complete test and inspection program for all hardware and software included in the system.

25.3.2.4.4 Compliance

The Yard Control System shall comply with all basic environmental, mechanical, electrical, programming diagnostic, and spare requirements and current practices for WMATA Yard Train Control Systems.

25.3.2.5 Special Yard Wayside Equipment Criteria

25.3.2.5.1 Vital Track Circuits

Single-rail, power frequency track circuits of the balancing impedance type, using vane-type vital track relays, shall be provided for all interlocking tracks, running tracks, and other yard tracks specified. These track circuits shall provide train detection for up to 0.6 ohms shunting resistance.

25.3.2.5.2 Non-Vital Track Circuits

Series-type AC track circuits shall be provided for the wash track and all shop lead tracks and storage tracks in the yard. These track circuits shall provide train detection for up to 0.6 ohms shunting resistance.

25.3.2.5.3 Yard Track Switch Layouts

Trailable switch machine layouts, complete with switch point detection, and all necessary rods and connecting hardware, shall be provided for all power track switch layouts in the yard. The switch machines shall exert at least 1000 lbs. closing force on the switch points. The switch layouts shall be trailable at low speeds without damage to the switch machines, rods, or special trackwork.

25.3.2.6 Special Functions

25.3.2.6.1 Sectional Route Release

Sectional Route Release shall be provided in the control of long or complex interlockings in order to reduce delays to trains and improve yard throughput.

25.3.2.6.2 Dragging Equipment Detection

Facilities shall be provided for detecting dragging equipment or cabling for trains leaving the yard, and for indicating such situation on the Yard Control Machine.

25.3.3 Yard Monitoring Facilities

25.3.3.1 Event Recording System

25.3.3.1.1 Description

Each Yard Train Control System shall be equipped with a complete, properly operating, microprocessor controlled Event Recording System which shall monitor, record, store, and display, in various prescribed formats, the status of various prescribed Yard Train Control functions over a period of time. The Event Recording System shall be accurate, user friendly, versatile in output formats, easily expandable, easy to troubleshoot and maintain, and shall meet all of the following basic minimum requirements:

25.3.3.1.1.1 The system shall be equipped to monitor 250 points. Modular construction shall be utilized such that the initial system can be easily expandable in the field to monitor up to 500 points.

25.3.3.1.1.2 All data points shall be monitored continually including during viewing and/or printing.

25.3.3.1.1.3 All detected changes of state shall be recorded with the device identification, new status, and the time and date of occurrence.

25.3.3.1.1.4 Event logs and/or displays shall be accurate to one second.

25.3.3.1.1.5 Displays shall be menu driven and manually initiated from a local or remote keyboard or other interrogating device.

25.3.3.1.1.6 Displayed data shall include the following information in a format easily readable and understandable by Train Control maintenance personnel:

- Type of Event,
- Date,
- Time of occurrence,
- Point identification, and
- New state.

25.3.3.1.1.7 Standby battery shall be provided as an integral part of the Event Recording System to prevent loss of the time base during external power failures or shut-down periods up to seven days in duration.

25.3.3.1.1.8 Controls shall be provided for setting the date and the time; for initiating the viewing and/or printing of stored data in the desired format, and for adding new devices to be monitored.

25.3.3.1.1.9 The system shall include a standard RS232C interface wired to one or more plug couplers.

25.3.3.1.1.10 Input wiring to the system shall be easily removable to facilitate testing.

25.3.3.1.1.11 Detection of an error in the Event Recording System (by the internal diagnostic subsystem) shall cause a change in status of the externally wired error detection contact closure.

25.3.3.1.1.12 The system shall include automatic and manually-initiated screen saving.

25.3.3.1.2 Input Storage

25.3.3.1.2.1 The minimum storage capability of the hard disk drive provided shall be 500 gigabytes or greater. Sufficient storage media for 32 days of events shall be furnished initially.

25.3.3.1.2.2 The program which controls the hard disk drive storage shall store the yard events in a file format labeled on a daily basis (0000-2400 hours) by date and year, with one separate file for each day. These files shall be further subdivided by the type of event, i.e., switch machines, controlled signals, track occupancy, auxiliary devices, alarms, etc.

25.3.3.1.2.3 The event storage program shall automatically rotate through the storage area, erasing the oldest of the 32 daily files at the start of each new day's recording.

25.3.3.1.3 Outputs

The processor shall have the capability of outputting information to a local or remote monitor, printing device or floppy disc in various menu driven, operator-selectable formats as approved by the Engineer. These formats shall be as described in the applicable Yard Train Control Contract documents.

25.3.3.1.4 Equipment and Installation

25.3.3.1.4.1 The major computer components of the Event Recording System shall be installed on a rack in the Yard (main) Train Control Room in a manner previously approved by the Engineer.

25.3.3.1.4.2 Indication contacts shall be provided on appropriate equipment for use by the Event Recording System.

25.3.3.1.4.3 Plug connector receptacles shall be provided for the Event Recording System wiring on the racks containing equipment to be monitored in the various Yard TCRs.

25.3.3.1.4.4 Interconnecting cables shall be provided between the event recording equipment and test contact receptacles on the various racks, and between the rack test contact receptacles and the appropriate test contacts on the equipment mounted on the racks.

25.3.4 Mainline Interface

25.3.4.1 Information Interface

25.3.4.1.1 Vital

Vital information, such as vital traffic circuits and vital track repeaters, shall be transferred between the nearest mainline station TCR and the appropriate yard TCR(s) by hard wired circuits carried in vital, multiconductor signal cable.

25.3.4.1.2 Non-Vital

Non-Vital information shall be transferred between the mainline station TCR and the appropriate yard TCR(s) by means of a Fiber Optics Interface System (FOIS) as prescribed in the applicable Yard Train Control Contract documents.

25.3.4.2 Transfer of Control

Wherever applicable, a portion of the Yard Lead Tracks containing one or more interlockings adjacent to the mainline station shall be so equipped that normal Yard control of that area may be transferred to Central Control upon request from Central, or may be transferred to control from the local mainline Interlocking Control Panel(s) in an emergency situation. The circuits and operational protocols necessary to accomplish the transfer of control shall be as prescribed in the applicable Yard Train Control Contract documents.

25.4 LIGHT RAIL (To be developed in future)

25.5 TRAIN CONTROL APPENDIX OF BASIC DESIGN INFORMATION

25.5.1 Definition of Train Control Terms

25.5.1.1 Standard Definitions by Others

25.5.1.1.1 Definitions pertaining to the Train Control Design and Equipment Criteria shall conform to the standard definitions promulgated by the following organizations unless otherwise defined in the Glossary of WMATA Train Control Terminology:

25.5.1.1.1.1 Applicable Parts of the Association of American Railroads (AAR)/American Rail-way Engineering and Maintenance-of-Way Association (AREMA) Signal Manual of Recommended Practice;

25.5.1.1.1.2 Electronic Industries Association (EIA);

25.5.1.1.1.3 The Institute of Electrical and Electronics Engineers, Inc. (IEEE).

25.5.1.1.2 Where definitions conflict, the order of priority shall be:

25.5.1.1.2.1 Glossary of WMATA Train Control Terminology contained herein;

25.5.1.1.2.2 AAR/AREMA Signal Manual;

25.5.1.1.2.3 EIA;

25.5.1.1.2.4 IEEE.

25.5.1.2 Glossary of WMATA Train Control Terminology

The following words, terms and phrases, as used in these Criteria, are defined as follows:

25.5.1.2.1 Abnormal Condition (as referred to in ATS description)

An event of unusual nature (i.e., associated with a low probability) exceeding the capabilities of Strategy Selection and Rescheduling.

25.5.1.2.2 Active Component

An electronic component, such as a transistor, which requires power supply energy in addition to the input signal to function, and produces current or voltage gain.

25.5.1.2.3 Active Element

An electronic component which converts or controls energy (e.g., a single integrated circuit, transistor, diode, relay, or operational amplifier).

25.5.1.2.4 Active Element Group

A network of piece-part components functioning with an active element.

25.5.1.2.5 Address

The bits of a message used to identify the destination or origin of the message.

25.5.1.2.6 Aerial Structure

Track support structure which carries the track above the local surrounding ground level.

25.5.1.2.7 Alarm Condition

Any off-normal condition which requires the attention of an operator, supervisor or maintainer.

25.5.1.2.8 Aspect, Signal

See "Signal Aspect."

25.5.1.2.9 At-Grade

That portion of the system which is constructed at the approximate elevation of the adjacent ground surface.

25.5.1.2.10 Audible Alarm

The sounding of a bell, buzzer, or other acoustic device to draw the attention of a Train Operator, ATC Maintainer, or Central Control Supervisor to an alarm condition.

25.5.1.2.11 Audio Frequency Track Circuit

See “Track Circuit, Audio Frequency.”

25.5.1.2.12 (The) Authority,

Washington Metropolitan Area Transit Authority (WMATA).

25.5.1.2.13 Automatic Local Control

A mode of system operation in which functions such as route initiation and dispatching are performed automatically by local wayside equipment.

25.5.1.2.14 Automatic Speed Regulator

That portion of the carborne ATO System which measures actual train speed and controls positive and negative tractive effort to maintain the desired speed.

25.5.1.2.15 Automatic Train Control (ATC)

The system for automatically controlling train movement, enforcing train safety, and directing train operations. ATC includes subsystems for Automatic Train Operation, Automatic Train Protection, and Automatic Train Supervision.

25.5.1.2.16 Automatic Train Operation (ATO)

The subsystem within Automatic Train Control which performs the on train functions of speed regulation, program stopping, and performance adjustment. This subsystem, in conjunction with the

Automatic Train Protection (ATP) System and the Train-to-Wayside Communications (TWC) System, also shares control of train door operation and train starting.

25.5.1.2.17 Automatic Train Protection (ATP)

The subsystem within Automatic Train Control which maintains safe train operation. ATP subsystems include train detection, speed-limit enforcement, train separation, interlocking, and train door control.

25.5.1.2.18 Automatic Train Supervision (ATS)

The subsystem within Automatic Train Control which monitors and provides controls necessary to direct the operation of a system of trains in order to maintain intended traffic patterns and minimize the effects of train delays on the operating schedule.

25.5.1.2.19 Auxiliary Switch Operation

The operation of a switch-and-lock movement or trailable yard switch by means of an independent manual control without clearing a signal or calling for a signal to clear. See also; "Switch Test Key."

25.5.1.2.20 Availability

The portion of total elapsed time that a system is operating or ready for operation.

25.5.1.2.21 Back-to-Back Signals

See "Signals, Back-to-Back."

25.5.1.2.22 Ballast Resistance

The total inter rail resistance caused by electrical leakage paths of a given section of electrically isolated unoccupied track.

25.5.1.2.23 Ballasted Track

Track structure in which the running rails and the propulsion rail insulators are affixed to individual crossties which are in turn supported by loose ballast.

25.5.1.2.24 Berth

The portion of track occupied by a train when stopped for loading and discharging passengers at a station platform.

25.5.1.2.25 Berthing

The precise positioning and stopping of a train at a passenger station platform.

25.5.1.2.26 Bit

A binary digit, 0 or 1 in number representation, with the radix 2.

25.5.1.2.27 Blending

The simultaneous action and proportional effort of both dynamic and mechanical braking to achieve the required total braking effort during the transition from all dynamic to all mechanical.

25.5.1.2.28 Block

A contiguous section of track of defined limits on which the movement of trains is governed by Automatic Train Control or wayside signals or both.

25.5.1.2.29 Block, Absolute

A block into which no other train is permitted to enter while it is occupied by another train.

25.5.1.2.30 Block, Interlocking

A contiguous section of track within an interlocking plant, the entrance to which is governed by interlocked signals and the use of which is governed by interlocking rules for automatic or manual train operation. An interlocking block may contain one or more track switches or track circuits or both.

25.5.1.2.31 Block, Traffic

A contiguous section of track between interlocking plants on which the prescribed direction of running can be reversed only when the block is unoccupied and no routes are established for entry into that block.

25.5.1.2.32 Block, Turnback

See "Turnback Block."

25.5.1.2.33 Block Design

The process of dividing the METRO trackage into sections having defined limits for the purpose of train detection and ATP speed command transmission, and the determination of the speed commands to be transmitted in each of the blocks so determined. The locations of the block boundaries and the speeds to be transmitted are determined by:

1. The location of fixed facilities such as substation negative propulsion return points, crossbonding locations, insulated rail joints and station platforms.
2. Civil restrictions due to grades, curves and special trackwork.
3. Safety considerations based upon the acceleration and braking characteristics of the transit vehicles.
4. Passenger comfort considerations for both the people on the transit vehicles and on station platforms.

25.5.1.2.34 Bond, Clamped

A type of electrical bond attached to the base of one or more running rails by means of a mechanical clamp.

25.5.1.2.35 Bond, Compression-Bolted

A type of electrical bond attached to the web of one or more running rails by means of a metal collar swaged onto a ribbed metal “pin” passing through the rail web and the bond connecting lug(s).

25.5.1.2.36 Bond, Cross

An electrical connection between the negative-propulsion-return rails of adjacent tracks, used to equalize negative propulsion return currents in the running rails. In audio-frequency track circuit territory, these bonds must be connected between the center taps of impedance bonds on the adjacent tracks.

25.5.1.2.37 Bond, Exothermic

A type of electrical bond attached to the running rails by exothermic means.

25.5.1.2.38 Bond, Impedance

A copper, single-turn, center-tapped coil unit of low resistance, wound with coils for inductively coupling train detection, speed command and TWC frequencies, as required. These units are installed between the running rails of WMATA mainline tracks for one or more of the following purposes:

1. To provide a path for negative propulsion return currents around insulated joints and/or from running rails to crossbonding or substation return cables.
2. To delineate the boundaries of audio frequency track circuits.
3. To inductively connect AF train detection signals between the

running rails and ATP transmitter and/or receiver modules.

4. To inductively connect AF speed commands and/or door control signals between the running rails and ATP transmitter and/or receiver modules.
5. To inductively connect TWC signals between the running rails and wayside TWC modules via the ATP modules.

25.5.1.2.39 Bond, Negative Return (or Propulsion Return)

A type of electrical rail bond designed to carry heavy negative propulsion return current at impedance bonds, rail joints, frogs, and switch point rails.

25.5.1.2.40 Bond, Pin Type

A type of electrical rail bond designed to be attached to the running rails by means of metal pins driven into holes in the web or head of the rails.

25.5.1.2.41 Bond, Railhead

A type of rail bond consisting of a length of electrical conductor having a device on one or both ends to facilitate connection to the head portion of the rail(s) to be bonded.

25.5.1.2.42 Bond, Rail Web

25.5.1.2.42.1 A type of rail bond consisting of a length of electrical conductor having a device on each end to facilitate connection to the web portion of the rails to be bonded together.

25.5.1.2.42.2 A type of rail bond consisting of length of electrical conductor welded, bolted or otherwise connected to the web portion of a rail.

25.5.1.2.43 Bond, Signal

A type of electrical rail bond designed to carry the relatively light current of a power frequency (60 Hz) track circuit.

25.5.1.2.44 Bond, Substation Return

25.5.1.2.44.1 An electrical connection from the center tap of an AF track circuit impedance bond or from the negative return rail of an ac track circuit or to a negative propulsion return bus lead from a substation.

25.5.1.2.44.2 An impedance bond having its center tap used for the negative propulsion return connection to a substation.

25.5.1.2.45 Bond, TWC

An impedance bond equipped with extra coils for the transmission and/or reception of TWC messages.

25.5.1.2.46 Bonding

The permanent joining of metallic parts to form an electrically conductive path which will assure electrical continuity and the capacity to conduct safely any current likely to be imposed.

25.5.1.2.47 Bridging Receiver (BR)

A device for receiving and decoding train detection frequency signals directly from the running rails and driving an appropriate track relay. See “Terminating Receiver.”

25.5.1.2.48 Brake Rate

The rate of deceleration caused by the braking system.

25.5.1.2.49 Bus

A conductor, or group of conductors, that serve as a common connection for two or more circuits.

25.5.1.2.50 Cab Signal

See "Signal, Cab."

25.5.1.2.51 Cable Jacket

A protective outer covering over the insulation, core, or sheath of a cable.

25.5.1.2.52 Cable Sheath

A conductive protective covering applied to cables. Note: A cable sheath may consist of multiple layers, of which one or more is conductive.

25.5.1.2.53 Central Computer Control

A mode of system operation in which functions such as route initiation and dispatching are performed by the Central Control Computer through the local equipment.

25.5.1.2.54 Central Control

25.5.1.2.54.1 The Operations Control Center (OCC) area in the Jackson Graham Building (WMATA Headquarters) where the main train control console, display units, and central automatic train supervision equipment and personnel are located.

25.5.1.2.54.2 Supervisory Control from the OCC as opposed to Local Supervisory Control from wayside locations.

25.5.1.2.55 Central Control Supervisor

The ATC system control console operator on duty at Central Control.

25.5.1.2.56 Central Manual Control

A mode of system operation in which ATC functions such as route initiation and dispatching are performed manually from Central Control through the local equipment.

25.5.1.2.57 Circuit, Track (See also "Track Circuit, Audio Frequency", "Track Circuit, Power Frequency", "Track Circuit, Series Type," and "Track Circuit, Vital.")

An electrical or electronic circuit in which defined portions of one or both running rails of a track constitute a portion of the conductors, and in which the shunting of the running rails is used to detect the presence of trains or equipment on the track. Three basic types are used on the WMATA METRORAIL System:

1. Double-Rail Track Circuit; A track circuit in which both running rails are isolated signal rails.
2. Single-Rail Track Circuit; A track circuit in which one running rail is an isolated signal rail and the other running rail is a common, non-isolated rail.
3. Series-Type Track Circuit; A non-vital, single-rail track circuit which is energized only when its signal rail is shunted to the opposite running rail.

25.5.1.2.58 Circuit, Traffic

A vital circuit used to determine the permissible direction of train operation over a segment of track between two interlockings and/or set(s) of back-to-back signals. (See "Block, Traffic.")

25.5.1.2.59 Circuit, Vital

Any circuit whose function directly affects the safety of train operation.

25.5.1.2.60 Civil Speed Limit

See "Speed Limit, Civil."

25.5.1.2.61 Clearance Point

The location between the diverging tracks emanating from a turnout at which the Authority's required clearance is achieved between the diverging tracks. This point is usually defined by the distances (along each of the diverging tracks) from the point-of-switch.

25.5.1.2.62 Closing-In

Operating a following train toward a preceding train which is either stopped or running slower than the following train.

25.5.1.2.63 Code Rate

The rate of on/off modulation. See "Rate Coding."

25.5.1.2.64 Command (noun)

1. (As used with respect to ATP or TWC messages from TCRs to trains) An electronic signal to start, stop, cancel, change or continue an operation governed by ATP or ATO, respectively.
2. (As used with respect to DTS messages from Central Control to TCRs) See "Request" and "Control."

25.5.1.2.65 Computer

Any device capable of accepting information, applying prescribed processes to it and supplying the results of these processes in a usable form.

25.5.1.2.66 Conduit

A tube-like structure for electrical wires or cables. Conduit may be either rigid or flexible, metallic or non-metallic, as specified.

25.5.1.2.67 Consist (noun)

The number and specific identity of cars which make up a train.

25.5.1.2.68 Contact Rail Assembly

An assembly of a special, insulated, non-running rail and its supports and cover boards, which is installed alongside a track and which carries high voltage electrical energy for the propulsion of trains on that track. See also "Rail, Third."

25.5.1.2.69 (The) Contractor

The successful Bidder who is awarded a Contract for providing all facilities and equipment described in Authority Specifications for the applicable Train Control System Contract.

25.5.1.2.70 Control (noun) (As used with respect to DTS messages from Central Control to wayside Train Control Rooms) A "Control" is actually only a non-vital supervisory "request" for certain action. If the applicable function is non-vital, the "Control" will be acted upon, but if the applicable function is a vital Train Control function, the "Control" will be treated as a "request" to the vital ATC wayside logic circuits and equipment, and will be granted only if it is safe to do so. See "Command" and "Request." See also, "Indication."

25.5.1.2.71 Control, Continuous

A type of control in which the train borne equipment is constantly in operative relation with the track elements and is immediately responsive to a change of conditions in the controlling section of track which affects train movement.

25.5.1.2.72 Control Limit

The extent of route over which a train protection (speed limit) command is controlled.

25.5.1.2.73 Control Limits

The boundaries limiting the area of trackage controlled from a Train Control Room (and its satellite TCER, if applicable). (See TCR and TCER).

25.5.1.2.74 Controlled Signal

See "Signal, Controlled."

25.5.1.2.75 Converging Route See "Route, Converging."

25.5.1.2.76 Coupling (verb)

The act of connecting one married-pair of transit vehicles to another by pushing their aligned automatic couplers together.

25.5.1.2.77 Cross Bond

See "Bond, Cross."

25.5.1.2.78 Crossover

Two turnouts, with track between the frogs, arranged to form a continuous passage between two tracks.

25.5.1.2.79 Crossover, Diamond

A double crossover which has the trailing point and facing point crossovers installed at the same location and in which the two crossover tracks between the running track frogs cross each other in a "diamond" configuration.

25.5.1.2.80 Crossover, Double

A pair of crossovers, one of the facing point type and another of the trailing point type, located in close proximity between the same two tracks. These two crossovers may be located either successively (Universal Crossover), or concurrently (Diamond Crossover).

25.5.1.2.81 Crossover, Facing Point

A crossover installed in such a manner that trains traveling in the normal direction of traffic on the main tracks will move from the points to the frog of the first turnout encountered, i.e., in which the crossover represents a potential diverging route to such trains.

25.5.1.2.82 Crossover, Trailing Point

A crossover installed in such a manner that trains travelling in the normal direction of traffic on the main tracks will move from the turnout frog to the switch points, i.e., in which the crossover represents a converging route to such trains.

25.5.1.2.83 Crossover, Universal

A double crossover which has the trailing point and facing point crossovers installed successively between the same two running tracks.

25.5.1.2.84 Crosstalk

Undesirable interference created by inductive coupling between one system and another system or from one portion of a system to another portion of the same system.

25.5.1.2.85 Current Schedule

The schedule residing in the Control Computer which is the set point for system control by the Traffic Regulation Program.

25.5.1.2.86 Current Revised Schedule

A revised schedule replacing the existing current schedule in the Control Computer.

25.5.1.2.87 Daily Safety Test (DST)

The speed command cycle test performed on a complete train before permitting the train to operate in the automatic mode.

25.5.1.2.88 Data Bit

One of the bits used to convey information in a message. (As opposed to a "housekeeping" bit.)

25.5.1.2.89 Data Transmission System (DTS)

The bi-directional, non-vital, digital communications system between Central Control and the Train Control Rooms.

25.5.1.2.90 Days

Unless otherwise stated, days that are listed as multiples of the number "15" shall be considered calendar days. Days that are listed as less than the number "15" shall be considered as working days.

25.5.1.2.91 Deceleration Rate

The rate of deceleration due to braking effort, train resistance, grade and curve resistance, or some combination of the above factors, as specified.

25.5.1.2.92 Decoder

A device which responds to valid incoming data and converts the incoming data format to the data format required by the device for which the data is intended.

25.5.1.2.93 Derail

A trackwork device for derailing rolling stock in case of an emergency.

25.5.1.2.94 Destination Code

A code consisting of two decimal digits assigned to a train to indicate the desired destination and type of service for the train. The code is used to control the destination signs on the train, and to select automatic routing for the train.

25.5.1.2.95 Diamond Crossover

See "Crossover, Diamond."

25.5.1.2.96 Direct Fixation

A type of track structure in which the running rails and the propulsion rail insulators are affixed to a concrete support slab or to special grout pads on the slab rather than to individual crossties set in ballast.

25.5.1.2.97 Dispatcher's Control Panel

A special type of Interlocking Control Panel for use by Dispatchers at terminal stations to locally control the terminal interlocking. Controls for the NEXT TRAIN signs are also included, where applicable.

25.5.1.2.98 Dispatching

The process of starting a train into revenue service from a terminal station, or from a specially equipped intermediate location.

25.5.1.2.99 Dispatch Receiver

A Train-to-Wayside Communications System receiver which is used to accept Train Ready and Train Length data from trains leaving a dispatch point other than a station platform.

25.5.1.2.100 Diverging Route

See "Route, Diverging."

25.5.1.2.101 Double Crossover

See "Crossover, Double."

25.5.1.2.102 Downstream

Relative to a specified reference point and for a given direction of travel, the area which will be reached after passing the specified reference point. Used in the same sense as the AAR term "in advance of." (See "Upstream.")

25.5.1.2.103 Drop (or Drop-Out)

A relay is said to "drop" or "drop-out" when the energization of its coil(s) is reduced to the point where its front contacts open.

25.5.1.2.104 Duct

A single enclosed runway for wires or cable.

25.5.1.2.105 Duct Bank

An arrangement of conduit or ducts providing two or more continuous ducts between two points.

25.5.1.2.106 Dwell (or Dwell Time)

The period of time measured from the instant a train stops in its berth at a station until the instant it resumes motion.

25.5.1.2.107 Dynamic Train Tests

The field tests conducted by the Contractor utilizing trains under electrical power.

25.5.1.2.108 Elevated

That portion of the system which is constructed above the adjacent ground surface. See "Aerial Structure."

25.5.1.2.109 Encoder

A device which adds security to and converts the data format produced by input devices to the data format required by associated data transmission links.

25.5.1.2.110 (The) Engineer

Wherever in the Criteria the term "Engineer" is used, it shall mean the Resident Engineer or other duly authorized representative of the Contracting Officer.

25.5.1.2.111 Entrance-Exit Type Route Control

Automatic route control implemented by defining first an entrance point and then an exit point.

25.5.1.2.112 Fail-Safe

An inherent characteristic of a system or circuit which ensures that any malfunction affecting safety will cause the system or controlled function of the circuit to revert to a state that is known to be safe.

25.5.1.2.113 Failure

An inability to perform an intended function.

25.5.1.2.114 Fiber Optics Interface System

A type of Wayside Code System (WCS).

25.5.1.2.115 Fleeting

A method of route control in which a route request is not canceled by the passage of a train, thus permitting safe automatic following moves over the same route.

25.5.1.2.116 Flyby Receiver

A Train-to-Wayside Communications System receiver which is used to accept and store destination codes from moving trains in approach to junctions and terminals.

25.5.1.2.117 Flyby Transmitter

A Train-to-Wayside Communications System transmitter which is used to transmit performance level information to moving trains at locations between passenger stations.

25.5.1.2.118 Frog

A trackwork component used at the intersection of two running rails to provide support for wheels and passageways for their flanges, thus permitting wheels on either rail to cross the other.

25.5.1.2.119 Grade Crossing

A location where a roadway and the METRORAIL tracks cross each other at the same elevation.

25.5.1.2.120 Guard Rail

A rail or other structure fastened parallel with the running rails of a track and used to prevent wheels from being derailed, or to hold wheels in correct alignment to prevent their flanges from striking either crossing frogs or the points or switches, or to prevent a derailed train from leaving the track right-of-way. See also, "Restraining Rail."

25.5.1.2.121 Hand Throw Switch

See "Switch, Hand Throw."

25.5.1.2.122 Headway

The time separation between two trains both traveling in the same direction on the same track. It is measured from the time the head-end of the leading train passes a given reference point to the time the head-end of the following train passes the same reference point.

25.5.1.2.123 Home Signal

See "Signal, Home."

25.5.1.2.124 Impedance Bond

See "Bond, Impedance."

25.5.1.2.125 Indication (as used with respect to messages from local equipment and trains)

A DTS message from the Train Control Room to Central or a Train-to Wayside Communications System message from the train to the Train Control Room which carries information concerning the status of some device or system. See "Control."

25.5.1.2.126 Indication, Signal

See "Signal Indication."

25.5.1.2.127 Inspection

Visual observation to ascertain proper physical condition, attachments, connections, clearances, size, joints, motion, rotation, operation and/or similar characteristics.

25.5.1.2.128 Insulated Joint (IJ)

See "Joint, Insulated."

25.5.1.2.129 Interface

The interconnection and/or inter-relationship between two or more systems, subsystems, circuits, persons or contracts, required to ensure continuity and proper operation.

25.5.1.2.130 Interlocking

An arrangement of signals and signal appliances so interconnected that their operations must succeed each other in proper sequence, thereby permitting train movements over controlled routes only if safe conditions exist.

25.5.1.2.131 Interlocking Control Machine

See “Yard Control Machine.”

25.5.1.2.132 Interlocking Control Panel (ICP)

A panel displaying a line diagram of the trackage in and near a particular interlocking or group of interlockings, and equipped with various pushbuttons, electrical switches, indicator lights and audible alarms to allow the control and monitoring of that section of trackage. See also, Dispatcher’s Control Panel.

25.5.1.2.133 Interlocking Limits

The boundaries of an area of trackage controlled by an interlocking, as defined by the insulated joints at the extreme opposing home signals of that interlocking. The term "within interlocking limits" denotes the

area of trackage over which routes are established and protected by the signals and signal appliances comprising that interlocking.

25.5.1.2.134 Interlocking Operator

A qualified person designated by the Authority to control the movement of transit cars and rail borne maintenance/service equipment within the limits of a METRORAIL yard.

25.5.1.2.135 Intrusion Detection Warning (IDW) System

A system used to detect tilting or penetration of WMATA METRORAIL boundary fence in areas adjacent to railroad or highway right-of-way, and to remove speed commands from WMATA tracks where such intrusion is detected.

25.5.1.2.136 Jerk (or Jerk Rate)

Rate of change of acceleration or deceleration equal to the second derivative of velocity. The normal unit is miles per hour per second per second (mphpsps).

25.5.1.2.137 Joint, Insulated (IJ)

A rail joint designed to prevent the flow of electric current from rail to rail by means of insulations placed so as to separate the rail ends and other metal parts connecting them.

25.5.1.2.138 Joint, Rail

A fastening design to align and connect the abutting ends of contiguous rails.

25.5.1.2.139 Joint Electronic Device Engineering Council (JEDEC)

Cooperative effort of Electronic Industries Association (EIA) and National Electrical Manufacturers Association (NEMA).

25.5.1.2.140 Junction

A location where train routes converge or diverge.

25.5.1.2.141 Line

As used with a color prefix, e.g., "Blue Line," "Red Line," one of the operational routings over which revenue service is regularly scheduled by the Authority. A "Line" may include all or parts of one or more geographical "Routes." See also "Route."

25.5.1.2.142 Load Weighing

A function incorporated in the rail transit vehicles which measures gross car weight and uses this information to achieve a constant effort to-weight ratio in the vehicles' traction system.

25.5.1.2.143 Local Control

Supervisory “control” from a local, wayside location as opposed to supervisory control from the OCC.

25.5.1.2.144 Locking

The electrical or mechanical establishment of a condition for a switch, interlocked route, speed limit, or automatic function which cannot be altered except by a prescribed and inviolate sequence of unlocking.

25.5.1.2.145 Locking, Approach

Electric locking effective while a train is approaching, within a specified distance, a signal displaying an "INTERLOCKING CLEAR" aspect, and which prevents, until after the expiration of a predetermined time interval after such signal has been caused to display a "STOP" aspect, the movement of any interlocked switch or derail in the route governed by the signal, and which prevents an "INTERLOCKING CLEAR" aspect from being displayed for any conflicting route.

25.5.1.2.146 Locking, Detector

Electric locking, effective while a train occupies a given section of a route, which prevents operation of switch-and-lock movements within that section.

25.5.1.2.147 Locking, Route

Electric locking, effective when a train passes a signal displaying an "INTERLOCKING CLEAR" aspect, which prevents the clearing of an interlocked signal for any conflicting route. It also prevents the movement of any switch or derail downstream of the train within the route entered. When required, it may be arranged so that as a train clears a track section of the route, the locking affecting that section is released. See "Sectional Release."

25.5.1.2.148 Locking, Time

Electrical locking which, after an interlocked signal is cleared, prevents the operation of any switch or derail in the route governed by that signal until the expiration of a predetermined time interval after that signal has displayed a STOP aspect. It also prevents other interlocked signals from being cleared for any conflicting route during the same time interval.

25.5.1.2.149 Locking, Traffic

Electrical locking which prevents changing the direction of traffic on a section of track between consecutive interlockings and/or between opposing intermediate signals while that section of track is occupied or while a request which would permit entry into that section has been granted or is being processed.

25.5.1.2.150 Logic Code

A tabular or graphic representation of control lines representing the speed commands that shall be transmitted in each block (for a given direction of traffic and route alignment) and the conditions under which each of the speed commands shall be transmitted.

25.5.1.2.151 Maintenance, Preventative

Maintenance procedure carried out on a routine basis in order to reduce in-service equipment failure.

25.5.1.2.152 Manual Local Control

A mode of system operation in which functions such as route initiation and dispatching are performed manually by personnel using local wayside equipment such as a local Interlocking Control Panel.

25.5.1.2.153 Marker (as used in the Program Stop System)

A wayside device used to transfer data to trains at a precise location.

25.5.1.2.154 Married Pair

Two transit cars, semi permanently coupled together, which share certain common equipment.

25.5.1.2.155 Maximum Authorized Speed (MAS) (or Maximum Allowable Speed)

The highest ATP speed command that can safely be transmitted to a train in a block for the purpose of enforcing civil speed limits. MAS is independent of block occupancy downstream from the given block. In blocks which lie in the approach to crossovers or diverging junctions, MAS can depend on which route is aligned.

25.5.1.2.156 Mean Time Between Failures (MTBF)

The arithmetic mean of the time between successive failures.

25.5.1.2.157 Mean Time to Restore (MTTR)

The arithmetic mean of time required to restore service after a failure has occurred. This time is measured from the time troubleshooting or repair work begins until restoration is complete. Time the equipment is out of service prior to the beginning of the repair work is not included in the "MTTR."

25.5.1.2.158 Modem

A modulator and demodulator housed in a common assembly.

25.5.1.2.159 Mole

A device containing four or more sockets for multiple connection of 1000 kcmil negative return cables.

25.5.1.2.160 Multiplexing

The simultaneous transmission of two or more message in either or both directions over the same transmission path.

25.5.1.2.161 Negative Return

Related to the return of 750 Vdc train propulsion current to the substations.

25.5.1.2.162 Negative Return Bond

See "Bond, Negative Return."

25.5.1.2.163 Negative Return Rail

See "Rail, Negative Return."

25.5.1.2.164 Negative Testing

Testing conducted to ensure that applicable systems and/or equipment are not performing in any manner which could have an unsafe or undesirable effect upon METRORAIL operations, METRO riders, or the public in general. See "Positive Testing."

25.5.1.2.165 Noise

Interference brought about by undesirable voltages or currents.

25.5.1.2.166 Nonsynchronized (as used in a data transmission system)

A type of code format which does not use timing as the basis for bit separation.

25.5.1.2.167 Non-Vital

Not affecting the safety of train operations.

25.5.1.2.168 Non-Reporting Block

A condition detected by the ROCS Computer when track circuits report their occupancy out of sequence.

25.5.1.2.169 Normal Direction (of Traffic)

For a given track, the direction in which all regularly scheduled revenue service operations are conducted. For a terminal station and its associated terminal crossover, when the crossover is on the "revenue service" end of the terminal station, the normal direction of traffic on a given platform track shall be the same as the normal direction of traffic on the same track on the opposite end of the terminal crossover. For pocket tracks, the normal direction of traffic shall be in the outbound direction.

25.5.1.2.170 Normal Position (of a track switch or derail)

The position arbitrarily defined by the track plans and control circuits as being the "normal" alignment. The "Normal Position" for a derail is the derailing position. See "Reverse Position.”

25.5.1.2.171 Normal Route: See "Route, Normal."

25.5.1.2.172 Normal Running: See "Running, Normal."

25.5.1.2.173 Off-Normal Operation

Operation at other than the normal schedule.

25.5.1.2.174 Operator

See "Train Operator" and “Interlocking Operator.”

25.5.1.2.175 Overcurrent Protection

A form of protection that operates when electrical current exceeds a predetermined value.

25.5.1.2.176 Overspeed Control

The portion of the carborne ATP equipment which enforces speed limits.

25.5.1.2.177 Parallel Format

A data format in which a group of data bits are input or output simultaneously. (See also, “Serial Format”)

25.5.1.2.178 Performance Level (PL)

A designation for a ratio of desired average actual speed between successive stations, to the maximum average speed which can be achieved between those successive stations, or; a ratio of the desired average actual speed between successive stations to the average speed used to determine normally scheduled run times between those successive stations. The desired Performance Level for a given direction between given stations (or flyby transmitter locations) is implemented by the transmission of a particular Performance Level related maximum ATS speed limit to the train at the initial station or flyby transmitter.

The Performance Levels are defined as follows:

- PL1: Maximum Performance; minimum run time.
- PL2: Normal Performance; run time 10% higher than that achieved with PL1 adjustment.
- PL3: Reduced Performance; run time 20% higher than that achieved with PL2 adjustment.
- PL4: Retarded Performance; run time 50% higher than that achieved with PL2 adjustment.

25.5.1.2.179 Pick (or Pick-Up)

A relay is said to "pick" or "pick-up" when energization of its coil(s) causes its front contacts to close.

25.5.1.2.180 Point Detector (or “Switch Circuit Controller”)

A device used to monitor the “position” of the points of a track switch and to open/close electrical circuits in accordance with the position detected; operated by a “point detector rod” connected to one of the switch points.

25.5.1.2.181 Point-of-Switch (PS)

The location on a track switch layout where the tips of the tapered switch-point rails touch the stock rails. See "Switch Point."

25.5.1.2.182 Positive Testing

Testing to ensure that applicable equipment circuits, systems and subsystems are performing the tasks which they are required to perform, in the manner specified. See "Negative Testing."

25.5.1.2.183 Processor

1. (Computing Systems) A system or mechanism that accepts a program as input, prepares it for execution, and executes the process so defined with data to produce results.
2. (Software) A computer program that includes the compiling, assembling, translating, and related functions for a specific programming language.

25.5.1.2.184 Program Stop: See "Stop, Program."

25.5.1.2.185 Propulsion Rail: See "Rail, Third."

25.5.1.2.186 Propulsion Return Rail: See "Rail, Negative Return."

25.5.1.2.187 Provide

As used in these Criteria, the word "provide" means "complete the final design, furnish, install, test, place in service, document, and train, in the manner described, and to the greatest extent possible compatible with the intent and limits of the Criteria," unless otherwise indicated.

25.5.1.2.188 Rack

A free standing, shock mounted, metal support frame or enclosure for the mounting of terminal boards, power supplies, equipment modules, relays or other train control devices.

25.5.1.2.189 Rack, Entrance

A rack equipped primarily with terminal boards for the termination of cables coming from outside the room or housing in which the rack is located.

25.5.1.2.190 Rack, Equipment

A rack equipped primarily with relays, equipment modules and/or other TC devices, other than power supplies.

25.5.1.2.191 Rack, Power

A rack equipped primarily with TC Power Supply units.

25.5.1.2.192 Rail (Track)

A rolled steel shape, commonly a T-section, designed to be laid and fastened end-to-end in two parallel lines on cross ties or other suitable supports to form a track for railway rolling stock. See "Rail, Running."

25.5.1.2.193 Rail, Closure

Either of the two rails of a turnout which connect the frog to the heels of the two switch point rails.

25.5.1.2.194 Rail, Contact

See "Rail, Third."

25.5.1.2.195 Rail, Guard

See “Guard Rail.”

25.5.1.2.196 Rail, Negative Return

A running rail used also for the return of electrical propulsion energy to a substation. Also known as a Propulsion Return Rail.

25.5.1.2.197 Rail, Propulsion

See "Rail, Third."

25.5.1.2.198 Rail, Propulsion Return

See "Rail, Negative Return.”

25.5.1.2.199 Rail, Restraining

See “Restraining Rail.”

25.5.1.2.200 Rail, Running

One of the two rails of a track which carry and guide the wheels of the rolling stock.

25.5.1.2.201 Rail, Signal

A running rail which carries low voltage electrical signals used for the detection, and possibly the control, of rolling stock carried thereon.

25.5.1.2.202 Rail, Stock

Either of the two continuous outside running rails of a turnout, against which the switch point rails bear.

25.5.1.2.203 Rail, Third

A non-running rail, fastened parallel to, and outside of the running rails of a track, but isolated electrically from the running rails, and used to carry high-voltage electrical energy to be used for the propulsion of certain rolling stock on the track. Also known as the Propulsion Rail or Contact Rail.

25.5.1.2.204 Rate Coding

A method of applying intelligence to a carrier by means of On/Off modulation at fixed sub-audio frequencies.

25.5.1.2.205 Reaction Time

25.5.1.2.205.1 For automatic control:

Time from the occurrence of a step change of control command or request to the first attainment of the new steady state value of the controlled variable, within a designated accuracy.

25.5.1.2.205.2 For human control:

The interval between the beginning of a stimulus and the beginning of the response of an observer.

25.5.1.2.206 Redundancy

The existence in a system of more than one means of accomplishing a given function, for purpose of increasing security or reliability.

25.5.1.2.207 Reliability

The probability of performing a specified function, without failure and within design parameters, for the period of time intended under actual operating conditions.

25.5.1.2.208 Remote Terminal Unit (RTU)

A modem or microprocessor unit installed at each ATC field control location (usually at passenger station TCRs) to act as the interface unit between the Data Transmission System (DTS) and the local ATC and support system functions.

25.5.1.2.209 Request (noun) (As used with respect to DTS messages from Central Control to wayside Train Control Rooms)

An electronic signal indicating a desire to start, stop, cancel, change or continue some ATC or support system function. (See "Command" and "Control.")

25.5.1.2.210 Rescheduling

The development of a new schedule based on a corrective strategy.

25.5.1.2.211 Restraining Rail

A special type of guard rail fastened in close proximity to the gauge side of the inside running rail on sharp curves. The purpose of the restraining rail is to bear upon the back of the transit vehicle wheels on the inner running rail in order to prevent undue pressure and head wear on the inside of the outer running rail of the curve. See “Guard Rail.”

25.5.1.2.212 Revenue Service

The transportation of passengers who have paid a fare.

25.5.1.2.213 Revenue System

The portion of the METRO System on which revenue service is conducted.

25.5.1.2.214 Reverse Direction (of Traffic)

The direction opposite to the normal direction of traffic on a given track.

25.5.1.2.215 Reverse Position (of a track switch or derail)

The position opposite to the position arbitrarily defined by the track plans and control circuits as being the "normal" alignment. The "Reverse Position" for a derail is the non-derailing position. See also, "Normal Position.”

25.5.1.2.216 Reverse Running

See "Running, Reverse.”

25.5.1.2.217 Revised Schedule

A new schedule generated and/or selected as described under Strategy Selection and Rescheduling.

25.5.1.2.218 Right Hand Running

Moving forward on the right-hand track, i.e., Normal Running.

25.5.1.2.219 Right-of-Way

The land or structure surface occupied by the Metrorail transit system, especially for its main line. Also, the land or structure surface used by another transportation facility such as a railroad or highway.

25.5.1.2.219.1 The right of traffic on a given route to take precedence.

25.5.1.2.220 Right-of-Way, Track

An area encompassing the track ties and rails and extending two feet beyond each end of each crosstie.

25.5.1.2.221 Right-of-Way Hazard

The existence of an abnormal condition on or near the tracks which could impair safe train movement.

25.5.1.2.222 Route

25.5.1.2.222.1 A block or specified succession of contiguous blocks in a given direction over which trains operate between two controlled signals.

25.5.1.2.222.2 A continuous track path in a given direction from one controlled signal to another.

25.5.1.2.222.3 A designation, e.g., "E" Route or "Greenbelt" Route, for a specific, contiguous geographical segment of the METRORAIL System. See also, "Line."

25.5.1.2.223 Route, Conflicting

One of two routes crossing, converging, overlapping, or opposing, which cannot be executed concurrently by trains without the possibility or certainty of collision. See also, "Route, Parallel."

25.5.1.2.224 Route, Converging

25.5.1.2.224.1 One route of two or more routes (through an interlocking) having different originating (entrance) points, but coming together in the same direction to share the same destination (exit) point.

25.5.1.2.224.2 A route over one or more trailing-point switches, having an exit point in common with one or more other routes originating at other entrance points. See also, "Route, Diverging."

25.5.1.2.225 Route, Diverging

25.5.1.2.225.1 One of two or more routes (through an interlocking) from a common entrance point, passing over one or more facing-point switches, and having an exit point different than another route from that same entrance point. See also, "Route, Converging."

25.5.1.2.225.2 A route differing from the arbitrarily defined NORMAL or "through" route, i.e., a route in which at least one facing-point switch is lined in its "REVERSE" position. This is usually a route departing from the tangent alignment of the switch (or switches). See also, "Route, Through" and "Route, Converging."

25.5.1.2.226 Route, Following

A route for movement of a successive train in the same direction into a given track block as allowed by the immediately preceding route into that track block.

25.5.1.2.227 Route, Interlocked

A route within interlocking limits, i.e., a route (over special trackwork) which is protected by an interlocking, fail-safe system of controls and controlled signals in such a manner that all conflicting or potentially conflicting routes must first be prevented. (See also, "Routes, Conflicting").

25.5.1.2.228 Route, Normal

25.5.1.2.228.1 With regard to traffic direction, a route established in the normal direction of train travel, i.e., a route which results in normal running.

25.5.1.2.228.2 A route (through an interlocking) in which all switches are lined in their defined "NORMAL" position.

25.5.1.2.229 Route, Opposing

A route which has as its destination or exit point a signal which serves as the entrance point for another route (over the same track) in the opposite direction.

25.5.1.2.230 Route, Parallel

One of two (or more) routes (through an interlocking) which can be executed concurrently (by trains) without danger of collision. See also, "Route, Conflicting."

25.5.1.2.231 Route, Reverse

With regard to traffic direction, a route in which trains run opposite to the normal direction of train travel, i.e., a route which results in reverse running.

25.5.1.2.232 Route, Through

The most commonly used or "main" route through a track switch, usually the tangent (straight) alignment. Also usually the route through the NORMAL setting of the switch. See also, "Route, Diverging."

25.5.1.2.233 Route Designation

The input to a train supervision device reflecting a desired routing by means of a two-digit destination code Route Locking See "Locking, Route."

25.5.1.2.234 Route Request

A non-vital electrical or electronic message ("command") from Central or a local Interlocking Control Panel to a wayside interlocking operational control point, requesting the establishment of a desired interlocking route.

25.5.1.2.235 Route Segment

A defined portion of route consisting of contiguous ATC blocks.

25.5.1.2.236 Routes, Conflicting

Two or more routes, opposing, converging, overlapping, or intersecting, over which train movements cannot be made simultaneously without possibility or certainty of collision. See also, "Routes, Parallel."

25.5.1.2.237 Routes, Parallel

Two or more routes (through an interlocking) over which train movements can be made simultaneously without danger of collision. See also, "Routes, Conflicting."

25.5.1.2.238 Running, Normal

Train movement forward on the right hand track, which is in the normal direction of traffic. Right-hand running.

25.5.1.2.239 Running, Reverse

Train movement forward on the left hand track, which is opposed to the normal direction of traffic. Left-hand running.

25.5.1.2.240 Running, Right-Hand

See "Right Hand Running."

25.5.1.2.241 Running Rail:

See "Rail, Running."

25.5.1.2.242 Safety Critical

A designation placed on a system, subsystem, component, device, or function denoting that correct operation is critical to the safety of personnel or equipment. Such a designation dictates incorporation of special safety design features. Vital functions are a subset of Safety Critical functions which must be implemented in a fail safe manner.

25.5.1.2.243 Safety Speed Limit

See "Speed Limit, Safety."

25.5.1.2.244 Scan Sheets

Sheets listing the successive "control" and "status" (indication) data points required for a given Remote Terminal Unit.

25.5.1.2.245 Schedule

A set of data providing the time/location information for all trains to be operated in a feasible manner on a system or in a specified area of a system, over a fixed period of time such as a 24-hour day or portion thereof.

25.5.1.2.246 Schedule Control

Traffic regulation, corrective strategy selection and rescheduling performed by the ATS system.

25.5.1.2.247 Schedule Error

The difference between actual time and current schedule time for a given event (e.g., the arrival of a train at a station).

25.5.1.2.248 Schedule Tolerance

Maximum permissible schedule error; for each schedule, direction, location and time, a different schedule tolerance may exist.

25.5.1.2.249 Sectional Release (of Route Locking)

The release of route locking in sections behind a train as the train proceeds past the clearance point(s) of one or more diverging switches through an interlocking. This is for the purpose of expediting the establishment of subsequent routes through the interlocking.

25.5.1.2.250 Sectional Release (of Switch Control)

The release of switch locking in sections behind a train as it first occupies, then vacates, detector tracks for one or more diverging switches as it proceeds through an interlocked route.

25.5.1.2.251 Security Bit

A bit inserted in a message to permit a validity check of that message after it is decoded.

25.5.1.2.252 Serial Format

A data format in which the data bits are input or output consecutively. (See also, "Parallel Format.")

25.5.1.2.253 Service Brake

The primary train brake system which is used to control train deceleration under normal operating conditions.

25.5.1.2.254 Sign (noun)

A wayside appliance which conveys information concerning train operation or location.

25.5.1.2.255 Sign, Approach Warning (AWS)

A sign which warns a train operator that the train is approaching a wayside signal which is not currently visible.

25.5.1.2.256 Sign, Next Train

An illuminated sign used at tail-track terminal stations to indicate to passengers which track the next revenue-service train will depart from.

25.5.1.2.257 Sign, Station Stop

A sign bearing the letter "S" which indicates the starting point for a programmed station stop.

25.5.1.2.258 Sign, Turnback

A sign bearing the letters "TB" which indicates the end of a turnback block and the location of a virtual Turnback Signal.

25.5.1.2.259 Signal (noun)

A wayside appliance which uses colored light aspects to convey information governing train movement. See "Signal Aspect."

25.5.1.2.260 Signal, Cab

An indicator or group of indicators located in the operating cab of a transit car or locomotive, which display(s) speed command information.

25.5.1.2.261 Signal, Clear

A signal displaying an aspect for an indication which permits movement of the train past the signal.

25.5.1.2.262 Signal, Controlled

A wayside signal capable of displaying either a stop aspect or an aspect indicating that train movement is permissible, the aspect displayed being determined by fail-safe control circuitry.

25.5.1.2.263 Signal, Holding (or Signal, Holdout)

A controlled signal located at a track circuit boundary on a tail track or yard lead, and used to prevent trains from moving into an area of trackage required to be left unoccupied in order to provide safe braking distance for trains stopping at a terminal station.

25.5.1.2.264 Signal, Home

A controlled signal located at an entrance to an interlocking and used to govern the movement of trains into that interlocking.

25.5.1.2.265 Signal, Intermediate

A controlled, non-Home, wayside signal located at the entrance to a yard lead or yard running track protected by Traffic Locking, and used to govern the movement of trains onto that track.

25.5.1.2.266 Signal, Marker

A wayside signal capable of displaying only a stop aspect and used to mark end-of-track locations.

25.5.1.2.267 Signal, Repeater

A wayside signal installed at a specified distance upstream from a wayside “controlled” or marker signal having limited sighting distance, and used to indicate the current aspect of that signal.

25.5.1.2.268 Signal, Turnback

A simulated, controlled wayside signal located at a turnback point and used, when approached in its "non-cleared" state, to initiate automatic turnback operation through an interlocking. The location of the turnback point, i.e., the location of the simulated wayside signal, is indicated in the field by a Turnback Sign.

25.5.1.2.269 Signal, Wayside

A signal located beside the track.

25.5.1.2.270 Signal Aspect

25.5.1.2.270.1 The appearance of the illuminated lens(es) of a wayside signal conveying an indication, as viewed from the direction of an approaching train.

25.5.1.2.270.2 The appearance of a cab signal conveying an indication as viewed by an observer.

25.5.1.2.271 Signal Aspect Name

The specific, unique term used to identify a particular signal aspect; often used as an abbreviation for the indication conveyed by that signal aspect, e.g., "Diverging Clear."

25.5.1.2.272 Signal Indication

The specific "operating instruction" information conveyed by the aspect of a signal.

25.5.1.2.273 Signal Rail

See "Rail, Signal."

25.5.1.2.274 Signals, Back-to-Back

25.5.1.2.274.1 A pair of controlled signals mounted to face in opposite directions along a given track, at a track circuit boundary and used to control train movements in both directions across that track circuit boundary.

25.5.1.2.274.2 Two controlled signals physically mounted back-to-back, i.e., facing in opposite directions between two adjacent tracks, with one signal governing train movements in one direction on one track and the other governing train movements in the opposite direction on the adjacent track. See also, "Signal, Intermediate."

25.5.1.2.275 Skip-Stop

The operating procedure or command which causes a train to pass a scheduled station-stop platform intentionally, without stopping.

25.5.1.2.276 Slide, Wheel

An extreme slip condition wherein the wheel has zero rotational speed and slip speed equals train speed.

25.5.1.2.277 Slip, Wheel

The difference between the surface speed of wheel tread and rail, usually transient and sporadic.

25.5.1.2.278 Speed, Balancing

The steady-state speed attained by the carborne traction system when resisting forces are exactly equal to applied forces.

25.5.1.2.279 Speed Limit, ATC

The upper limit of safe train speed as enforced by the ATP subsystem.

25.5.1.2.280 Speed Limit, ATO

The upper limit of train speed as enforced by the ATO Subsystem.

25.5.1.2.281 Speed Limit, Civil

For a given section of track, the maximum speed allowed as determined by the physical characteristics of the track structure and limited to ensure the comfort of passengers on trains and on station platforms.

25.5.1.2.282 Speed Limit, Safety

The maximum speed at which a train can safely negotiate a given section of track. The safety speed limit is set to minimize potential passenger injury.

25.5.1.2.283 Speed Sensor

A device which produces an output signal whose frequency is proportional to axle angular velocity.

25.5.1.2.284 Speed Zone

A section of track which has the same civil speed limit throughout its length. For a given direction of traffic, a more restrictive speed zone is one which has a lower civil speed limit than the preceding adjacent speed zone; a more permissive speed zone is one which has a higher civil speed limit than the preceding adjacent speed zone.

25.5.1.2.285 Static Testing

All levels of testing which can be completed without using an electrically energized train.

25.5.1.2.286 Stock Rail

See "Rail, Stock."

25.5.1.2.287 Stop, Absolute

A train stop which permits no exceptions such as reduced speed running, movement within restricting limits, or similar alternatives.

25.5.1.2.288 Stop, Emergency

A train stop initiated by an emergency brake application. Once initiated, the brake application cannot be released until the train has stopped.

25.5.1.2.289 Stop, Program

The stopping of a train at a station platform under closed-loop braking in accordance with a speed-distance profile which will cause the train to stop at a predetermined point.

25.5.1.2.290 Storage Track

A track used for the storage of rapid transit cars or railborne maintenance vehicles.

25.5.1.2.291 Strategy Selection and Rescheduling

A set of actions initiated by Central Control designed to compensate for major disturbances to METRO operation. These actions include altering the current schedule, skipping stations, changing routes, and changing the number of trains in revenue service.

25.5.1.2.292 Subsystem

A subsystem comprises elements within a system which are interconnected to perform a specific function.

25.5.1.2.293 Subway

That portion of the WMATA-METRORAIL system which is constructed beneath the ground surface.

25.5.1.2.294 Superelevation

The increased elevation of the outer rail of a track on a curve to counteract overturning force.

25.5.1.2.295 Superelevation, Unbalanced (Eu)

For a given gauge, radius of curvature, and speed and configuration of rolling stock; the difference between the superelevation required to exactly balance the overturning force and the actual superelevation (Ea) installed.

25.5.1.2.296 Supervisor

A qualified WMATA METRORAIL employee whose function is to supervise METRORAIL mainline operations. See also, “Interlocking Operator.”

25.5.1.2.297 Switch (Electric)

A device by mean of which an electric circuit maybe opened or closed.

25.5.1.2.298 Switch (Track)

A pair of switch points with their fastenings and operating rods providing the means for establishing a route from one track to another. See also "Turnout.”

25.5.1.2.299 Switch, Hand Throw

A non-power-operated track switch, i.e., a switch which has its points operated only by a rod-connected hand-throw mechanism.

25.5.1.2.300 Switch, Trailable

A track switch which may be trailed at limited speed without damage to the switch layout. See “Trail” and “Trailable Switch Operating Layout.”

25.5.1.2.301 Switch-and-Lock Movement

A device which performs the three functions of unlocking, operating and locking a switch or derail.

25.5.1.2.302 Switch Correspondence

Agreement between the called-for alignment of a switch and the actual alignment of that switch.

25.5.1.2.303 Switch Machine

A general term for a mechanism used to control the movement of the points of a track switch.

25.5.1.2.304 Switch Point

A moveable tapered running rail, the point of which is designed to fit against one of the stock rails of a switch.

25.5.1.2.305 Switch Position, Normal

See "Normal Position."

25.5.1.2.306 Switch Position, Reverse

See "Reverse Position."

25.5.1.2.307 Switch Test Key

A control panel device (twist button or toggle switch) which controls the operation of a turnout (or crossover) without calling for a route over that turnout. If a route over that turnout has already been called and locked, the Switch Test Key shall not be able to control the turnout until the route is unlocked and the Test Key has been restored to correspondence with the track switch position. See also; "Auxiliary Switch Operation."

25.5.1.2.308 System

When used alone as a proper noun, shall refer to the WMATA Rail Rapid Transit System. When "system" is used alone as a common noun, it shall refer to the specific assemblage of equipment and circuitry under discussion.

25.5.1.2.309 Tail Track

25.5.1.2.309.1 Mainline Terminal Tail Track

A portion of track located beyond the outbound end of the terminal turnback interlocking. If the interlocking is located at the inbound end of the terminal station, the station platform tracks will be located on the two tail tracks, thus requiring the installation of NEXT TRAIN signs, since both platform tracks may normally be used to dispatch revenue service trains.

25.5.1.2.309.2 Yard Tail Track

The portion of a non-storage track from a bumping post or other end-of-track location to the first interlocking special trackwork location encountered by that track. Usually used by trains making a turnback move at a converging route switch.

25.5.1.2.310 Technician, Train Control

An employee whose function is to maintain and repair Automatic Train Control equipment and to perform certain emergency manual operations as required.

25.5.1.2.311 Terminal

25.5.1.2.311.1 A METRORAIL station and its associated turnback interlocking which is designated as the terminus of a route in the Regional METRO System. Usually located at the outbound end of a "Line."

25.5.1.2.311.2 A device to which electrical conductors may be connected conveniently.

25.5.1.2.312 Terminal, Tail Track

A METRORAIL terminal station having its turnback interlocking located at the inbound end of the station. See "Tail Track."

25.5.1.2.313 Terminal, Temporary

A station and its associated turnback interlocking which is not located at the planned permanent terminus of a route in the Regional METRORAIL System, but which is used as a terminal temporarily until the route can be extended.

25.5.1.2.314 Terminate

To fasten or attach to one or more electrical terminals in a prescribed manner. As used in these Criteria, the term does not necessarily imply stub ending, i.e., a circuit which is "terminated" in a certain location does not necessarily end at that location; more than one wire may terminate on a given terminal.

25.5.1.2.315 Terminating Receiver (BR)

A special type of Bridging Receiver which is configured/tuned in such a manner that the applicable train detection frequency signal(s) will not be permitted to propagate beyond the point in the track at which the receiver is connected to the track.

25.5.1.2.316 Time, Door Open

The elapsed time from the instant the train doors are fully open until they are requested to close.

25.5.1.2.317 Time, Down

The elapsed time during which equipment is not capable of doing useful work because of misadjustment, malfunction, or maintenance in progress.

25.5.1.2.318 Time, Reaction

See "Reaction Time."

25.5.1.2.319 Time, Warmup

The elapsed time from application of power to an operable device until it is capable of performing its intended function.

25.5.1.2.320 Time Constant

Time interval from the beginning of change of a controlled variable, in response to a step forcing function, to the attainment of a stated value.

25.5.1.2.321 Time Division Multiplexing (TDM)

The process of transmitting two or more signals over a common path by using different time intervals for different signals.

25.5.1.2.322 Timetable

A tabulation of the times that trains are expected to arrive at, or depart from certain locations based upon a feasible operating schedule, with time measured by the master clock. The time location information for passenger stations is the same as is found in the schedule to which the timetable is related.

25.5.1.2.323 Track

An assembly of two running rails and the associated material used to fasten them in parallel a fixed distance apart, for the purpose of supporting the movement of trains of transit cars, locomotives and various work equipment.

25.5.1.2.324 Track, Main

A track which is normally under the control of the Automatic Train Control System, i.e., a Revenue Service track.

25.5.1.2.325 Track, Yard Running

A yard track connecting two non-adjacent, but successive interlockings or intermediate signal locations.

25.5.1.2.326 Track, Platform

A 600-ft. mainline track aligned with the ends of a passenger station platform and defined by a TWC impedance bond at each end.

25.5.1.2.327 Track Circuit

See “Circuit, Track.”

25.5.1.2.328 Track Circuit, Audio Frequency (AF Track Circuit)

A double rail track circuit designed to be energized by alternating current in the Audio Frequency range. AF Track Circuit isolation is achieved by the installation of specially tuned impedance bonds, with or without insulated rail joints.

25.5.1.2.329 Track Circuit, Power Frequency

A track circuit designed to be energized by 60 Hz alternating current.

25.5.1.2.330 Track Circuit, Series-Type

Non-vital, normally deenergized track circuit in which the track relay becomes energized only when rolling stock completes a series circuit by shunting the running rails comprising part of that circuit.

25.5.1.2.331 Track Circuit, Vital

A normally energized arrangement of electrical and/or electronic equipment and conductors which include defined lengths of the track running rails, and which permits detection of trains within the defined limits of the running rails due to deenergizaton of the track relay caused by the shunting of the running rails. See also, "Circuit, Track.”

25.5.1.2.332 Track Transformer

A transformer designed to couple signal energy to or from the rails of a track circuit.

25.5.1.2.333 Traction Supply System or Traction Power System

The electrical system which supplies and distributes propulsion power.

25.5.1.2.334 Traction System

The system of wheels, motors, driving mechanism, brakes, direct controls and appurtenances which propel or brake a married pair of transit cars in response to input commands or requests from the train control system.

25.5.1.2.335 Tractive Effort, Negative

Retarding force developed by the train braking system.

25.5.1.2.336 Tractive Effort, Positive

Propelling force developed by the train propulsion system.

25.5.1.2.337 Traffic

Having to do with the direction of train operations over a segment of track between consecutive interlockings and/or sets of signals. See "Traffic, Normal" and "Traffic, Reverse.”

25.5.1.2.338 Traffic Circuit

See "Circuit, Traffic."

25.5.1.2.339 Traffic, Normal

See "Normal Direction (of Traffic)."

25.5.1.2.340 Traffic, Reverse

See "Reverse Direction (of Traffic)."

25.5.1.2.341 Traffic Regulation

The use of changes in dwell time, performance level, and acceleration rate to return a train to its schedule.

25.5.1.2.342 Traffic Regulation Program

An ATS program to correct or stabilize schedule error within the schedule tolerance.

25.5.1.2.343 Trail (verb), or Trail Through

To operate a piece of railborne equipment in the converging direction through a misaligned track switch.

25.5.1.2.344 Trailable Switch Operating Layout

An assembly consisting of a special, trailable switch machine and its associated rods and miscellaneous hardware, which, in addition to operating the switch in the normal manner, also permits the switch to be trailed through by a train at limited speed without damage to the switch points or the layout.

25.5.1.2.345 Train

A single married pair or multiple married pairs (of transit cars), coupled together to form a single unit which shall be suitably identified when used in Revenue Service. See “Train Identity.”

25.5.1.2.346 Train, Non-Revenue

Any train in test, maintenance, emergency or inspection service, which may not be used by the public.

25.5.1.2.347 Train, Revenue

Any train in transit service on main tracks, which may be used by the public. See "Revenue Service."

25.5.1.2.348 Train Control (TC)

A general term indicating equipment, circuitry, material or documentation related to the controlled operation and routing of the transit vehicles.

25.5.1.2.349 Train Control Equipment Room (TCER)

A room housing wayside Train control equipment, but no Remote Terminal Unit. A "satellite" train control room located and used primarily to house train control energy equipment and track circuit modules due to operational distance restrictions imposed by track circuit signal attenuation and/or voltage drop considerations. See Train Control Room (TCR).

25.5.1.2.350 Train Control Room (TCR)

25.5.1.2.350.1 Mainline

A room located in a passenger station or at some other strategic point to house wayside ATC equipment including a Remote Terminal Unit. A major wayside control point for the ATC System.

25.5.1.2.350.2 Yard

A room located at some strategic point in the yard to house Train Control equipment.

25.5.1.2.351 Train Detection Equipment

The track circuits and associated equipment used to detect the presence of trains.

25.5.1.2.352 Train Identity (ID)

The code assigned to each train which contains the train destination, train number, and train length.

25.5.1.2.353 Train Operator

An Authority employee aboard the controlling cab of a train in service whose principal duties are to oversee safety and to execute non-automatic operations.

25.5.1.2.354 Train Shunt Impedance

The inter rail impedance affected by a train.

25.5.1.2.355 Train-to-Wayside Communications (TWC) System

A non-vital, bi-directional, digital data communications system for the transfer of information between the trains and wayside equipment at passenger station platforms and certain other intermediate locations. See “Dispatch Receiver,” “Flyby Receiver” and “Flyby Transmitter.”

25.5.1.2.356 Turnback Block

A contiguous section of mainline track, defined at one end by an interlocking home signal and at the other end by a Turnback Sign (and by a virtual “Turnback Signal.”) Within this block, the direction of running of a train leaving the interlocking may be reversed while the track is occupied by that train and the associated “Turnback Signal” has not been cleared. See “Signal, Turnback.”

25.5.1.2.357 Turnback Point

That point along a mainline track, at least maximum train length downstream from the exit point from interlocking limits, which will not be passed by a train which is to use that interlocking to reverse direction. Required turnback points will be indicated by appropriate symbols on the Contract Drawings. Turnback points are always located at a track circuit boundary and shall be identified by a Turnback (TB) sign.

25.5.1.2.358 Turnback Sign

See “Sign, Turnback.”

25.5.1.2.359 Turnback Signal

See "Signal, Turnback.”

25.5.1.2.360 Turnout

An arrangement of a switch and a frog with closure rails by means of which rolling stock may be diverted from one track to another.

25.5.1.2.361 Unsafe Condition

Any condition which endangers human life or property.

25.5.1.2.362 Universal Crossover

See "Crossover, Universal.”

25.5.1.2.363 Upstream

Relative to a specified reference point and for a given direction of travel, the area which will have been passed prior to reaching the specified reference point. Used in the same sense as the AAR term "in approach of." See also, "Downstream.”

25.5.1.2.364 Vital

Affecting the safety of train operations.

25.5.1.2.365 Wash Track

A shop track or Yard Lead equipped with machines for washing the transit cars.

25.5.1.2.366 Wayside (adjective)

Having to do with, or located along, the METRORAIL trackwork right-of-way.

25.5.1.2.367 Yard Control Machine, or; Yard Control Console

An assembly of equipment in and on a cabinet, including a panel containing a diagram of the yard trackage and major service buildings, which is used for the control and monitoring of track switches, wayside signals, snowmelters and other Train Control functions in the Yard. See also, Interlocking Control Panel.

25.5.1.2.368 Yard Control Room

The room containing the Yard Control Machine, Communications Console, and other panels and equipment for monitoring and controlling propulsion power and other yard functions.

25.5.1.2.369 Yard Lead

25.5.1.2.369.1 A length of yard running track connecting the yard storage and service area with the mainline.

25.5.1.2.369.2 A length of non-Revenue-Service mainline track connecting the Revenue Service area of mainline track to a yard.

25.5.1.2.370 Yard Limits

The outer boundaries of the area of trackage normally controllable by the Yard Control Machine.

25.5.1.2.371 Yard Running Track;

See "Track, Yard Running."

25.5.1.2.372 Yard Storage Track

See "Storage Track."

25.5.1.2.373 Yard Train Control Room

See "Train Control Room" (TCR).

25.5.1.3 Abbreviations

This section lists various abbreviations for terms and organizations and prescribes the meanings for the abbreviations as used in these Criteria.

ABBREVIATION LIST

Abbreviation	Meaning
A	Amber or Approach or Arrival
AAR	Association of American Railroads

	50 F Street, N.W. Washington, DC 20001
ABN	Abnormal
AC	Alternating Current
ACI	Automatic Car Identification
AEG	Active Element Group
AF	Audio Frequency
AFF	Above Finished Floor
AHD	Ahead
AIIM	Association for Information and Image Management (Formerly "NMA" - National Micrographics Association) 1100 Wayne Ave. Silver Spring, MD 20910
Amp	Ampere
ANSI	American National Standards Institute, Inc. 1430 Broadway New York, NY 10018
APTA	American Public Transit Association 1201 New York Ave., N.W. Washington, DC 20005
ARB	Always Reporting Block
A.R.E.A.	American Railway Engineering Association (Obsolete; See “AREMA”)
AREMA	American Railway Engineering and Maintenance-of-Way Association 8201 Corporate Dr., Ste. 1125 Landover, MD 20785-2230

ASQC	American Society for Quality Control 230 W. Wells Street Milwaukee, WI 53203
ASTM	American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103
ATC	Automatic Train Control
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
ATU	Auxiliary Terminal Unit
AWG	American Wire Gauge
AWS	Approach Warning Sign
B	Back or Barrier
BCD	Binary Coded Decimal
BK	Back
BP	Bumping Post or Bypass or Back Repeater
BR	Terminating Receiver
C	Centigrade (Celcius) or Check or Central or Case or Correspondence or Curve
CAU	Computerized Analyzer Unit
CB-CL	Crossbond Conduit Line
C.C.	Curve to Curve
CD-ROM	Compact Disk - Read-Only Memory
CHK	Check
CHP	Chilled Water Plant

CIA	Communications Interface Assembly
CIOC	Communications Input/Output Channel
Ckt	Circuit
Cm	Centimeter
CMOS	Complementary Metal Oxide Semiconductor
COMM	Communications or Communications Equipment Room
CRT	Cathode Ray Tube
C.S.	Curve to Spiral
C.S.A.	Canadian Standards Association
CSXT	CSX Transportation (Railroad)
CTS	Carrier Transmission System
CWR	Continuous Welded Rail
D	Deploy or Deployed
DC	Direct Current
DEJ	WMATA IDW/Railroad Derailment/Dragging Equipment Interface Junction Box
DJ	Distribution Junction Box
DIO	Direct Input/Output
DOS	Disk Operating System
DPS	Drainage Pumping Station or Design Profile Speed
DR	Dispatch Receiver
DTS	Data Transmission System
E	Light or East or End or Superelevation or Equivalent

E_a	Actual Superelevation (in inches)
E_u	Unbalanced Superelevation (in inches)
ECTFE or E-CTFE	Ethylene-Chlorotrifluoroethylene
EE	Emergency Exit
EIA	Electronic Industries Association 1722 Eye Street, N.W. Washington, DC 20006
EMI	Electromagnetic Interference
EMS	Engineer's Monitoring System
ENSS	WMATA Office of Engineering Support Services
E.O.C.	End of Contract
E.O.L.	End of Loop
EOP	End of Platform
E.O.T.	End of Track
EPROM	Erasable Programmble Read-Only Memory
ES	East Stick
ETFE	Ethylene-Tetrafluoroethylene
ETLT	Equal To or Less Than
ETS	Emergency Trip Station
F	Fahrenheit or Traffic or Flashing or Field or Failure
F&I	Fire and Intrusion
FA Fig	Fire Alarm Figure
FL	Flasher or Flashing or Fleeting
FOIS	Fiber Optic Interface System (A type of WCS)

FR	Fly-by Receiver
FRA	Federal Railroad Administration (Part of U.S. Government -Dept. of Transportation) 400 7th Street, S.W. Room 8206 Washington, DC 20590
F.R.E.	Fiberglass Reinforced Epoxy
FS	Fan Shaft
FSK	Frequency Shift Keyed
Ft	Foot, Feet
FT	Fly-by Transmitter
FTA	Federal Transit Administration (Part of U.S. Government - Dept. of Transportation; formerly, Urban Mass Transportation Administration) 400 7th Street, S.W. Room 9400
FUT	Future
FUTU	Future (on RTU Scan Sheets)
FVD	Flammable Vapor Detector
G	Signal or Guard
G.R.S.	Galvanized Rigid Steel
GRS	General Railway Signal Corporation P.O. Box 20600 Rochester, NY 14602-0600
GTET	Greater Than or Equal To
I	Interface or Interlocking or Insulated
I.B.	Inbound
ICEA	Insulated Cable Engineers Association 155 East 44th Street New York,

	NY 10017
I.C.P.	Interlocking Control Panel
ID	Train Identity
IDW	Intrusion Detection Warning
IEEE	Institute of Electrical and Electronics Engineers, Inc. 345 East 47th Street New York, NY 10017
IF	Interface
IFC	Interface Case
IFJ	Interface Junction Box
IJ	Insulated Joint or Interlocking Junction Box
In	Inch, Inches
IVP	Interlocking Vital Processor
AJ	unction Box
JB	Junction Box
K	Indication or Thousand
Kcmil	Thousand Circular Mils
L	Loop or length or light
LCC	Local Console Controller
LED	Light Emitting Diode
L.H.	Left Hand
LJ	Loop Junction Box
LMC	Local Manual Control
LSTSLS	Transit Systems, Inc 2 Whipple Place, Suite 302 Lebanon, NH 03766-1356
LTET	Less Than or Equal To
LW	Lunar White

M	Marker Coil or Maintainer or Manual
mA	Milliampere
MAL	Malfunction
MAS	Maximum Authorized Speed
Max	Maximum
MDS	Maintainer's Diagnostic System
METRO	Washington Metropolitan Area Transit Authority See "WMATA"
Mg	Milligram
Min	Minimum or minute
MIS	Management Information System
MJ	Marker Junction Box
Mm	Millimeter
MTBF	Mean Time Between Failure
M/W	Maintenance of Way
N	Normal or North or Negative or Next
NBD	Normal Braking Distance
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
2101 L St., N.W., Suite 300 Washington, DC 20037	
N.I.C	Not Included in (this) Contract
N.I.S.T.	National Institute of Standards and Technology (Part of U.S. Government Department of Commerce; formerly, National Bureau of Standards) Gaithersburg, MD 20899
NMA	National Micrographics Association (VOID) See "AIIM"

N/mm^2	Megapascal (Newtons per millimeter squared)
NOR	Normal
NRB	Non-Reporting Block
NS	North Stick
NTP	Notice to Proceed
N.T.S.	Not to Scale
NV	Non-Vital
NVIP	Non-Vital Interlocking Processor
NX	Entrance/Exit
O	Overload or Operating or Overlap
O.B.	Outbound
OCC	Operations Control Center (Central) - (Located in the Jackson Graham Building)
OFS	Order For Services
ORD	Operational Readiness Date
P	Repeater or Processor or Panel or Platform
PAU	Portable Analyzer Unit
PB	Pushbutton
PC	Printed Circuit
P.I.T.O.	Point of Intersection (of centerlines) of Turnout
PL	Panel Lighting or Performance Level
P.O.C.	Point on Curve
P.O.T.	Point on Tangent
PROM	Programmable Read-Only Memory

PS	Point of Switch
PSS	Program Station Stop
PVC	Polyvinyl chloride
P.V.C.	Point of Vertical Curve (Begin Vertical Curve)
P.V.I.	Point of Vertical Intersection (of profile tangents)
P.V.T.	Point of Vertical Tangent (End Vertical Curve)
Q	Request or Quality Factor
R	Radius or Red or Reverse or Receive or Route or Retract or Retracted or Restriction or Rail or Restraining, or, as a suffix, Vital Relay
RAFTS	Rail Audio Frequency Test Set
RAP	Rail Administrative Procedure (WMATA)
RCVR	Receiver
R.E.	Resident Engineer
R.H.	Right Hand or Relative Humidity
Rms	Root Mean Square
ROD	Revenue Operations Date
RTU	Remote Terminal Unit
R.W.	Retaining Wall
S	Stick or South or Station Stop or Start or Storage or System or Spiral or Sign
SAS	Supervisory Alarm System
S&I	Service and Inspection (Yard)
SBD	Safe Braking Distance
S.C.	Spiral to Curve

SCI	Substantial Completion Inspection
S.C.& I.	Special Control & Indication (cable)
SEJ	Sewage Ejector
Sig	Signal
SM	Snowmelter
SMF	Snowmelter Failure
SOP	Standard Operating Procedure (WMATA)
SP	Sump Pump
SS	Substation or Station Stop or South Stick
SSR	Substation Return
SSR-CL	Substation Return Conduit Line
S.T.	Spiral to Tangent
STA	Station or Stationing
STAP	Station Processor
SYPM	WMATA Systems Program Management (Part of Department of Design and Construction)
SZJ	(IDW) Sub-Zone Junction Box
T	Track or Time or Transmit or Tunnel or Tangent
TABIL	Train Arrival Bus Indication Light
TAILS	Train Arrival Indication Light System
TB	Turnback or Tie Breaker
TBS	Tie Breaker Station
TC	Train Control
TCER	Train Control Equipment Room
TCR	Train Control Room

TD	True Distance
TE	Time Element
TJ	Track Junction Box
TK	Track
TM	Track Module
TPS	Traction Power Substation
TRK	Track
TRN	Train
T.S.	Tangent to Spiral
TWC	Train-to-Wayside Communications
TYP	Typical
UE	Unauthorized Entrance
UG	Underground
UL	Underwriters Laboratories
US&S	Ansaldo Signal N.V. (formerly Union Switch & Signal, Inc.) 1000 Technology Drive P.O. Box 420 Pittsburgh, PA 15219-3120
V	Volt(s) or Vital or Velocity
V_c	Civil Speed Limit
V_s	Safety Speed Limit
VAC, Vac	Volts Alternating Current
VC	Vertical Curve (Length)
VDC, Vdc	Volts Direct Current
VP	Vital Processor
VS	Vent Shaft
VXI	VMEbus Extensions for Instrumentation

W	Switch or West or Warning or White or Wall
WCS	Wayside Coding System (See FOIS)
WMATA	Washington Metropolitan Area Transit Authority 600 Fifth Street, NW Washington, DC 20001
WS	West Stick
WTP	Wayside Test Procedure
W.W.	Wing Wall
X	Transmit or Cross
XFMR	Transformer
XLPE	Cross-Linked Polyethylene
XMTR	Transmitter
Y	Combination or Collector
Z	Control or call
ZB	Impedance Bond

25.5.2 Tables of DTS Function:

TABLE I, TRAIN OPERATION "CONTROLS"

Group	No.	Function Name
Train/ Station	1A	Set Train Identification; RUN NUMBER, PLATFORM (No.) and DESTINATION, PLATFORM (No.)
Train/Sta.	1B	HOLD WITH DOORS CLOSED, PLATFORM (No.)
Train/Sta.	1C	HOLD WITH DOORS OPEN, PLATFORM (No.)
Train/Sta.	1D	TERMINATE DWELL, PLATFORM (No.)
Train/Sta.	1E	ATS-PERFORMANCE, PLATFORM (No.)
Train/Sta.	1F	ATS-PERFORMANCE, FLY-BY (No.) TK (No.)
Train/Sta.	1G	ATS-ACCELERATION, PLATFORM (No.)
Train/Sta.	1H	SKIP STOP MARKER (Tk./Dir./Dist.)
Train/Sta.	1I	DOOR CLOSE WARNING, PLATFORM (No.)
Track	1J	RESET IDW SYSTEM
Interlkg.	2A	SET LOCAL CONTROL
Interlkg.	2B	SET CENTRAL CONTROL
Interlkg.	2C	SET NORMAL SWITCH (No.)
Interlkg.	2D	SET REVERSE SWITCH (No.)
Interlkg.	2E	CANCEL SWITCH (Number)
Interlkg.	2F	ROUTE REQUEST SIG (No.)
Interlkg.	2G	CANCEL ROUTE

Interlkg.	2I	CANCEL FLEET SIG (No.)
Interlkg.	2J	SET AUTO ROUTE SIG (No.)
Interlkg.	2K	CANCEL AUTO ROUTE SIG (No.)
Interlkg.	2L	INHIBIT AUTO OPER SIG (No.)
Interlkg.	2M	CLEAR DEST REG SIG (No.)
Interlkg.	2N	TERMINAL MODE (Number)
Interlkg.	2O	SET SNOWMELTER ON
Interlkg.	2P	SET SNOWMELTER OFF
Misc.	3A	DESTINATION, PLATFORM (No.)
Misc.	3B	TRAIN LENGTH, PLATFORM (No.)
Misc.	3C	TIME PULSE - MIN
Misc.	3D	TIME PULSE - HRS/24 HRS.
Train Dispatch	4A	TRAIN NEEDED, PLATFORM (No.)
Train Dispatch	4B	DISPATCH WARNING

TABLE III, TRAIN OPERATION INDICATIONS

GROUP	NO.	FUNCTION NAME
TWC	1A	RUN NUMBER, PLATFORM (No.)
TWC	1B	DESTINATION, PLATFORM (No.)
TWC	1C	TRAIN LENGTH, PLATFORM (No.)
TWC	1D	DOOR OPEN MANUAL TK (No.)

TWC	1E	TRAIN READY TRACK (Number)
TWC	1F	TRAIN BERTHED TRACK (Number)
TWC	1G	TRAIN MOTION TRACK (Number)
TWC	1H	DOOR CLOSE (RIGHT or LEFT) TK (No.)
TWC	1I	PSS ACTIVE TK (Number)
TWC	1J	ATP CUTOUT TK (Number)
TWC	1K	TRAIN IN ATO TK (Number)
Track	2A	BLK OCCP TK (No.)
Track	2B	TEMP SPEED RESTRICTION TK (No./Dir.)
Track	2C	RIGHT OF WAY HAZARD (No.) TK (No.)
Track	2D	DRAGGING EQUIPMENT DETECTED FOR (RR) TK (Number)
Interlkg.	3A	LOCAL IN CONTROL
Interlkg.	3B	CENTRAL IN CONTROL
Interlkg.	3C	LOCAL CONTROL REQUEST
Interlkg.	3D	SWITCH (No.) CALLED NORMAL
Interlkg.	3E	SWITCH (No.) CALLED REVERSE
Interlkg.	3F	SWITCH (No.) NORMAL
Interlkg.	3G	SWITCH (No.) REVERSE
Interlkg.	3H	SIG CLEAR TK (No.) SIG (No.)
Interlkg.	3I	ENT RECV TK (No.) SIG (No.)

Interlkg.	3J	FLEETED TK (No.) SIG (No.)
Interlkg.	3K	AUTO ROUTE IN EFFECT SIG (Number)
Interlkg.	3L	APPR LKD TK (No.) SIG (No.)
Interlkg.	3M	RTE LKD TK (Number)
Interlkg.	3N	AUTO OPER MODE (No.)
Interlkg.	3O	CENTRAL LOCKED OUT (Sig. No., No., No.)
Interlkg.	3P	DEST SIG (No.)
Interlkg.	3Q	TRAFFIC DIRECTION NORMAL (or REVERSE)
		TK (No.) and Direction of Traffic Zone ® or N)
Interlkg.	3R	SNOWMELTER ON
Interlkg.	3S	PROCESSOR FOR INTLKG FAILURE
Interlkg.	3T	PROCESSOR FOR INTLKG PROBLEM or;
		PROCESSOR FOR STATION PROBLEM
Interlkg.	3U	PROCESSOR (A, B, C, or D) FOR INTLKG ONLINE
Misc. TC Room	4A	CIRCUIT POWER FAILURE
Misc. TC Room	4B	POWER TRANSFER

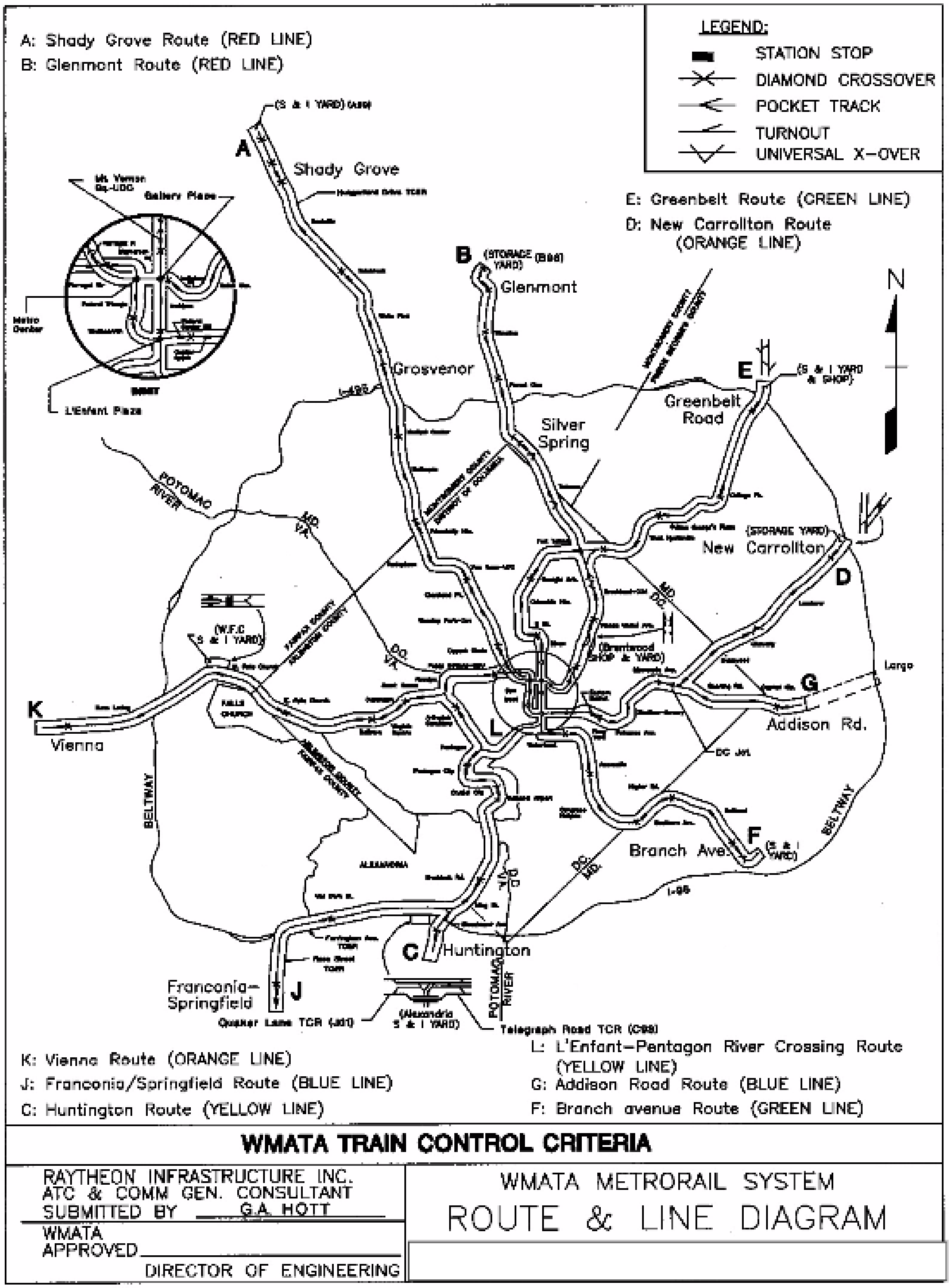
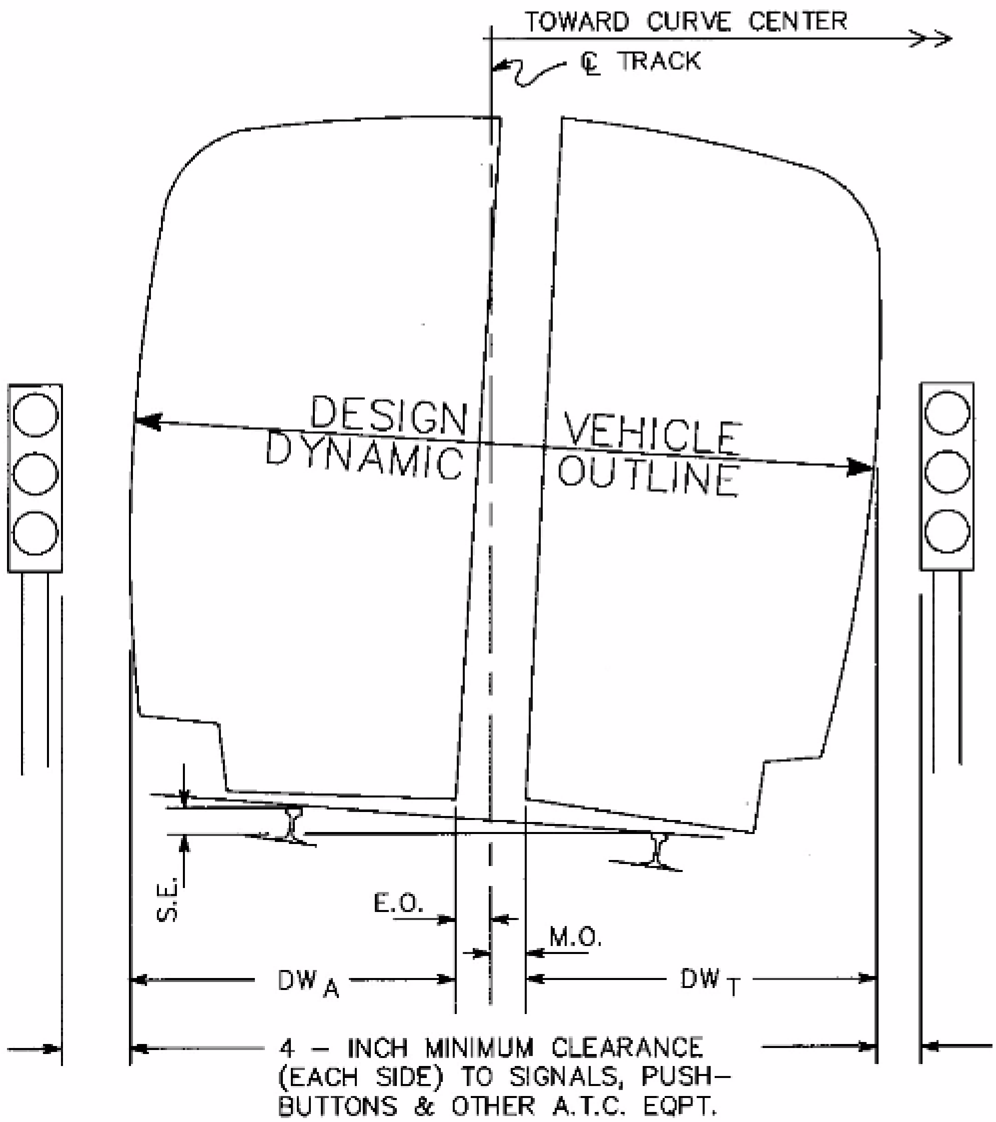


FIGURE 25 - TC-1



NOTES:

1. FOR DESIGN VEHICLE CLEARANCES, CONSIDER THE END OVERHANG, E.O., EQUAL TO THE MIDDLE ORDINATE, M.O.
2. M.O. (IN FT.) $= R - \sqrt{R^2 - 676}$
   WHERE R = CURVE RADIUS (IN FT.).
3. FOR VALUES OF DW_A AND DW_T, SEE PAGES TA–3 & TA–4
4. SEE ALSO DWG. ATCINF–CE–030, A.T.C. CLEARANCE ENVELOPE.

TC–2 – A.T.C. CLEARANCE DIAGRAM

FIGURE 25 - TC-2

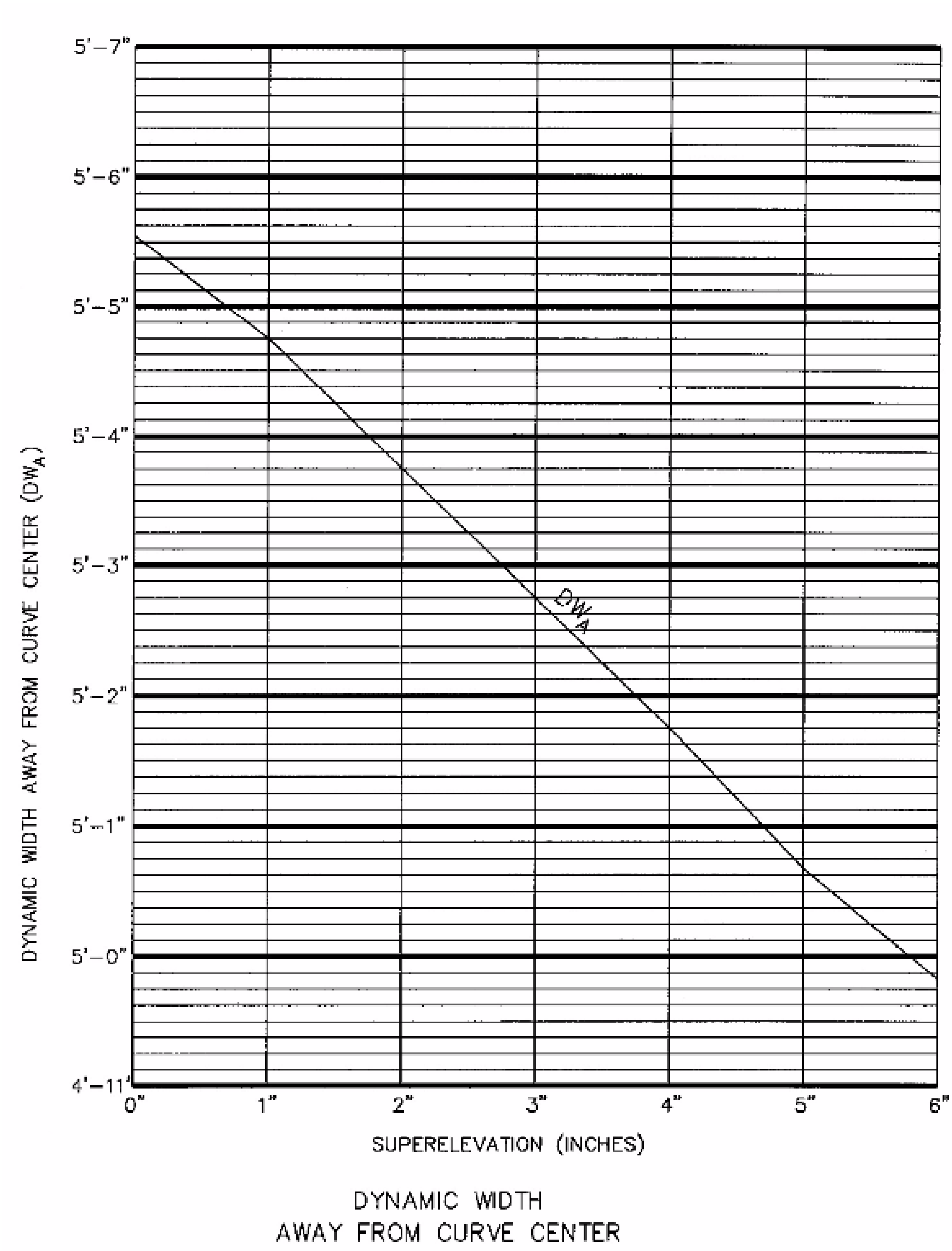


FIGURE 25 - TC-3

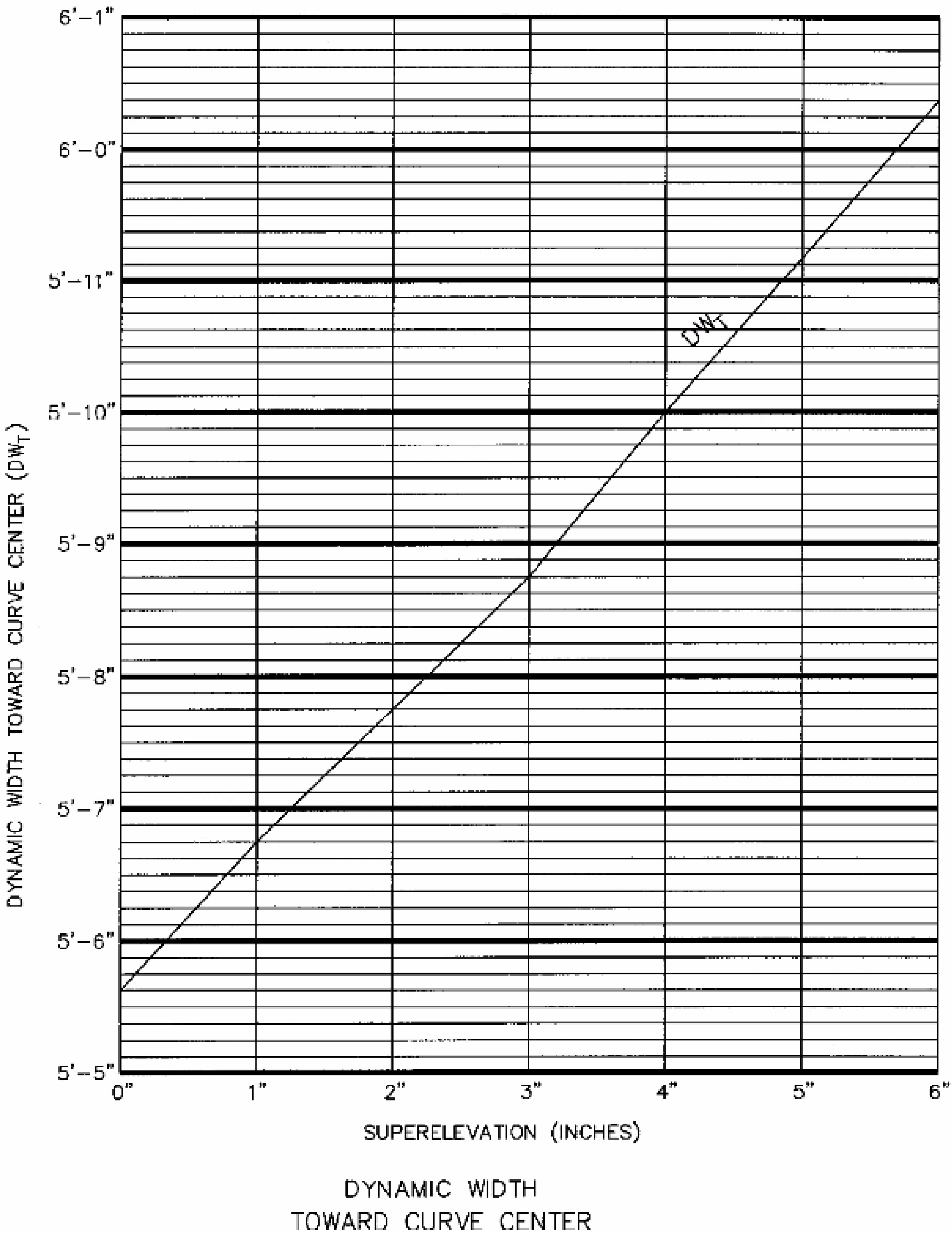


FIGURE 25 - TC-4

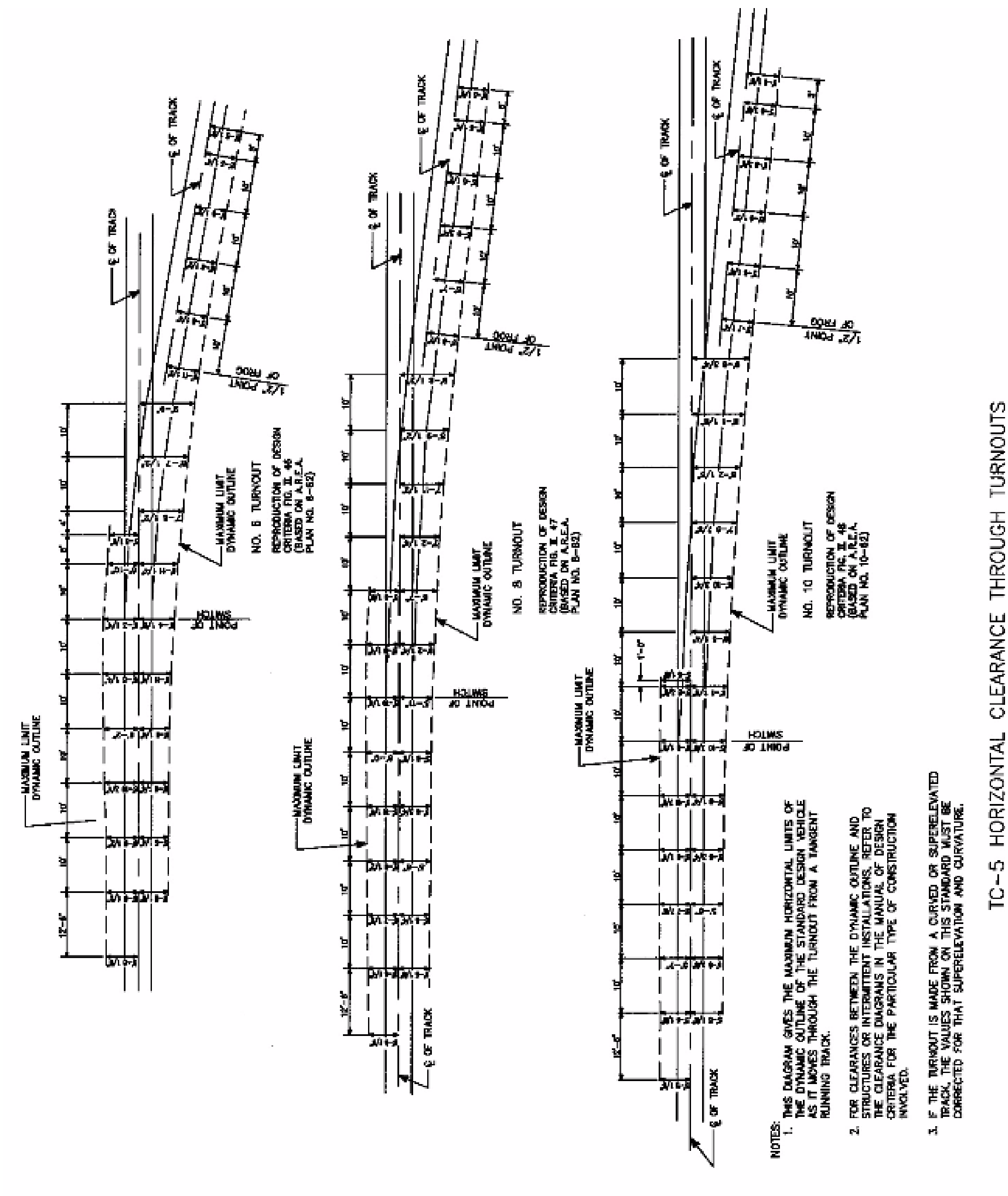
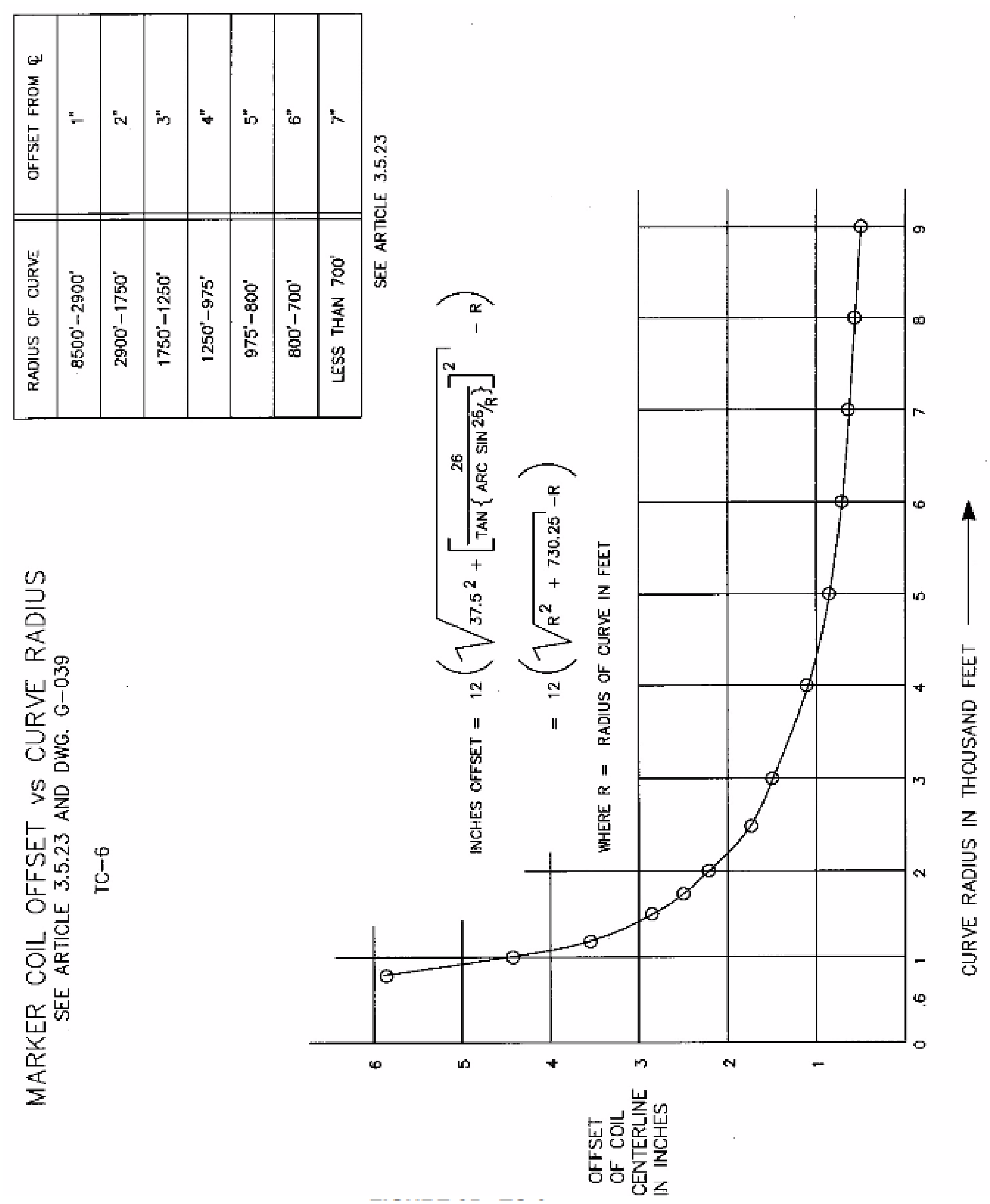


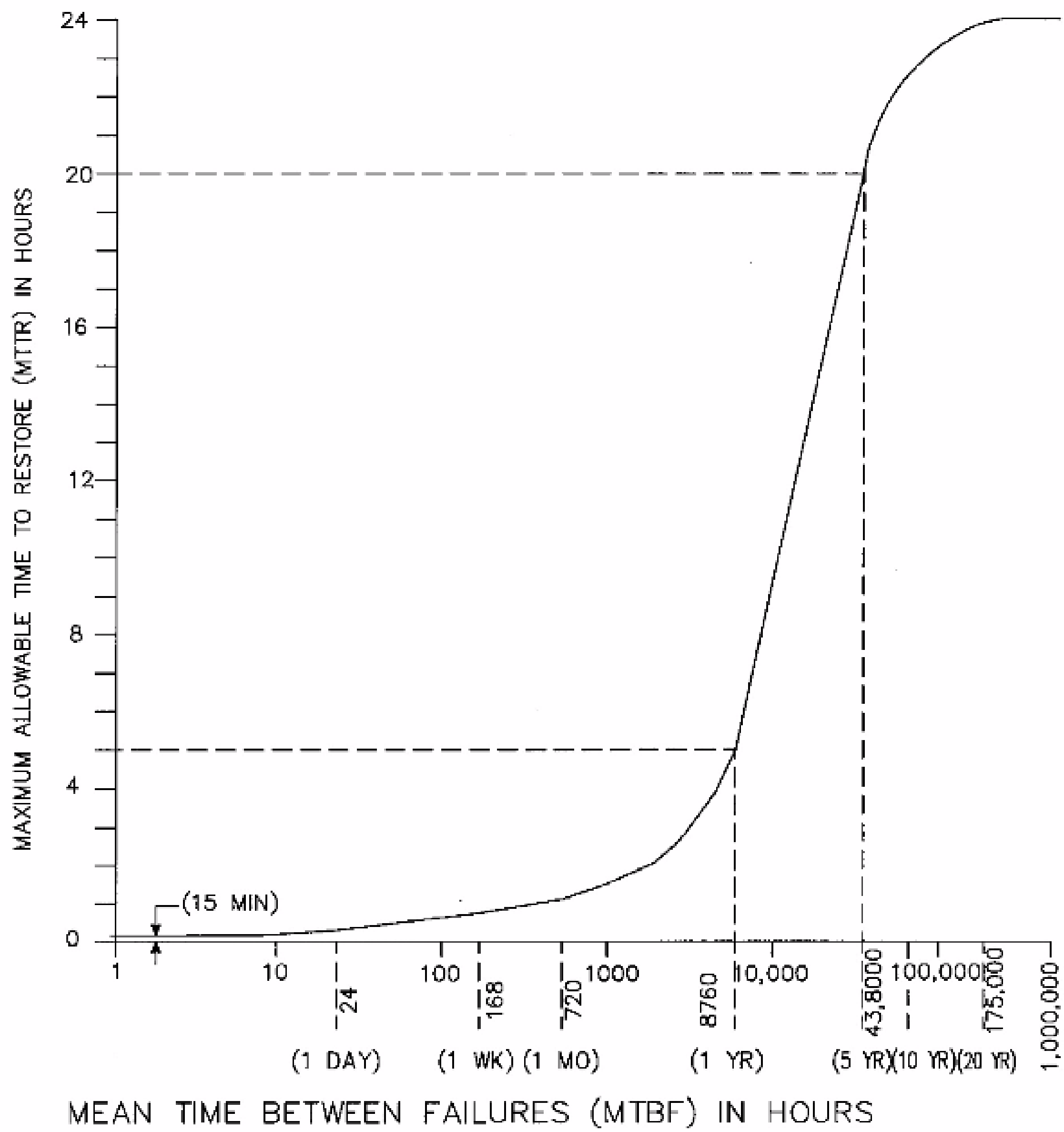
FIGURE 25 - TC-5



RADIUS OF CURVE	OFFSET FROM ℄
8500'-2900'	1"
2900'-1750'	2"
1750'-1250'	3"
1250'-975'	4"
975'-800'	5"
800'-700'	6"
LESS THAN 700'	7"

$$\text{INCHES OFFSET} = 12\left(\sqrt{37.5^2 + \left[\frac{26}{\tan\{\arcsin \frac{26}{R}\}}\right]^2} - R\right) = 12\left(\sqrt{R^2 + 730.25} - R\right)$$

FIGURE 25 - TC-6

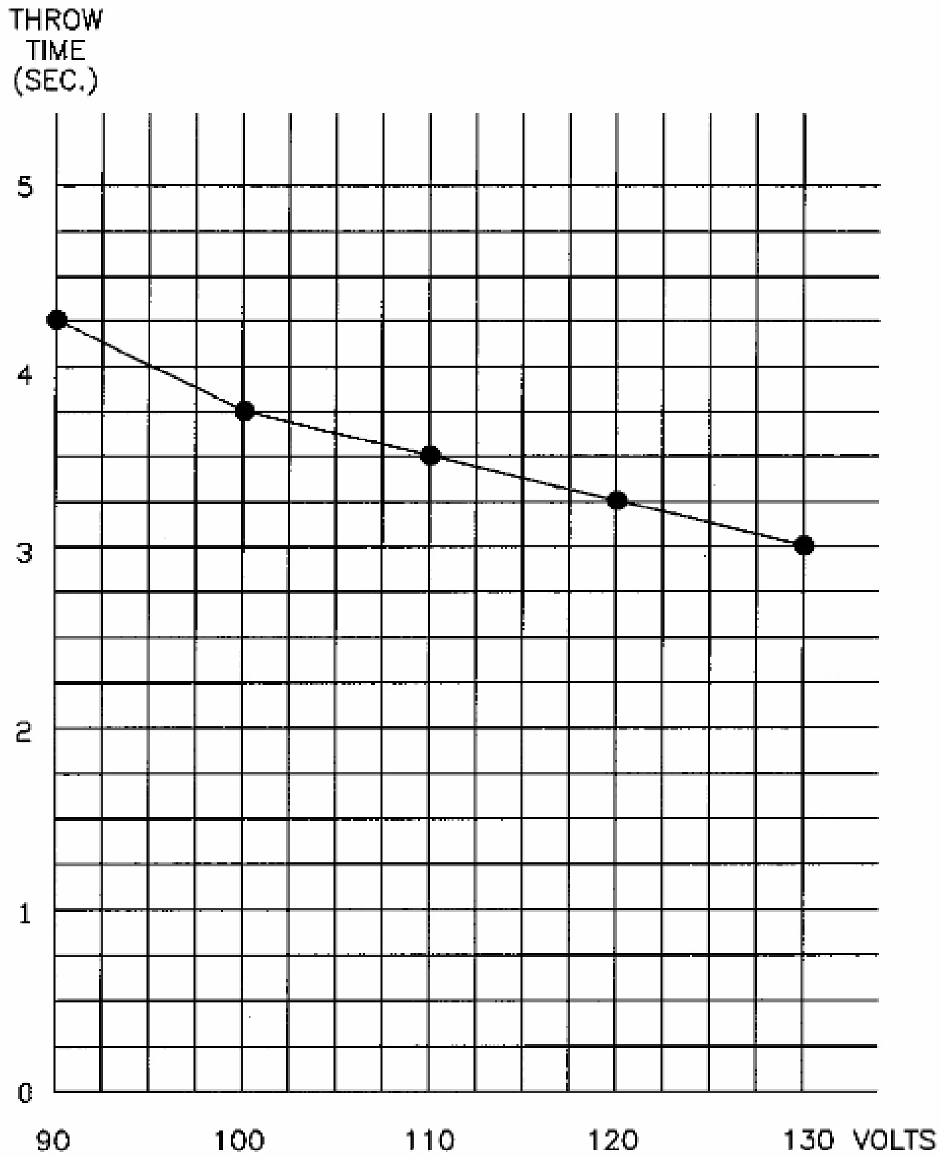


TC–7 – MICROPROCESSOR SYSTEM MTTR

GRAPH SHOWING THE MAXIMUM ALLOWABLE TIME TO RESTORE A MICROPROCESSOR SYSTEM FOR ANY MEAN TIME BETWEEN ITS FAILURES

FIGURE 25 - TC-7

SWITCH OPERATING TIME VS VOLTAGE



WHEN SWITCH-AND-LOCK MOVEMENT OPERATING VOLTAGE IS BETWEEN 90 VOLTS AND 130 VOLTS, SWITCH OPERATING TIME SHALL BE LESS THAN THE MAXIMUM THROW TIME INDICATED ABOVE.

FOR V=90-100, T= 8.75- .05 X V

FOR V=100-130, T= 6.25- .025 X V

FIGURE 25 - TC-8

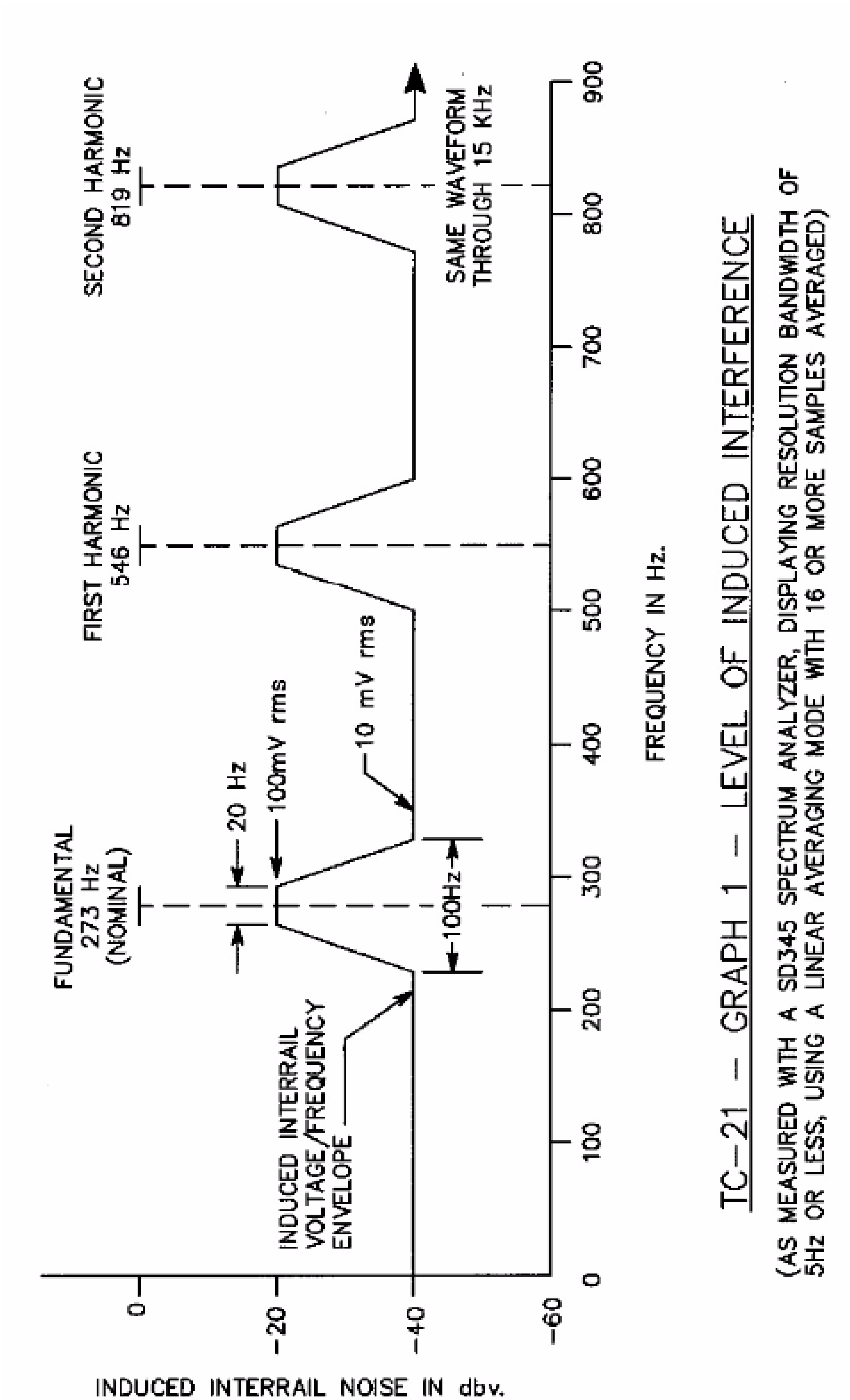
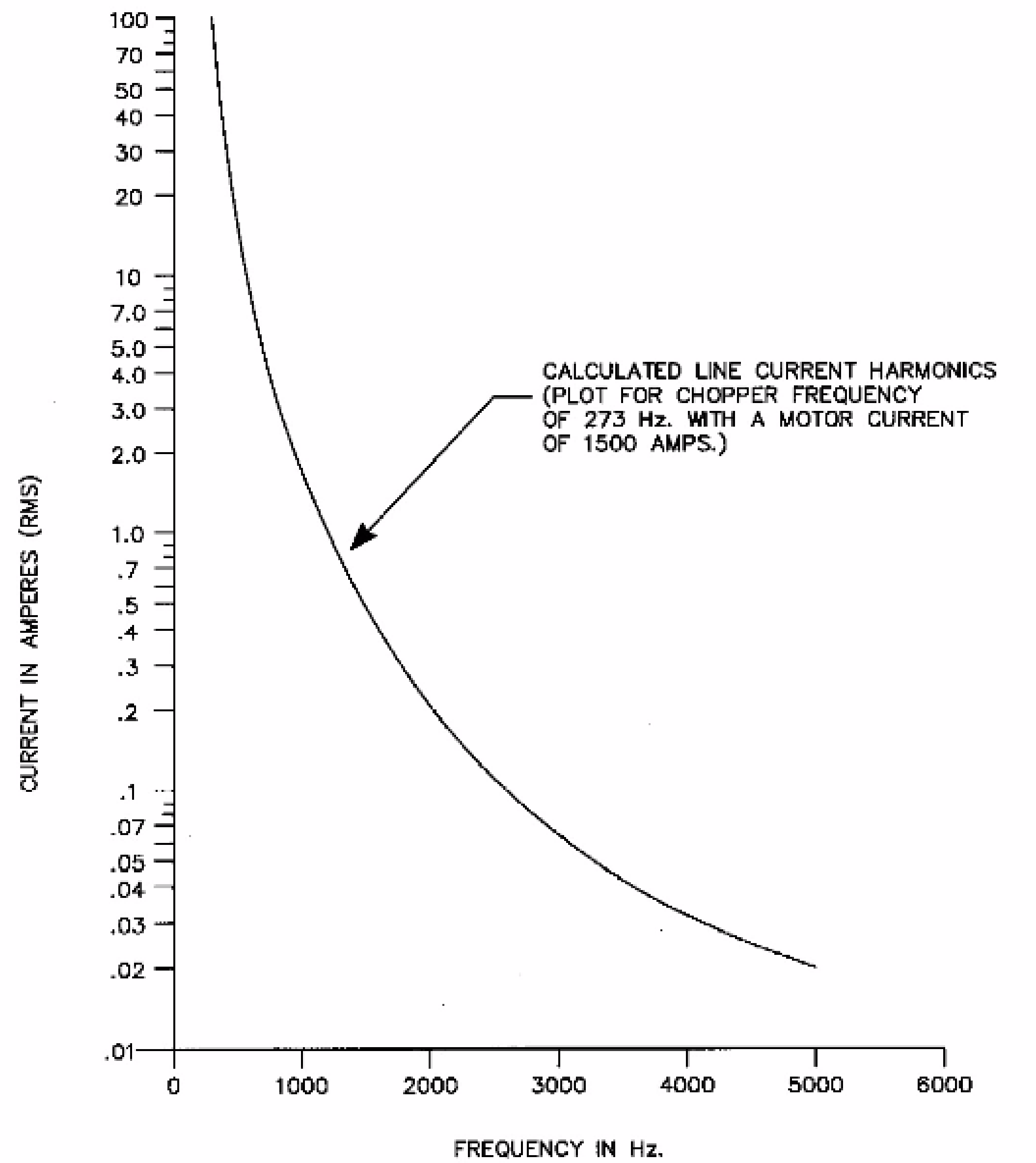


FIGURE 25 - TC-21



TC-22 – GRAPH 2 – LEVEL OF CONDUCTIVE INTERFERENCE

FIGURE 25 - TC-22

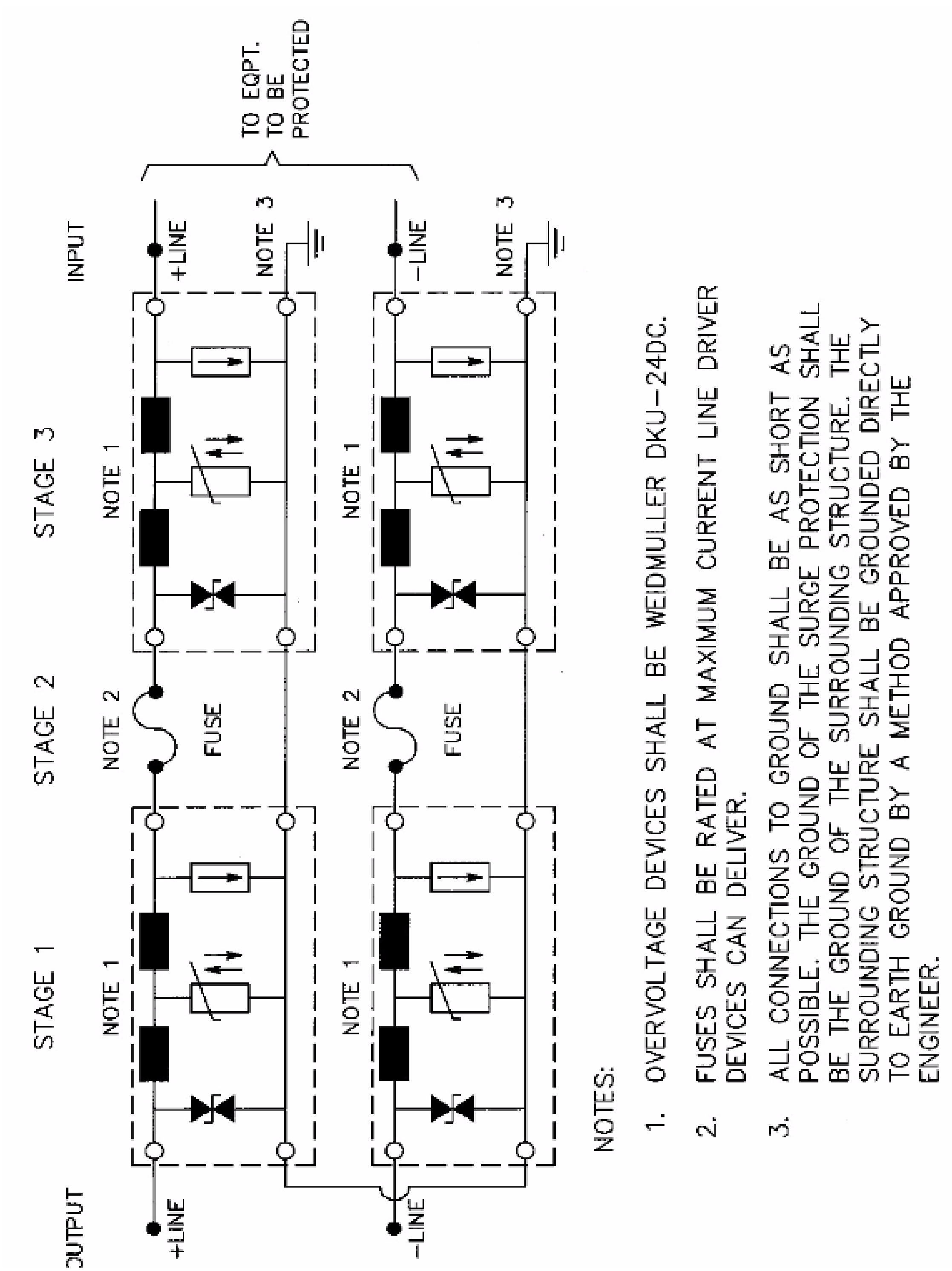


FIGURE 25 - TC-23

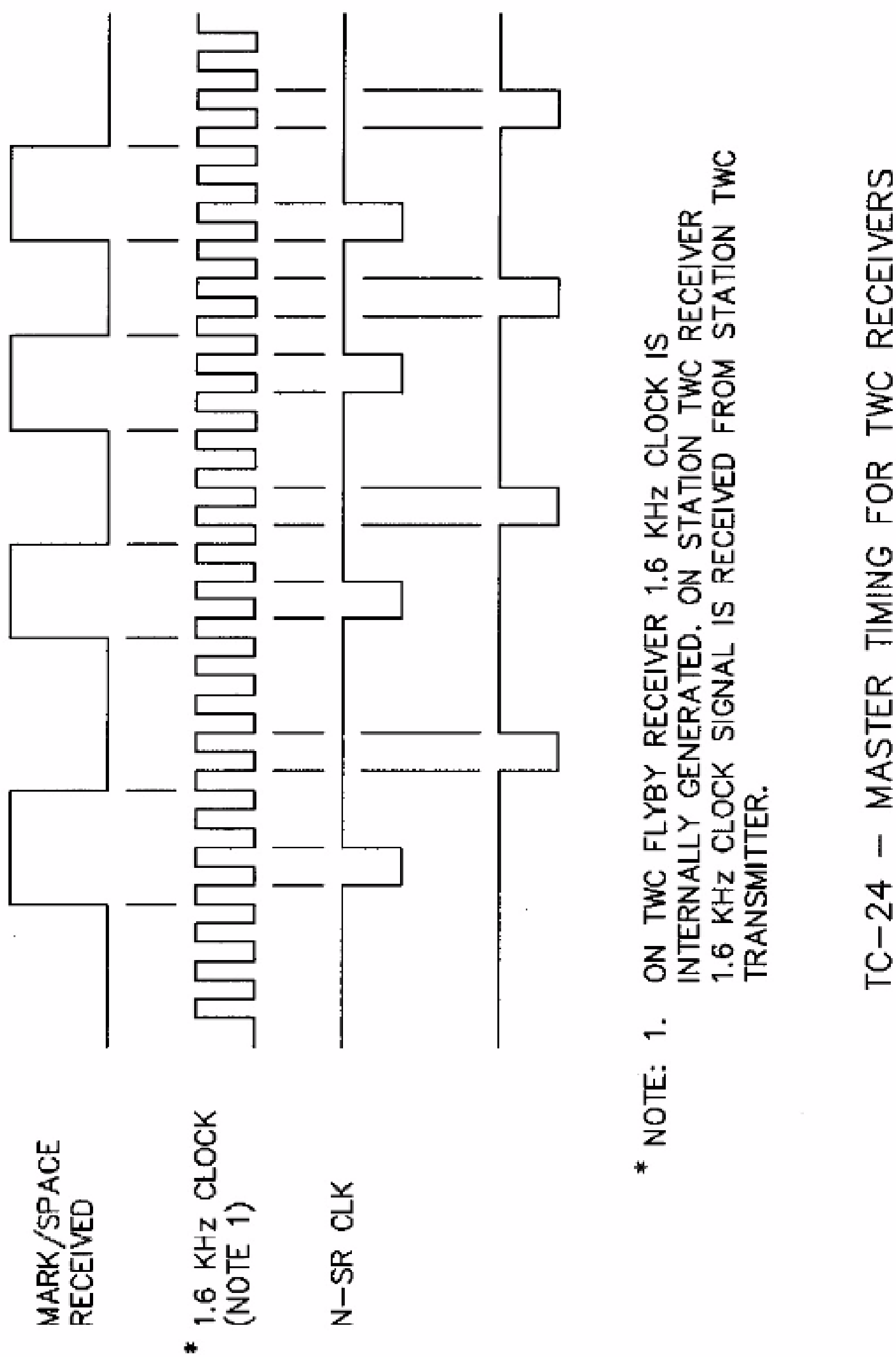
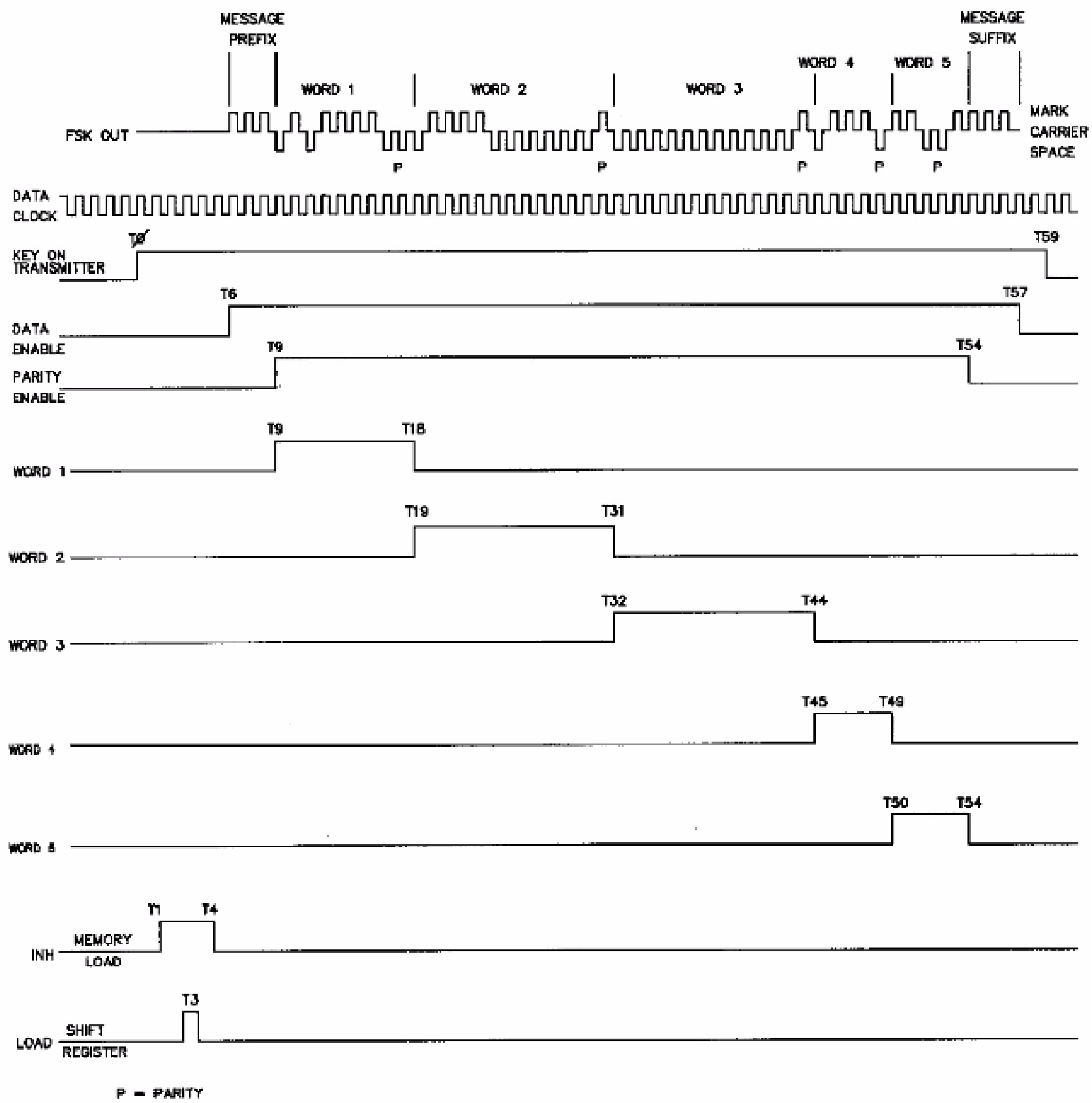
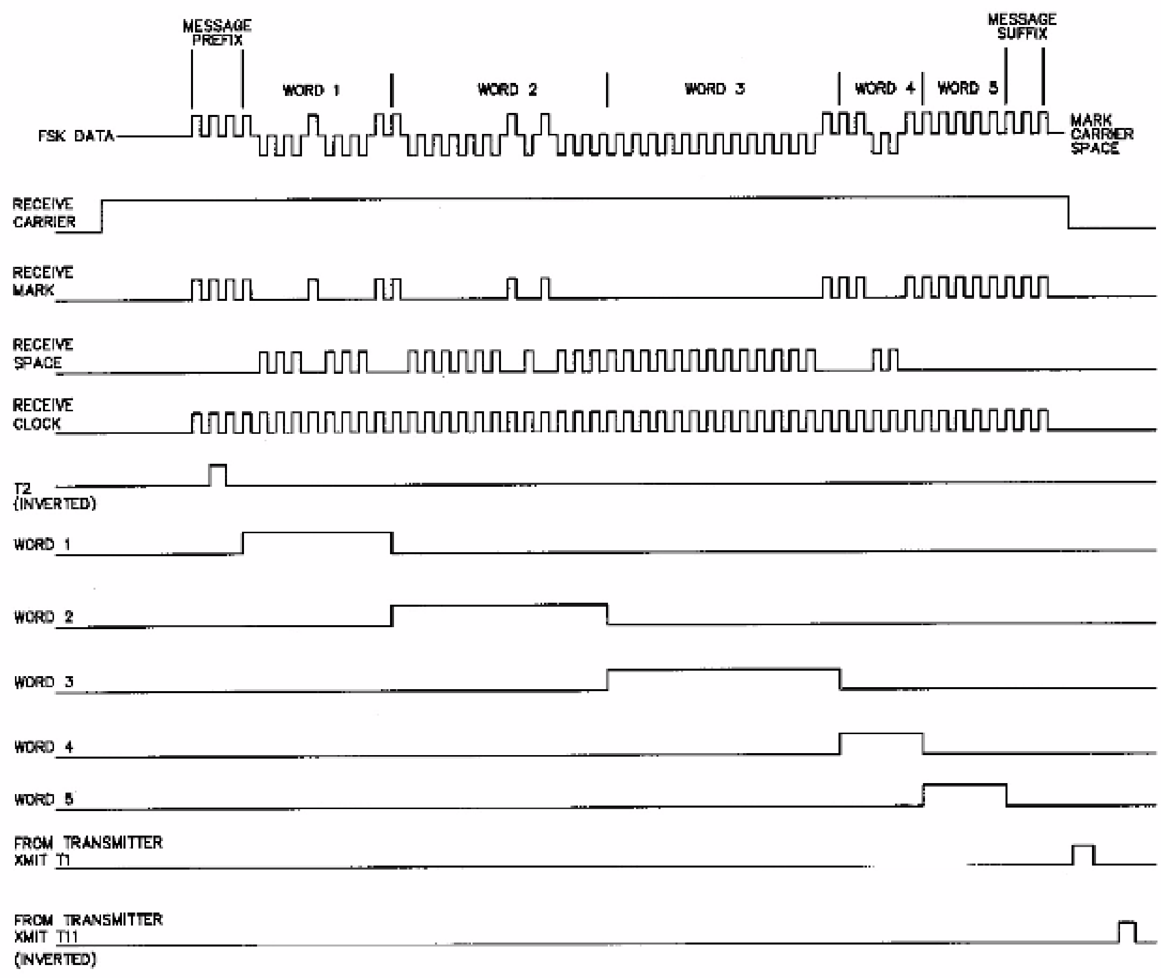


FIGURE 25 - TC-24



TC–25 – TWC STATION TRANSMITTER TIMING DIAGRAM

FIGURE 25 - TC-25



TC–26 – TWC STATION RECEIVER TIMING DIAGRAM

FIGURE 25 - TC-26

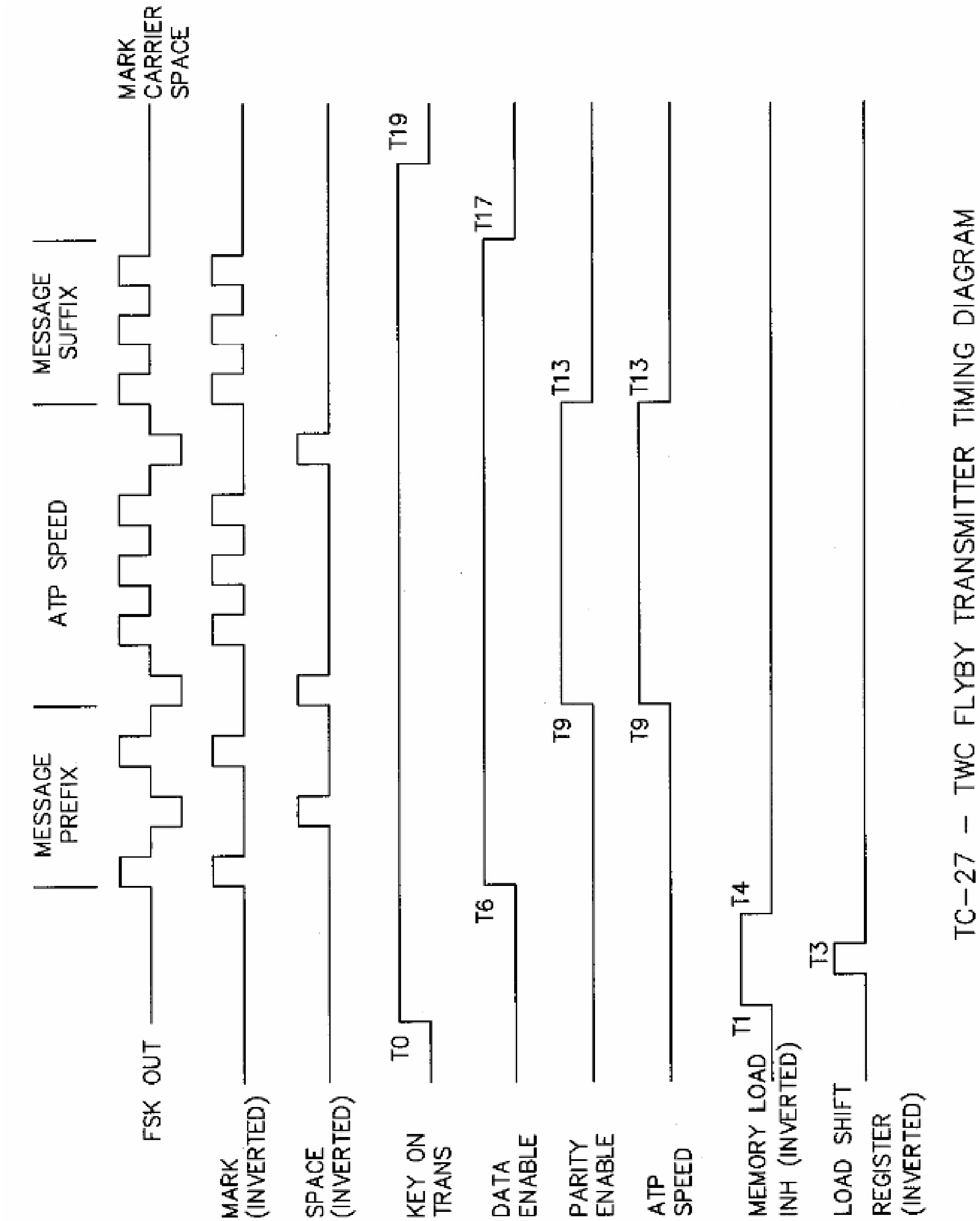


FIGURE 25 - TC-27

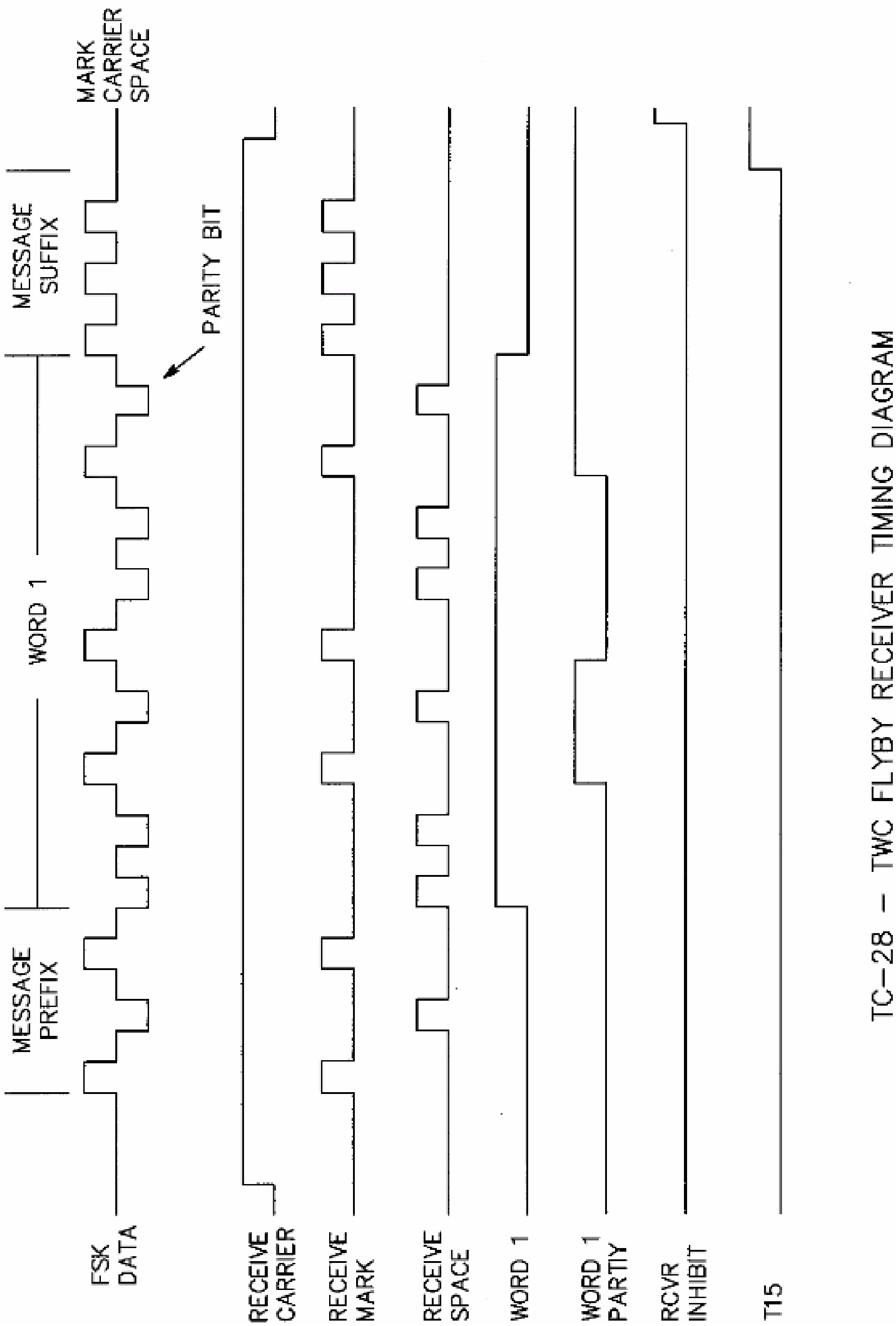


FIGURE 25 - TC-28

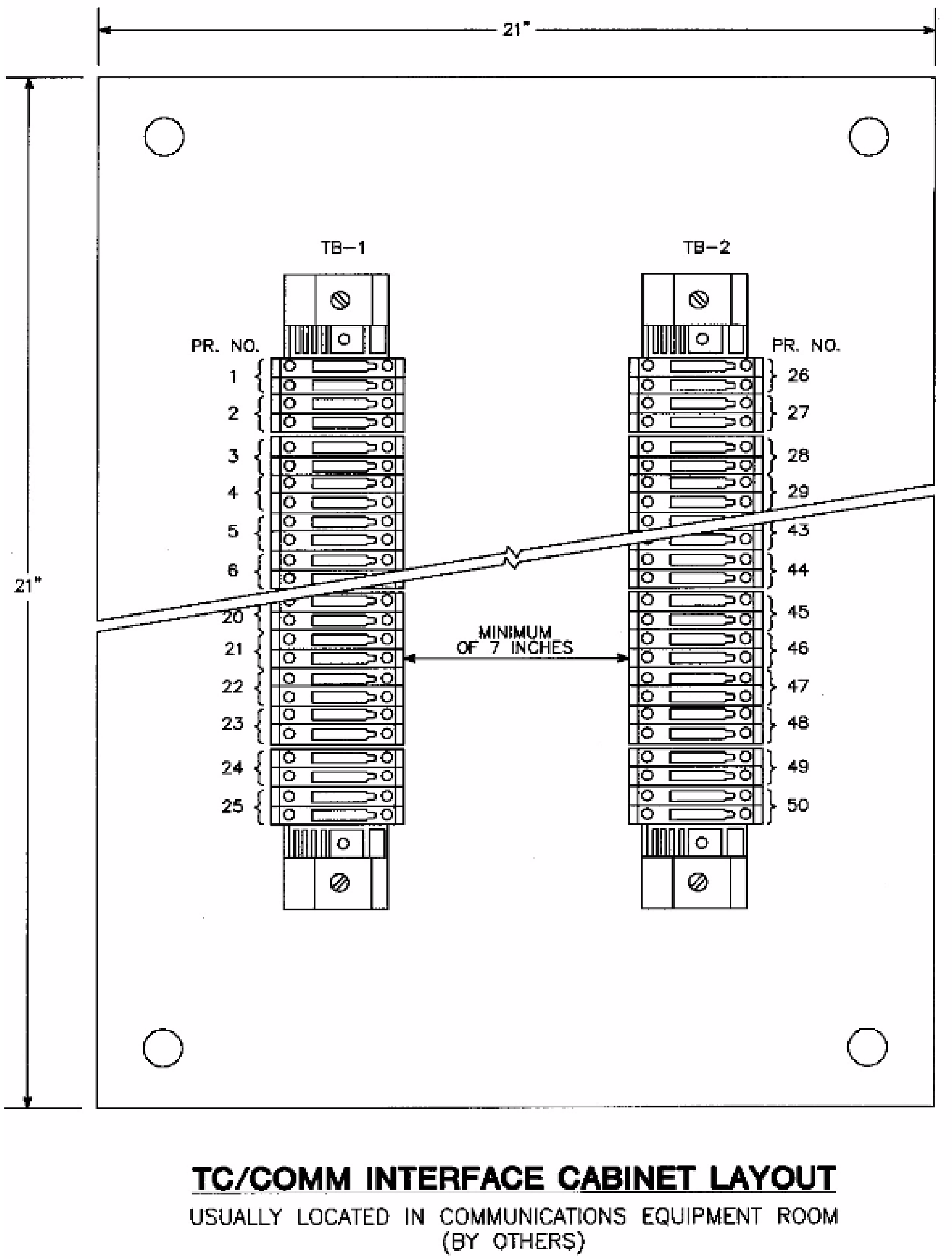


FIGURE 25 - TC-29

TC-30: TC/COMM INTERFACE CABINET WIRING & DESCRIPTION

WIRING SCHEDULE

TERMINAL BLOCK 1			TERMINAL BLOCK 2	
PAIR NO.	USE		PAIR NO.	USE
1	SPARE		26	STATION INTRUSION DTS
2	SPARE		27	STATION FIRE DTS
3	SPARE		28	AFC INTRUSION DTS
4	SPARE		29	SPARE
5	SPARE		30	SPARE INT. DTS
6	SPARE		31	SPARE FIRE DTS
7	SPARE		32	SPARE INT. DTS
8	SPARE		33	SPARE FIRE DTS
9	SPARE		34	SPARE INT. DTS
10	SPARE		35	SPARE FIRE DTS
11	TIME HR/24 HR		36	SPARE INT. DTS
12	TIME MIN		37	SPARE FIRE DTS
13	SPARE		38	SPARE INT. DTS
14	SPARE		39	SPARE FIRE DTS
15	SPARE		40	SPARE INT. DTS
16	SPARE		41	SPARE FIRE DTS
17	ACI-1 WHEN REQUIRED		42	SPARE INT. DTS
18	ACI-2 WHEN REQUIRED		43	SPARE FIRE DTS
19	SPARE		44	SPARE INT. DTS
20	SPARE		45	SPARE FIRE DTS

21	SPARE		46	SPARE INT. DTS
22	SPARE		47	SPARE FIRE DTS
23	SPARE		48	SPARE INT. DTS
24	SPARE		49	SPARE FIRE DTS
25	TCM TELEPHONE		50	SPARE

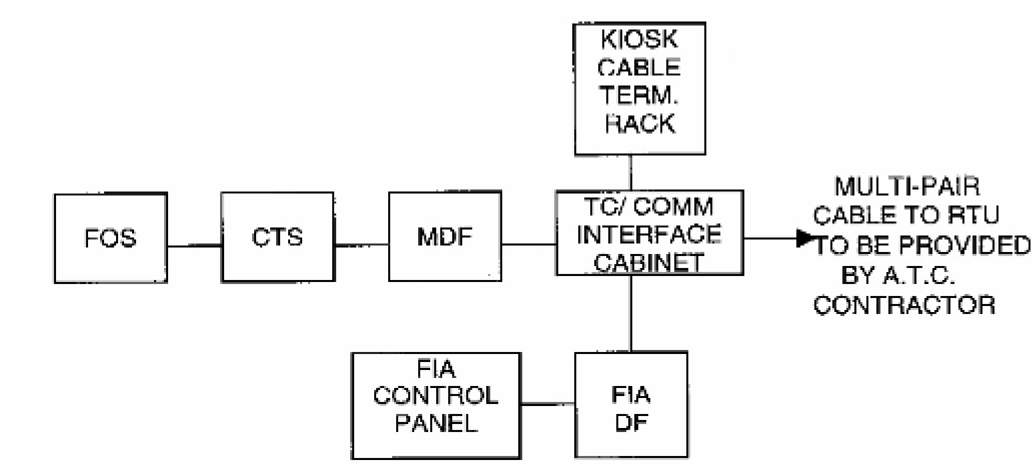


FIGURE 25 - TC-30

TRAINING CLASSES --- GENERAL REQUIREMENTS

EQUIPMENT/SYSTEM & CLASS NAME	PRESENTATIONS & DESCRIPTION	CLASS TIME & TRAINEES
Non-Vital Station Processor Maintainer's STAP Training Course	4 Presentations Operation and Maintenance of the STAP System	3 to 5 Days Each 12 Trainees Each
Non-Vital Station Processor Engineer's Station Processor Training Course	1 Presentation Programming, Reprogramming, and Maintenance of the STAP System to the board level	5 to 10 Days 12 Trainees
Data Transmission Sys.(DTS) DTS Field Maintainer's Training Course	4 Presentations Operation and Maintenance of the RTU, CAU, A/D Converter and Multiplexer Equipment and Circuitry	5 Days Min., Each 12 Trainees Each
Data Transmission Sys.(DTS) DTS Shop Maintainer's Training Course	2 Presentations Troubleshooting to the Component Level	5 Days Each 8 Trainees Each
Data Transmission Sys.(DTS) Engineer's DTS Training Course	1 Presentation Program, Reprogram and Maintenance of DTS	5 Days Minimum 12 Trainees
Non-Vital Interlocking Processor (NVIP) Systems Field Maintainer's Training Course for NVIP Systems	1 Presentation Operation, Maintenance and Troubleshooting o Non-Vital portion of Interlocking Control System	5 to 10 Days 12 Trainees
Non-Vital Interlocking Processor (NVIP) Systems Engineer's Training Course for NVIP Systems	1 Presentation Operation, Maintenance and Troubleshooting o Non-Vital portion of Interlocking Control System	5 to 10 Days 12 Trainees
ATC System and IVP Systems Maintainer's ATC/IVP Training Course	4 Presentations Operation, Maintenance and Trouble-shooting of the complete ATC System with Special emphasis on the Interlocking Vital Processor Systems	5 to 10 Days Each 12 Trainees
Interlocking Vital Processor Systems (IVP) Engineer's Training Course for IVP Systems	1 Presentation Programming, Maintenance and Re Programming of the IVP Systems to the Board Level	5 to 10 Days 12 Trainees

Train Control Room (TCR) Equipment and Systems TCR Maintenance Training Course	4 Presentations Operation, Maintenance and Trouble-shooting of Vital Control Systems, Power Supply Systems, Grounding & Surge Protection Systems, and Non-Vital Systems	10 Days Each 12 Trainees Each
Wayside Equipment & Systems Wayside Maintenance Training Course	4 Presentations Operation, Troubleshooting & Field Maintenance of Switch Machines, Signals, Impedance Bonds, Marker Coil Layouts, Signal & Negative-Return Bonding, Snowmelter Layouts, Vital & Non-Vital Relays, Test Equipment	10 Days Each 12 Trainees Each

FIGURE 25 - TC-31

SECTION 26 - COMPUTER SYSTEMS

26.1 GENERAL (Future)

26.2 HEAVY RAIL

26.2.1 RAIL OPERATIONS CONTROL CENTER (OCC) OVERVIEW

The overall supervisory control of WMATA METRORAIL operations is conducted by specially trained WMATA personnel at a central control facility known as the Operations Control Center (OCC), located in the Jackson Graham Building (WMATA Headquarters) in downtown Washington, DC. This central control facility, part of the ATC Automatic Train Supervision (ATS) System, contains: a control computer; a hot backup computer, and; a computer for software development, which also serves as the ultimate backup computer.

The control computer receives and transmits messages between the operations control center and station locations via the Data Transmission System (DTS). It communicates with the central control operator by providing displays on a large scale screen and on individual video displays, and by accepting operator input from the computer control consoles. The control computer performs schedule adjustments by changing station dwell times and train performance levels. These changes are sent to the applicable station Remote Terminal Units (RTUs) via the DTS.

The METRORAIL system can operate as a stand-alone entity without the computer complex at the OCC. However, without the capabilities provided by the ATS software in the central control computer, the display system, and the DTS, the job of monitoring and supervising the METRO operations, especially to maintain schedules, would be more difficult. This is especially true when an abnormal condition (e.g., a malfunctioning train) is encountered.

The general Train Control and ancillary functions provided to aid the central control operators are:

26.2.1.1 Display System

26.2.1.1.1 Train System Displays

26.2.1.1.2 Train and Interlocking Detail Displays

26.2.1.1.3 Train Information Displays

26.2.1.1.4 Electrical System Displays

26.2.1.1.5 Train and Electrical System Alarm Displays

26.2.1.1.6 Geographic Displays

26.2.1.2 Traffic Regulation Monitoring

26.2.1.2.1 Schedule Control

26.2.1.2.2 Schedule Adjustment Strategies

26.2.1.2.3 Schedule linkage of train put-ins

26.2.1.3 Supervisory Capability

26.2.1.3.1 Train Control requests to wayside ATP system

26.2.1.3.2 Interlocking requests to wayside ATP system

26.2.1.3.3 Commands to wayside ATS equipment

26.2.1.3.4 Commands to wayside support system devices

26.2.1.4 Status Monitoring and Alarm Processing

26.2.2 AUTOMATIC TRAIN SUPERVISION SOFTWARE

The software for the central computer has been designed in a building block approach and provides the primary functions of Traffic Regulation, and Control and Display.

26.2.2.1 Traffic Regulation

26.2.2.1.1 All trains in the METRO system under central computer supervision enter revenue service, run, and terminate revenue service according to times provided by predetermined train schedules. These train schedules are the basis for Traffic Regulation Control. A train schedule is defined as a set of arrival and departure times at successive locations which completely dictates a train's intended movement from entry into revenue service until layup. A train schedule defines, among other things, the scheduled arrival time and the scheduled dwell time at every station traversed by a given train. A unique schedule is defined for each train that is in revenue service or is about to enter revenue service. The system schedules are selected by the central control operators at the start of revenue service on a particular day.

26.2.2.1.2 Traffic Regulation automatically maintains the scheduled headways between all of the trains operating in the territory and regulates train movements for time schedule adherence, proper merging of trains at rail line junction points, and optimum utilization of terminal locations. This is achieved by control of both station dwell time, and train performance (speed) and acceleration levels which govern the interstation running time.

26.2.2.1.3 The four main components of the Traffic Regulation software are Put-in Processing, the Line Algorithm, the Terminal Algorithm, and Strategy Selection. Also, statistics of the actual performance of trains are gathered for off-line analysis.

26.2.2.1.3.1 Put-in Processing

The Put-in Processing software initiates train entry into revenue service either from a storage point, such as a yard or a pocket track, or from a terminal station after a train reversal. The primary function of the Put-in Processing software is to construct a schedule for the next terminal-to-terminal run of the train so that the Terminal Algorithm and the Line Algorithm can control it. Another function performed is the lighting of warning lamps at yards prior to the scheduled dispatch of a train so that the yard personnel can prepare a train for revenue service.

26.2.2.1.3.2 Line Algorithm

26.2.2.1.3.2.1 The primary function of the Line Algorithm is to attenuate delays due to minor line disturbances as quickly as possible and prior to the arrival of trains in areas where the probability of such delays is high. Line disturbances are events or conditions which cause a train to be early or late with respect to its schedule. Such events cause the Line Algorithm to affect the dwell time of a train at a station and the performance of a train departing from a station. The Line Algorithm minimizes or eliminates the effects of delays by adjusting the dwell and performance level of a train such that the departure schedule error at a station and the arrival schedule error at the next station are both minimized.

26.2.2.1.3.2.2 There are four performance levels. Performance Level 1 (PL1) requests the train to run at the maximum safe interstation speed, resulting in the minimum safe interstation run time. The normal schedule for a train is based on PL2, which is approximately 10 percent slower than PL1. This gives traffic regulation a catch-up capability by allowing it to requestPL1 to reduce a train's lateness. PL3 and PL4 are approximately 10 percent and 20 percent slower than PL2 and are used when trains are ahead of schedule.

26.2.2.1.3.2.3 Each of the four performance levels may be combined with a request for either full or half acceleration, thus providing eight different interstation run times. For each station platform the program can select either a normal dwell time or another value which lies within the range of minimum and maximum dwell times for that platform. Dwell times available for some platforms can be varied with the time of day.

26.2.2.1.3.3 Terminal Algorithm

26.2.2.1.3.3.1 A special case handled by a part of Traffic Regulation called the Terminal Algorithm is used to avoid conflicts between trains at terminals having a crossover interlocking located between the terminal station and the penultimate station. Since these interlockings are used to reverse trains, conflicts in the use of the interlockings can be generated by trains arriving at and departing from a terminal station at close headways. A route conflict exists whenever two trains attempt to traverse conflicting routes through an interlocking at the same time.

26.2.2.1.3.4 Strategy Selection

26.2.2.1.3.4.1 The central control operators have the capability of providing corrective strategies through the Strategy Selection program whenever required. The control philosophy employed here is that the operator is the best judge of what corrective action is most suitable in any given situation and the computer is most useful as a device to display the options available and to implement the selected option. The Strategy Selection programs include Replace Train, Delete Train, Add Train, Eliminate Gap, Create Gap, Offset Schedule, Tilt Schedule and Skip Stop. All act to either modify or maintain the existing schedule.

26.2.2.1.4 Control and Display Software

26.2.2.1.4.1 The Control and Display software drives the displays and alarm logs and responds to central control operator inputs through the console. The Control and Display software responds to field changes or when requested by an operator input to update train displays. It examines the data returned from the field and marked as changed by the Data Base Processor software. It then updates displays and alarm messages for the central operator as required.

26.2.2.1.4.2 The Control and Display software provides the processing of all operator inputs and coordinates execution of the software required by those inputs. These commands allow the central control operators to manually supervise system operation and to request specific displays.

26.2.3 OCC SYSTEM HARDWARE

The system hardware is used to perform the required Automatic Train Supervision functions and backup functions. The individual components are integrated to provide the means by which the various software components perform their functions.

26.2.3.1 General Purpose Computer Subsystem

Three interconnected computers comprise this subsystem. Each computer consists of a central processor with byte addressing, floating point and memory protection instructions, a priority interrupt system, and a power monitoring circuit.

The computer systems are networked to each other and to the peripheral devices through a dual Ethernet network.

26.2.3.2 Communications Subsystem

To handle the specialized data transmission, the central computers are connected to two Front End Processors are connected through the DTS to the various field devices and permit the transfer of data to and from the central control computer. The FEPs receive the raw data from the field and forward change information to the central processors.

26.2.3.3 Control and Display Subsystem

26.2.3.3.1 The Control and Display subsystem, used by the central control operators in controlling the system, has as its main functions; the presentation of system status, operational data and alarms to the central operator, and the execution of system commands from the console.

26.2.3.3.2 Video displays provide the display facility: "Closeup" views of the interlockings; System alarms (Train and E&S Alarm); Performance statistics (Train Information); Electrification system (Traction Power); and the state of mechanical support equipment at a station selected by the operator (Support Station). In the event that a video display malfunctions, the central control operators have the capability of reconfiguring the displays so that a desired display can be moved to a working display.

26.2.3.3.3 A Large Scale Display System provides an overview display of the METRO System and can also be used to display any of the System's local or special displays.

26.2.3.3.4 All alarm conditions on the METRO System, whether the result of train control indications, calculations, traction power and support system indications or computer indications, are displayed in tabular form on the appropriate alarm display and can archived to a history file.

26.3 BUS GARAGE / SHOP FACILITIES (Future)

26.4 LIGHT RAIL FACILITIES (Future)

26.5 HEAVY RAIL YARD / SHOP FACILITIES (Future)

26.6 PARKING GARAGE (Future)

SECTION 27 - COMMUNICATIONS

27.1 GENERAL COMMUNICATION SYSTEM

27.1.1 The purpose of the Rail Communications System is to provide state-of-the-art, efficient and reliable communications between all elements of the Rail System. Verbal, data and visual communications shall be furnished.

Communications service shall be provided for train operations, passenger station operation and security, transit police operations, maintenance operations, and monitoring and alarming of all areas for fire, biochemical detection, and unauthorized entry.

The design of the Communication systems must be coordinated with the design of the Train Control system, the Traction Power system, the Fare Collection system, the IT components, miscellaneous support facilities, revenue and nonrevenue vehicles and equipment, and other components or elements of the transit system.

The communications system shall incorporate the most modern proven designs available to provide the highest degree of safety, efficiency, and reliability.

All equipment and systems shall be designed for immediate 10% expansion.

All equipment and systems shall be designed and constructed with consideration given to physical and electrical environment such as temperature and humidity, range of operation, vibration and shock, dust and weather, electric and magnetic fields, electromagnetic coupling of conductors, pairs and cables, transient peaks of electrical grounding, and voltage and current.

Mechanical configuration of equipment shall provide for ease of inspection and replacement.

Electrical test points, adjustments, fuses, equipment alarms, and indication shall be provided at front panels wherever possible.

All electronic equipment shall be standard, commercially available solid state devices, wherever practicable. Plug-in printed circuit card construction shall provide extender units as standard equipment. Communications and equipment design shall be in accordance with one or more of the following codes and specifications where applicable. The intent of these regulations should also be maintained where new devices or methods are introduced, even through the details of the specifications do not apply.

NOTE: See IT Design Criteria for Phones, Network, and structured cabling design criteria.

27.1.2 Design

A Communication Room shall be provided in each rail station, rail yard building, parking garage, bus garage building, or any other facility that WMATA builds. Larger buildings shall be provided with multiple COM rooms. The Communication (COM) room shall be conditioned space and provided with an HVAC sized to provide the designed heat load plus a 40 percent growth margin.

A telephone closet or Bell room shall be provided near each kiosk within the station. ¾"x4' x8' foot plywood shall line the walls of the telephone closets.

Typical Communication conduits shall be as shown on the design drawings.

CAT6 and Fiber Optic patch panels shall be provided in the COM rooms and in the Kiosks. The Communication system shall include the following equipment:

- Public Address System
- Radio System
- Video Surveillance System
- Fire Alarm System
- Intrusion Detection System
- Access Control System
- Call for Aid System
- Information Display System
- Kiosks
- Operation Control Centers

NOTE: See IT Design Criteria for Phones, Network, and structured cabling design criteria.

27.1.3 Power for Communications

The Electrical Power System shall provide power distribution from the 3-phase, 4-wire, 120/208 VAC, primary power feed, provided by others, to the communications room.

Communication devices with redundant power supplies shall be connected to different power sources. One side shall be connected to the Emergency supply and the other side shall be connected to the Normal supply.

The design shall provide for a 120/208 VAC Emergency Power Distribution System for each Passenger Station, and shall include as a minimum:

- A 120/208 VAC, 3-phase, 4-wire Emergency power distribution panel board with solid neutral bus and ground bus, main lugs rated 100 Amp and a minimum of 20 single-pole breakers.
- AC Power Disconnect Switch with minimum ampere rating of 100 Amp
- AC Emergency power distribution panel in the Kiosk
- AC Normal power distribution panel in the Kiosk
- AC power receptacles.

27.1.4 Grounding

All conduit shall be electrically insulated from equipment racks and equipment cabinets; power ground shall be separate and isolated from the communications ground.

Conduit containing branch circuit conductors shall be insulated from the equipment racks and cabinets by means of short lengths of non-conducting conduit.

Short lengths of flexible metallic conduit shall be provided in the equipment cabinets and on the equipment racks between the non-conducting conduit and the ac power receptacle strips.

Each branch circuit shall contain a separate neutral conductor to the Communications Equipment Room Power Distribution Panel board.

27.1.5 Surge Suppression

Surge suppression shall be provided on all incoming lines that are exposed to the external environment.

27.2 PUBLIC ADDRESS SYSTEM

27.2.1 Purpose

The purpose of the Public Address (PA) system is used to provide audio information to the public, employees, and contractors in both the public and non-public areas of passenger stations.

27.2.2 Design

A Public Address system shall be installed in each passenger rail station and be designed and maintained to have a Speech Transmission Index (STI) of 0.7.

The Public Address system shall allow announcements to be made with the following priority and from the following locations:

- The Station Fire Alarm Panel
- The Rail Operational Control Center at:
- Jackson Graham Building
- Carmen Turner Facility
- The Kiosk Wireless Microphone
- The Kiosk Wired/Gooseneck Microphone
- The End of Line Station / Dispatcher’s Office (Block House)

27.2.3 Major System Components

The PA system shall include the following major components:

- JGB OCC Head End
- CTF OCC Head End
- Station IP to Audio converter
- Redundant Station Amplifiers
- Station Speakers
- Kiosk Control Panel with Microphone
- Wireless Microphone System
- Intercom
- Priority Mixer
- Ambient Noise Sensor and Processor
- Compressor / Limiter
- Digital Audio Equalizer

27.2.4 Basis of Design

The basis of design for the PA system is as follows:

- OCC Head End – Penta
- Station IP to Audio Converter – Barix
- Audio Amplifiers –
- Speakers

- Intercom - Commend

27.2.5 OCC Head End

The Rail Operations Control Center (OCC) uses the PENTA PA Control Equipment to select and broadcast in the following way:

- System wide announcements to all Metro Rail Stations
- Announcements to selected Lines (i.e., Red Line, Green Line, or Blue/Orange Lines)
- Individual Passenger Stations

27.2.6 Passenger Stations Public Address System

Each passenger station in the WMATA Rail System shall be designed to have an independent Public Address (PA) System. The Passenger Station PA System provides for general purpose and emergency evacuation announcements throughout the passenger station.

PA coverage shall be provided to all public and nonpublic areas of the station.

Each station shall be provided with a priority mixer. The line mixer shall be used to control the level of the individual audio inputs. A single output shall be taken from the mixer and input to the power amplification. When an announcement of a higher priority is initiated, the lower priority announcement is removed from the amplifier’s input until the high priority announcement is completed.

Below ground stations shall be provided with a noise compensated circuits for the platform and mezzanine areas. This noise compensation circuit shall be used to automatically adjust the PA volume when trains are arriving or departing the station. Above ground stations shall not be provided with noise compensated circuits.

Stations shall be provided with non-noise compensated circuits for service rooms and non-revenue passageways. Service rooms shall be provided with a volume control circuit.

The operation of the Passenger Station PA System from the Kiosk is accomplished by simultaneously depressing the push-to-talk pushbuttons on the hand-held microphone and the Kiosk PA Control Panel, then speaking into the hand-held microphone.

Kiosks shall be provided with a portable wireless microphone. The wireless microphone shall work from any location on the platform or mezzanine(s). The wireless microphone shall by-pass and takes the place of the normal kiosk microphone when the wireless microphone is keyed. This feature is used to allow the kiosk attendant freedom of movement beyond the kiosk for various reasons including crowd control.

When a selection is made by a Passenger Operations Supervisor in the Rail Operations Control Center, the audio path of the console is connected to the station PA via an IP connection.

The PA system design shall have redundant power amplifiers. The Power Amplifiers shall be connected to the Amplifier Supervisory Control Unit. One Power Amplifier shall be connected to the "MAIN CHANNEL" of the Amplifier Supervisory Control Unit, and the second Power Amplifier shall be connected to the "auxiliary channel" of the Amplifier Supervisory Control Unit. Each Amplifier Supervisory Control Unit shall monitor the associated Power Amplifiers and, upon sensing a malfunction of the "main channel" Power Amplifier, shall automatically transfer the audio path to the "auxiliary channel" Power Amplifier.

The Passenger Station PA Speakers shall be designed to be wired in either noise-compensated or non-noise compensated circuits. Noise-compensated circuits shall be used in areas where train noise must be overcome by automatically adjusting the PA volume. The station mezzanine area and Platform areas are of noise compensated circuits which use Automatic Level Control. For areas where noise compensation is required, circuits shall be wired to the Loudspeaker Distribution Panel designated for noise-compensated circuits. Non-noise compensated circuits shall be used in all other areas. In areas where noise-compensated circuits are not required, circuits shall be wired to the Loudspeaker Distribution Panel designated for non-noise compensated circuits. Passenger station service rooms and non-revenue passageways are examples of areas that require non-noise compensated speaker circuits.

The PA amplifiers shall have a constant voltage output of 70.7 volts. Each loudspeaker shall be equipped with an audio transformer to match the 70.7 volt line with the loudspeaker. The transformers shall have various taps to allow for adjustment of the sound level in a particular area. Each transformer shall have a minimum of four taps. The power rating for each of the taps shall be determined during installation.

The design and deployment of public address speakers shall be coordinated with architectural design. The speaker quantities and locations shall be determined by the coverage requirements. A sufficient quantity of speakers shall be placed in passenger stations to give even volume distribution without objectionable loudness from any one speaker location. Speakers shall be feed from two different amplifiers in an alternating feed pattern so that if one amplifier fails, PA audio is provided to all coverage locations.

27.2.7 End-Of-Line Stations

The PA system for End-Of-Line Stations shall be designed to have a Dispatcher PA input at the Station. The Dispatcher PA System input shall provide access to the Passenger Station PA System to make announcements at any time that the station PA system is not already in use.

A Dispatcher's PA Control Panel shall be provided in the dispatcher's office and function in an identical manner as the Kiosk Public Address Control Panel. The Dispatcher's PA Control Panel shall have a Zone Selection capability. The Dispatcher PA system Zone Selection shall provide the Dispatcher with the ability to choose between either (1) All Station Speakers or (2) Platform Speakers Only.

27.2.8 Intercoms

Each Kiosk in the WMATA Rail System shall be provided with an Attendant/Passenger Interphone System. The Attendant/Passenger Interphone System shall provide for communication between passengers and the Kiosk Attendant at the Kiosk. The Attendant/Passenger Interphone System shall serve both the "PAID" and the "UNPAID" side of each Kiosk.

Additionally, a separate Intercom System shall be provided at the Dispatcher's Room to provide verbal communications between the Train Control Room, the Dispatcher's Room, and the Operations Room. See Call-For-Aid Specification Section 16728.

27.3 CALL-FOR-AID SYSTEM

27.3.1 Purpose

The purpose of the Call-For-Aid system is to provide emergency communication between people (employees or patrons) on the platform, elevator cabs, elevator landings, elevator machine room, areas refuge, dispersal areas, and the kiosk (or rollover location). Additionally, the Call-For-Aid system provides for emergency communications between the people (employees or patrons) using the station elevators and the kiosk (or rollover location).

27.3.2 Design

The Call-For-Aid System shall provide a means of reporting emergency situations from the passenger station platforms to the Station Manager(s). Intercom facilities between Call Station Panels mounted on pylons or designated areas (approximately 200 feet from the end of each platform) and a control panel within the station Kiosk shall permit easy verbal communications between the Station Manager and Rail System passengers. The Call-For-Aid stations shall be clearly visible to the general public and employees.

Previously, the Call-for-Aid system was known as the Passenger Emergency Reporting System (PERS), Integrated Intercommunication System (IIS) or Raimax system.

27.3.3 Major System Components

The Call-For-Aid System shall include the following major equipment:

- Kiosk Call-For-Aid Control Panel (located in the Kiosk)
- Call-For-Aid Control Unit (located in COM room)
- Integrated Power Amplifier (located in COM room)
- Call Station Panels
    - Platform (located at designated positions on the station platform)
    - Elevator Landing Call Station Panel (located on each station elevator landing)
    - Elevator Cab Call Station Panel (located in each station elevator cab station)
    - Areas of Refuge
    - Areas of Dispersal
- Kiosk Exterior Speaker Horn and strobe (located on the top of the Kiosk)

NOTE: The Call-For-Aid System on parking garage elevators is a separate system than the Call-For-Aid System within the station.

27.3.4 Basis of Design

The basis of design for the Call-For-Aid system is Commend USA.

27.3.5 Call-For-Aid Control Panel

The Kiosk Call-For-Aid Control Panel design shall provide the interface point between the Station Manager and the Call-for-Aid system. The Call-For-Aid Control Panel shall be mounted in the kiosk and shall provide the controls, indications and input/output devices to the Station Manager. The Call-For-Aid IP Master Server Control Unit shall be installed in the communication room.

As a minimum the Call-For-Aid Control Panel design shall include:

- A Push-To-Call pushbutton switch with an LED indicator for each Call Station. This switch shall control a half-duplex audio path to each Call Station.
- A monitor speaker.
- A timer circuit to inhibit automatic termination of an emergency call.
- The capability to transfer an emergency call to both Rail Operation

Control Centers.

- A Call-For-Aid Reset Switch to restore the PERS system to its normal condition ready to receive the next emergency call.

27.3.6 Call-For-Aid Control Unit

The Call-For-Aid Control Unit design shall provide the required interfaces between the Kiosk Call-For-Aid Control Panel, the Call Station Panels, and the Integrated Power. The Call-For-Aid Control Unit design shall accommodate eight Call Station Panels and shall be able to:

- Establish and control the audio paths between the Call Station Panels and the Kiosk Control Panel(s).
- Detect calls initiated at the Call Station Panels and provide appropriate outputs for indications on the Kiosk Call-For-Aid Control Panel.
- Provide signals to a Kiosk Exterior Speaker Horn and strobe (to generate a chime) and to a calling Call Station Panel (to generate a call-waiting tone) to indicate that an emergency call has been initiated at that Call Station Panel.
- Provide the appropriate dc power, ground and reset control paths to the Call Station Panels.
- Provide the appropriate outputs for the control of the talk/listen functions of the Call Station Panels.
- Automatically terminate an unanswered call, after the preset time period.
- Provide the appropriate interfaces to the Call Station Panels and the Kiosk Call-For-Aid Control Panel for the activation and termination of the call waiting tone.
- Detect the loss of dc power over a 10 second interval ("FAULT") at each of the Call Station Panels, and then provide the appropriate outputs for the FAULT indication on the Kiosk Call-For-Aid Control Panel.
- Provide the appropriate interfaces for the connections of the Call Station Panels and the Kiosk Call-For-Aid Control Panel to the Call-For-Aid Control Unit.
- Provide signals to a Kiosk Exterior Speaker Horn and Strobe, to generate a chime/tone, to indicate that the Call-For-Aid has been activated.
- The design shall provide a PAS/Call-For-Aid Muting Circuit in the passenger station Kiosk to mute the monitor loudspeaker of the Kiosk Public Address System Control Panel when the "PUSH-TO-TALK" pushbutton on the Kiosk Call-For-Aid Control Panel is depressed. This shall prevent the possibility of creating an acoustical feedback path

between the Call-For-Aid and the Public Address System.

27.3.7 Integrated Power Amplifier

As a minimum the Integrated Power Amplifier design shall provide the audio amplification necessary to simultaneously drive any combination of the four Call Station Panel speakers and the Kiosk Call-For-Aid Control Panel monitor speaker, the necessary audio pre-amplification adjustments, audio filtering and chime generation.

27.3.8 Platform Call Station Panels

The Call Station Panel design shall provide the interface points between the WMATA Rail System patrons and the Call-For-Aid System. The Call Station Panels shall provide the controls, indications, input/output devices, and instructions which are necessary for the patrons to operate the Call-For-Aid System.

As a minimum the design shall include a loudspeaker and a contact pushbutton switch on the Call Station Panel to initiate an emergency call between that Call Station Panel and the Kiosk Call-For-Aid Control Panel.

Two Platform Call Station Panels shall be mounted on each center platform for a total of two Platform Call Station Panels in each center platform station.

Two Platform Call Station Panels shall be mounted on each split platform for a total of four Platform Call Station Panels in each split platform station.

A Call-For-Aid Call Station panel shall be provided on the each and every landing of all station elevators.

A Call-For-Aid Call Station panel shall be provided in each and every cab of all station elevators.

A Call-For-Aid Call Station panel shall be provided for Areas of Refuge.

A Call-For-Aid Call Station panel shall be provided for Areas of Dispersal.

The Call-For-Aid stations shall be clearly visible to the general public and employees.

27.3.9 Kiosk Exterior Speaker Horns

The design shall include Kiosk Exterior Speaker Horns/Lights to provide for the broadcasting of the chime/tone that indicates an emergency call has been initiated at a Call Station Panel. It shall provide for the broadcasting of the chime/tone that indicates activation of the Automatic Public Address Announcement System.

27.4 INFORMATION DISPLAY SYSTEMS

27.4.1 Purpose

The purpose of the Information Display system is to provide real time digital signage information to rail customers.

27.4.2 Design

There are two major information display systems in each rail station. The first system is called the Passenger Information Display System (PIDS) and the second system is the Kiosk Information Display System (KIDS).

The PIDS is designed to provide train arrival information and the displays are mounted along the platform and on the non-paid side of the mezzanine.

The KIDS is designed to provide general rail system information or alerts and the displays are mounted on the Kiosk. The specific purpose of this display is to inform the public about service disruption prior to the public entering the paid portion of the station.

27.4.3 Major System Components

The Information Display system shall include the following major components:

Passenger Information Display System

- OCC Head End
- Ethernet Connection from COM room switch to Converter
- Station COM Room Converter
- RS-485 Cabling
- Platform Display
- Platform Display Mounting Bracket Kiosk Information Display system
- Software Head End
- Ethernet Connection to Network Switch
- Digital Media Player
- HDMI Cable
- Kiosk Display
- Mounting Bracket

27.4.4 Basis of Design

The basis of design for the Information Display shall be as follows:

- PIDS Display - GDS
- PIDS Head End Software - COMNET

- KIDS Display - Ciil
- KIDS Head End Software - Provided by WMATA IT
- KIDS Media Player - Cisco

27.4.5 Passenger Information Display System (PIDS)

The location of the platform information display shall be in accordance with ADA requirements. New stations shall be provided with a minimum of two displays along each track. Fonts and display images shall be in accordance with ADA requirements.

A platform display shall be provided on the platform at each location where a station entrance elevator is located on the platform.

A mezzanine display shall be mounted in a location that is readable on the non-paid portion of the station.

27.4.6 Kiosk Information Display System (KIDS)

The location of the kiosk information display shall be in accordance with ADA requirements. New stations shall be provided with a minimum of one display. Fonts and display images shall be in accordance with ADA requirements.

A minimum of one Kiosk Information Display shall be mounted on each kiosk. Some kiosk locations may require two Kiosk Information Displays to be mounted. The display shall be readable when traveling from the Non-Paid to the Paid portion of the station entrance.

27.5 FIRE DETECTION AND ALARM SYSTEM

27.5.1 Purpose

The purpose of the Fire Alarm system is to detect a fire and provide audible and visual warnings to assist Washington Metropolitan Area Transit Authority (WMATA) employees in protecting the public, fellow employees, and WMATA property.

27.5.2 Design

The design shall be in accordance with NFPA 72 and all local fire codes. In cases of conflict local codes will prevail.

The design shall provide an addressable, electrically supervised, closed circuit fire detection and notification system for the Rail Transit System. The design shall include Heat/Smoke Detectors, manual pull stations, monitoring modules, audible and visual notification devices, control equipment, and fire alarm system annunciators located in passenger stations and associated ancillary buildings. It shall be complete with all necessary hardware, software and memory specifically tailored for this installation. It shall be possible to permanently modify the software on site by using a plug-in programmer.

Detectors such as fixed temperature heat detectors, combination rate of rise/fixed temperature heat detectors, combination smoke/fixed temperature detectors, ionization/photoelectric detectors, duct smoke detectors, and water flow switches, shall be included. Ionization detectors with extra contacts to operate the deluge solenoid shall be provided at single-entrance passenger stations. Rate compensated heat detectors are to be used in exterior stations at elevator landings to control recall operations.

During fire alarm activation in a station audible and visual alarms and indications shall be provided in the station Kiosks. Kiosk personnel shall have 30 seconds to acknowledge the alarm before the signal is automatically forwarded to all notification devices in the station. Alarm and trouble signals shall automatically be sent to both JGB-OCC and CTF-OCC via DTS and Network connection, and to the off-site third party monitoring company. These signals shall be displayed at the Security Operational Control Center (SOCC) when it becomes operational.

Manual Pull Stations with local audible/visual alarms (typically a horn/strobe-light) shall be located in hallways connecting passenger station service rooms to the public areas and in the station kiosks. Activation of a Manual Pull Station shall cause a Fire Alarm and energize the audible/visual alarm on the Kiosk Annunciator.

The design shall include automatic and permanent recording of a fire alarm by the Fire Alarm Control Panel and head ends at CTF and JGB. This record shall include date, time, and location of each alarm and trouble.

Battery calculations shall be provided on a per power supply/charger basis. These calculations shall clearly indicate the quantity of devices, the device part numbers, the supervisory current draw, the alarm current draw, totals for all categories, and the calculated battery requirements (which reflect a 20% DEGRADE, for 24 hour supervisory, 5 minute alarm operation). Battery calculations shall also reflect all control panel components, remote annunciator, and auxiliary relay current draws. Failure to provide these calculations shall be grounds for the complete rejection of the submittal package.

All fire alarm devices shall be accessible for periodic maintenance. Should a device location indicated on the Contract Drawings not meet this requirement, it shall be the responsibility of the installing contractor to bring it, in writing, to the attention of the WMATA. Failure to bring such issues to the attention of WMATA shall be the exclusive liability of the installing Contractor.

27.5.3 Major System Components

The design of the FIA System shall include the following major components:

- Common Control Unit
- Kiosk Fire Alarm Annunciator Panel
- Fire Alarm System Interfaces

27.5.4 Basis of Design

The basis of design for the fire alarm system is the Edwards EST3 addressable fire alarm system.

27.5.5 Common Control Unit

A Common Control Unit shall be located in the Communications Equipment Room and shall contain all the logic, software and circuitry required to supervise and control the Fire and Intrusion Detectors where applicable.

The Common Control Unit shall be modular in construction and provide for ease of maintenance and expansion. It shall contain trouble circuitry powered from a dedicated power source that electrically supervises all zone circuit wiring for a "Short" or an "Open."

The Common Control Unit shall support the following functions:

- Provide audible and visual "Alarm" indications at the Kiosk Annunciator Panel
- Provide audible and visual "Trouble" indications at the Kiosk Annunciator Panel
- Provide contact closures to indicate "Alarm" conditions
- Provide contact closures to indicate "Trouble" conditions
- Provide a network interface for connection to the Fire Alarm head end
- Provide a phone interface for connection to the Fire alarm head end and third party monitoring company
- Provide common system controls at the Kiosk FIA Annunciator Panel

The Common Control Unit shall be provided with twenty-four (24) hours of battery backup for panel, sensors, and alarm indicators.

The Common Control Unit shall utilize a fused neutral line design. The neutral line shall be supervised and the indication of a blown fuse shall illuminate the LED integrated in the reset pushbutton located on the Kiosk FIA Annunciator Panel.

27.5.6 Kiosk Fire Alarm (FA) Annunciator Panel

A Kiosk FA Annunciator Panel shall be located in each passenger station Kiosk and contain indicators identifying the "Alarm" condition and "Trouble" condition of each detector.

The Kiosk FA Annunciator Panel shall contain an audible Annunciator that indicates an alarm condition by using one tone and indicates a trouble condition by using a different tone.

The Kiosk FA Annunciator Panel shall also include the following indicators and pushbuttons for common system controls:

- Trouble Silence Momentary Contact Pushbutton
- Alarm Acknowledge Momentary Contact Pushbutton
- Reset Momentary Contact Pushbutton with integral LED
- Lamp (LED) Test Momentary Contact Pushbutton
- Power "On" Indicator
- Manual Fire Alarm Pushbutton

27.5.7 Fire Alarm System Interfaces

The design of the Fire Detection System shall provide controls and/or interfaces with the following systems and equipment:

27.5.7.1 Ventilation Fans

Selected ventilation fans shall shutdown when a Fire Alarm associated with an area being serviced by a ventilation fan is initiated in a passenger station room or an ancillary building within the passenger station.

27.5.7.2 Sprinkler System

Tamper switches shall detect any movement of the Fire Main manual shut-off valves and provide a "Trouble" condition for the associated Sprinkler System. Monitor Modules will relay activation of sprinkler flow switches back the control panel as an alarm condition.

27.5.7.3 Other Fire Suppression Systems

Clean agent, dry chemical, or other alternative fire suppression systems shall be monitored by the fire alarm system. The fire alarm system will be notified of system discharge and the facility will be set into alarm.

27.5.7.4 Fare Gates

The Fare Gates shall open when a Fire Alarm is initiated in a passenger station room or an ancillary building within the passenger station in order to facilitate egress.

27.5.7.5 Entrance Escalators

The Entrance Escalators shall stop when a Fire Alarm is initiated in a passenger station room or an ancillary building within the passenger station. Escalators in the direction of egress will be permitted to continue operation.

27.5.7.6 Elevator Machine Room

All elevators associated with the Elevator Machine Room shall immediately return to a designated level when a Fire Alarm is initiated in a passenger station room or an ancillary building within the passenger station. Additionally elevator cab controls (except for emergency controls) shall be rendered inoperative as long as smoke is detected within the associated Elevator Machine Room.

27.5.7.7 Smoke Control System

The fire alarm system shall be capable of initiating smoke control system operation. This may include starting fans, closing louvers and doors, or dropping fire barriers to separate hazard areas from areas of refuge.

27.5.7.8 Public Address

The Fire Alarm system shall provide a canned message to the station Public Address system when a Fire Alarm is initiated in a passenger station room or an ancillary building within the passenger station. After a predetermined time delay, a "Reset" circuit shall be provided that will silence the Fire Alarm warning being broadcast by the PA system. . Fire Alarm messages shall take precedence over normal system broadcasts.

27.6 ACCESS CONTROL SYSTEM

27.6.1 Purpose

The purpose of the Access Control system is to limit access into service rooms and other areas of concern to authorized WMATA employees and/or contractors. Additionally, the Access Control system shall keep a record of who enters each room.

27.6.2 Design

The design shall include automatic and permanent recording of each entry and/or exit. This record shall include date, time, and location of each alarm and trouble.

27.6.3 Major System Components

The Access Control system shall include the following major components:

- Card Reader
- Access Controller
- Request To Exit Sensor
- Door Contact Switch
- Door Strike
- Request to exit Push Button if maglock is used

27.6.4 Basis of Design

The basis of design for new Access Control systems is a Honeywell/Pro-Watch platform. This system includes a PoE door controller in conjunction with a card reader which is capable to read Mifare Plus S, HID 26-Bit cards, and 37-Bit HID Tags. .

27.6.5 Specific Locations for Access Control

27.6.5.1 Rail

Access Control shall be provided at the following locations within the station and along the right of way:

- Train Control Room
- Communication Service Room
- AC Rooms (typically two per station)
- Traction Power Substation
- Tie Breaker Station
- Common Passage Way

27.6.5.2 Bus and Miscellaneous Facilities

Access Control shall be provided at the following locations:

- Electrical Service Rooms
- Communication Service Rooms
- Mechanical Service Rooms
- Parts and Material Storage Locations
- Tool Cribs
- Clerk's Office
- Pedestrian Entrances

- Human Resource Office
- Police Office
- Superintendent Offices
- Locations where high value items are stored

27.7 INTRUSION DETECTION AND ALARM SYSTEM

27.7.1 Purpose

The purpose of the Intrusion Alarm system is to detect an unauthorized intrusion and provide an intrusion alarm to assist Washington Metropolitan Area Transit Authority (WMATA) employees in protecting the public, fellow employees, and WMATA property.

27.7.2 Design

The design shall be an addressable, electrically supervised, closed circuit intrusion detection system for the Rail Transit System. The design shall include intrusion detection devices such as tape or switches and shall be provided on doors, windows, louvers, and other intrusion points as required in substations, passengers stations, tie-breaker stations, fan and vent shafts, AFC machines, train control and communications buildings which require protection against unauthorized entry.

An Intrusion Detection System shall be installed in the passenger station, equipment areas, ancillary buildings within the passenger station limits and ancillary buildings or outside areas located along the right-of way that are accessible to the public. Intrusion Detectors shall provide alarms indicating unauthorized entry for each of the following conditions:

- A broken or opened window connected to a public or outside area.
- A broken or opened air duct cover, louver or grating connected to a public or outside area, if the shortest side is greater than six inches.
- A protected door when opened.

Audible and visual alarms and indications shall be provided in the station Kiosks. An alarm and trouble shall be sent to both JGB-OCC and CTF-OCC via DTS and Network connection. These signals shall be displayed at the Security Operational Control Center (SOCC) when it becomes operational.

The design shall alarm the following:

- Automatic Fare Collection Equipment Intrusion Alarm
- Revenue Cart Storage Area Intrusion Alarm
- Ancillary Structure Intrusion Alarm

- Rail Station Intrusion Alarm
- Tie Breaker Station Intrusion Alarm
- Traction Power Substation Intrusion Alarm
- Panic Buttons

The design shall include automatic and permanent recording of an intrusion alarm. This record shall include date, time, and location of each alarm and trouble.

27.7.3 Major System Components

The Intrusion Detection System shall include the following major components:

- Intrusion Detection Devices
- Alarm Indications
- Special Protection Devices

27.7.4 Basis of Design

The basis of design for the intrusion and detection system is the Honeywell/Pro-Watch platform.

27.7.5 Specific Location for Intrusion Detection

27.7.5.1 Rail

The design shall incorporate the latest state-of-the-art intrusion detectors. The following criteria shall be used in the design layout of Intrusion Detection:

- Intrusion Detector shall be provided on each entrance elevator door
- Intrusion Detector shall be provided on each fare collection equipment array
- Intrusion Detector shall be provided on protected doors to areas containing multiple rooms or corridors
- Intrusion Detector shall be provided on each door of ancillary buildings along the right-of-way
- Intrusion Detector shall be provided on each door of the Tie Breaker Station
- Intrusion Detector shall be provided on each door of the Traction Power Substation
- Trip wire and window break sensors shall be provided across louver openings and windows
- Magnetic Switches shall be used on grates and doors to detect when

they are opened

- Panic Buttons shall be provided inside station kiosks
- Panic Buttons and motion detectors shall be provided inside office areas where cash or other valuables are handle or stored
- Intrusion Detectors shall be weather tight or installed in a Weather tight enclosure
- Tamperproof Intrusion Detectors shall be provided

27.7.5.2 Bus

The design shall incorporate the latest state-of-the-art intrusion detectors. The following criteria shall be used in the design layout of Intrusion Detection:

- Intrusion Detector shall be provided on each building entrance door
- Intrusion Detector shall be provided on service rooms protected by access control
- Trip wire and window break sensors shall be provided across louver openings and windows
- Magnetic Switches shall be used on grates and doors to detect when they are opened
- Panic Buttons and motion detectors shall be provided inside office areas where cash or other valuables are handle or stored

27.7.5.3 Special Protection Areas

Doors leading from an outside or public area into a protected zone, including roll-up doors, shall be furnished with additional features.

- A key-operated access control switch, a non-locking pushbutton switch, and a magnetic switch shall be provided
- Roll-up doors shall be equipped with only a key-operated access control switch and a magnetic switch

27.8 VIDEO SURVEILLANCE SYSTEM

27.8.1 Purpose

The purpose of the Video Surveillance system is to provide real time and recorded video for use by all departments at WMATA as well as for viewing by our regional partners.

27.8.2 Design

The design shall be based on IP camera technology and Network Video recorders located in the station communication equipment rooms. Where possible, the cabling connecting the cameras to the network switches shall be CAT6 copper connections. Small form factor network switches (packaged in NEMA 4X enclosures) shall be located throughout the station to minimize fiber optic cabling. Both fixed-lens cameras and pan tilt zoom cameras shall be provided in IP-66 enclosures.

27.8.3 Major System Components

The Video Surveillance system shall include the following major components:

- IP Cameras with removable storage
- Video Recording
- Viewing Stations (on site and remote)
- Network Connections
- Video Analytics
- Structured Cabling

27.8.4 Basis of Design

The basis of design for the Video Surveillance system shall be

- Fixed View Cameras – Axis
- Pan Tilt Zone Cameras – Axis
- Thermal Cameras – Axis
- 360 Degree Cameras - Axis/Mobotix
- Network Video Recorder – Pivot3 hardware with Verint software
- Viewing Station – Dell hardware with CNL software
- Secondary Network Equipment – COMNET switches
- Video analytics – BRS & Axis
- OCC & SOCC Viewing – Dell hardware and CNL software

27.8.5 Cameras

The design shall use IP cameras. These cameras may be fixed cameras, Pan-Tilt Zoom (PTZ) cameras, or Thermal cameras. The cameras shall provide a minimum of three (3) days local storage.

Both fixed-lens cameras and PTZ cameras shall be provided in IP-66 enclosures.

The design, placement, and installation of the cameras shall be coordinated with the architectural design to provide an appearance that is acceptable to the architects.

The design, placement, and installation of the cameras shall be coordinated with the station lighting to ensure that adequate illumination is provided for proper camera operation.

Cameras shall be mounted to provide for ease of maintenance.

IP Cameras shall be configured using an enterprise software package from the camera supplier.

27.8.6 Camera Coverage

27.8.6.1 Rail

Rail Stations - Public Areas				
Coverage Description	Camera	Analytics Required?	Purpose	Comm ents
Platforms	Fixed	No	Situation Awareness	95 % Coverage
Platforms Edges	Fixed	Yes	Support Analytics	100 % Platform Edge Coverage
Track Bed in Station	Fixed	Yes	Situation Awareness	100 % Coverage
End of Platforms - Facing Platform	Fixed	No	Facial Recognition	100 % Coverage
End of Platforms - Facing Trac a	Fixed	No	Situation Awareness	Thermal Camera
Station Entrance Escalators	Fixed	No	Situation Awareness	100 % Landings & 80 % Travel
Station Escalators	Fixed	No	Situation Awareness	100 % Landings & 50 % Travel

Rail Stations - Public Areas				
Coverage Description	Camera	Analytics Required?	Purpose	Comm ents
Passageway from Entrance T Kiosk	Fixed	No	Situation Awareness	100 %
Fare Vending Machines	Fixed	No	Situation Awareness	100% Theft & Vandalism Protection
Fare Gate Array	Fixed	No	Situation Awareness	100 %
Entrance Elevators Cabs	360E	No	Situation Awareness	360 Degree Cameras
Entrance Elevators Landings	Fixed	No	Situation Awareness	95% Coverage
Kiosks - Facing Entrance	Fixed	No	Facial Recognition at Choke Points	Crown of Kiosks - 60 Pixels / ft.
Kiosks - Facing Exit	Fixed	No	Situation Awareness	Crown of Kiosks - 60 Pixels / ft.
Areas of Rescue Assistance (AORA)	PTZ	Yes	Situation Awareness	95% Coverage
Pedestrian Bridges	Fixed	No	Situation Awareness	95 % Coverage
Entrance Canopies	PTZ	Yes	Facial Recognition	Analyti cs
Call For Aid Boxes	PTZ	Yes	Situation Awareness	Coverage of Person

Mezzanine Area	Fixed	No	Situation Awareness	90% Coverage
Pedestrian Walkways to/from the Station	Fixed	No	Situation Awareness	95% Coverage
Pedestrian Walkways within the Station	Fixed	No	Situation Awareness	85% Coverage
WMATA Bus Bays	Fixed	No	Situation Awareness	85% Coverage

Rail Stations - Non-Public Areas				
Coverage Description	Camera	Analytics Required?	Purpose	Comments
Hallways to Public Bathrooms	Fixed	Yes	Situational Awareness	Off-Path Detection
Traction Power Rooms	Mini-PTZ	No	Facial Recognition	Situational Awareness
Train Control Rooms	Mini-PTZ	No	Facial Recognition	Situational Awareness
COM Rooms	Mini-PTZ	No	Facial Recognition	Situational Awareness
Rail Stations - Non-Public Areas				
Coverage Description	Camera	Analytics Required?	Purpose	Comments

Hallways to Public Bathrooms	Fixed	Yes	Situational Awareness	Off-Path Detection
AC Power Rooms	Mini-PTZ	No	Facial Recognition	Situational Awareness
Rail Stations - Miscellaneous Areas				
Coverage Description	Camera	Analytics Required?	Purpose	Comment s
Ticket Sales Booth - Internal	Fixed	No	Situation Awareness	100% Revenue Handling
Ticket Sales Booth - External	Fixed	No	Situation Awareness	100% Revenue Handling
Bridges	Fixed	No	Situation Awareness	95% Above and Below Coverage
Bike Racks	Fixed	No	Situation Awareness	100%
Vent Shaft Exit/Entrances	Fixed	No	Situation Awareness	ID Choke Points, tracks
Portals	Fixed	Yes	Situation Awareness	ID Choke Points, tracks

Rail System Yards				
Coverage Description	Camera	Analytics Required?	Purpose	Comments
Yard Perimeter	Fixed / Therm	Yes	Intrusion Detection	100% Perimeter Coverage
Yard interior	Mini-PTZ	No	Situational Awareness	100% Train Movement
Yard Service Rooms (Traction Power, Train Control, COM, AC Power)	Mini-PTZ	No	Intrusion Detection	Motion Detection
Yard IT Service Rooms/Closets	Mini-PTZ	No	Intrusion Detection	Motion Detection

27.8.6.2 Bus

Bus Garages				
Coverage Description	Camera	Analytics Required?	Purpose	Comments
Parking Lot Perimeter	Fixed / Therm	Yes	Intrusion Detection	100% Perimeter Coverage
Parking Lot Interior	Mini-PTZ	No	Situational Awareness	Motion Detection

Power Service Rooms	Mini-PTZ	No	Situational Awareness	Motion Detection
IT Service Rooms / Closets	Mini-PTZ	No	Situational Awareness	Motion Detection
COM Service Rooms	Mini-PTZ	No	Situational Awareness	Motion Detection

27.8.6.3 Parking

Parking Garages				
Coverage Description	Camera	Analytics Required?	Purpose	Comme nts
Exit Lane	Fixed	No	License Plate Recognition	100% Coverage
Exit Lane	Fixed	No	Facial Recognition	100% Coverage
Entrance Lane	Fixed	No	License Plate Recognition	100% Coverage
Entrance Lane	Fixed	No	Facial Recognition	100% Coverage
Elevators	360E	No	Situational Awareness	360E
Elevator Landings	Fixed	No	Situational Awareness	95% Landing

Pedestrain Entrance	Fixed	No	Situational Awareness	100%
Power Service Rooms	Mini-PTZ	No	Situational Awareness	Motion Detection
IT Service Rooms	Mini-PTZ	No	Situational Awareness	Motion Detection
COM Service Rooms / Closets	Mini-PTZ	No	Situational Awareness	Motion Detection

27.8.6.4 Miscellaneous Locations

Miscellaneous Locations				
Coverage Description	Camera	Analytics Required?	Purpose	Comments
Parking Lot Perimeter	Fixed	Yes	Intrusion Detection	100% Perimeter Coverage
Parking Lot Interior	Mini-PTZ	No	Situational Awareness	100%
Power Service Rooms	Mini-PTZ	No	Intrusion Detection	Motion Detection
IT Service Rooms	Mini-PTZ	No	Intrusion Detection	Motion Detection
COM Service Rooms	Mini-PTZ	No	Intrusion Detection	Motion Detection

27.8.7 Video Recording

A Network Video Recorder (NVR) shall be installed in each COM room. The Network Recording device shall provide 30 days of video storage at a resolution that is acceptable to MTPD and Rail Operations.

The NVR shall be provided with redundant power feeds originating from separate power distribution panels.

27.8.8 Viewing Stations

The design shall provide for camera viewing in the Kiosks, in the Gate House, in the Yard Masters office, in the Dispatchers End of Line office, in the various control centers, and on the desktop viewing stations throughout the authority.

27.8.8.1 Rail

27.8.8.1.1 Kiosk Viewing Station

Each kiosk shall be provided with four (4) monitors. These four (4) monitors and two (2) touch screens shall be connected to a computer workstation running on a CNL thick client which will control cameras and provide alarms inside the kiosk. The workstation shall be mounted within the kiosk's floor-mounted cabinets.

27.8.8.1.2 End-of-Line Dispatch Office Viewing Stations

Each End-of-Line dispatch office shall be provided with a workstation, mounting hardware and a minimum of four monitors.

27.8.8.1.3 Rail Yard Gate House Viewing Station

Each gate house shall be provided with four (4) monitors mounted up high on the inside of the guard shack. These four (4) monitors shall be connected to a computer workstation inside the guard shack. The workstation shall be running a CNL thick client. This thick client will control cameras and provide alarms inside the guard shack. Refer to Communications Standard Drawings, Sheet SD-CM-CCTV-010 for mounting details.

27.8.8.1.4 Rail Yard Control Tower Viewing Stations

Each Yard Master Office shall be provided with four (4) monitors. These four (4) monitors shall be connected to a computer workstation that is running a CNL thick client. This thick client will control cameras and provide alarms.

27.8.8.1.5 Miscellaneous Offices

Each yard's RTRA Superintendent and CMNT Supervisor shall be provided with one (1) monitor connected to a computer workstation that is running a CNL thick client. The thick client will control cameras and provide alarms.

27.8.8.1.6 Control Centers

The ROCC and the SOCC shall be provided CNL software to existing workstations to enable system-wide CCTV viewing.

27.8.8.1.7 Remote Desktop Viewing Stations

The VMS shall allow remote viewing of cameras at selected individual desktop viewing stations.

27.8.9 Network Connections

All IP cameras shall be connected to IP switches with Power-Over-Ethernet (POE) capability.

Each rail station's backbone network switch is located in the station's COM room, with ancillary switches provided within each station's kiosk. Small-form network switches installed within NEMA 4X enclosures, placed strategically throughout each rail station, provide peripheral network connectivity for the IP cameras.

Each rail yard's backbone network switch is located in the yard's main COM room, with ancillary switches provided at various locations throughout the yard. Where required, small-form network switches installed within NEMA 4X enclosures provide peripheral network connectivity for IP cameras.

Refer to Communications Standard Drawings for typical equipment enclosure details.

27.8.10 Structured Cabling

27.8.10.1 CAT 6 Cabling

Cat 6 cable shall be used in cases where wiring between the various system components is less than 328 ft. This includes between cameras and media converters or network switches, and between peripheral network switches and primary or ancillary network switches.

Throughout the rail system, exterior cameras or peripheral network switches wired directly into COM rooms with Cat6 cable shall be landed on a pre-network switch surge protector.

In cases where hi-voltage power wires and Cat6 cabling are installed within a single wire raceway, including light poles, the Cat6 shall be routed through flexible, weather-tight conduit run internal to the raceway.

27.8.10.2 Fiber Optic Cabling

FOC shall be installed in cases where the distance between media converters or peripheral network switches and primary or ancillary network switches exceeds 328 ft. max.

27.8.11 Video Analytics

Video analytics shall be provided at each station, rail yard, or other locations.

Video analytics software can either reside on the end device or may reside on a dedicated server in the COM room.

As a minimum, the video analytics shall detect and alarm:

- Unauthorized access into the Right of Way whether falling or jumping
- Unauthorized passage though End of Platform gates

- Intrusion Detection on the Rail Yard Perimeter
- Motion Detection on Vent/Shafts
- Motion Detection in Service Rooms

27.8.12 IT Security

The cameras and all other IP connected equipment shall comply with all WMATA IT security requirements including strong passwords, managed ports, and other related security requirements.

27.9 LAND MOBILE RADIO SYSTEMS

27.9.1 Purpose

The purpose of the radio system is to provide public service grade wireless voice communication both above ground and belowground for general WMATA operational communication and emergency communications.

27.9.2 Current Systems Design

The current WMATA Mobile Radio System consists of a 490 MHz Comprehensive Radio Communication System (CRCS) for above ground and below ground communication. The CRCS consists of a frequency modulated, UHF T-Band, (operating in the 470-512 MHz portions of the frequency band) digital, single-cell simulcast trunked Motorola Smart Zone 3.0z radio system, used for communicating with radio users throughout the entire WMATA service area.

Additionally, multiple Local Jurisdictional Public Safety Radio Systems (PSRS) operating in the 800 MHz frequency band are installed in underground locations throughout the rail system.

The CRCS provides voice and data communications among Bus, Rail, Metro Transit Police (MTPD), Para-Transit, Maintenance, and Administrative personnel and vehicles. The existing CRCS is composed of 10 remote above ground sites, 15 voice channels, 4 data AVL (bus) channels, one mobile data channel and one paging channel.

The WMATA CRCS shall consist of multiple talk groups. Some of the major talk groups include:

- (OPS-1)
- (OPS-2)
- (OPS-3)
- (OPS-4)
- (MPTD)

- BUS
- Maintenance

27.9.3 Major System Components

The radio system shall include the following major components:

- Above Ground Radio System
- Below Ground Radio System
- Public Safety Radio System (PSRS)
- Distributed Antenna System

27.9.4 Basis of Design

The basis of design for the radio system is Motorola's mobile radio network. Any new system equipment must be compatible with the base platform.

27.9.5 Above-Ground (AG) Radio System

The above ground Comprehensive Radio Communication systems (CRCS)radio system shall provide DAQ 3.4 quality with 95/95% reliability in street portable radio coverage with the radio mounted on the hip, Rail cars , Buses and all base stations such as rail end-of-line offices, guard shacks, yard tower offices and other locations requiring coverage throughout the entire WMATA service area.

27.9.5.1 (AG) Rail Stations

All rail stations that are above ground will require adequate radio communications coverage to each room or space within these facilities to which MTPD, emergency responders, or WMATA employees can access using the existing above ground simulcast radio system. Mobile Radio Service extension shall be accomplished by the design and installation of Off-the-Air BDA Radio Repeater System(s). If BDA repeaters are needed at these stations, the WMATA CRCS frequencies listed in Table 1 shall be accommodated. An Inter-modulation Study of the Frequencies listed in Tables 1 through 5 shall be completed and notification made to the Authority of any potential problems.

27.9.5.2 (AG) Wayside Facilities

All above ground way facilities to Include TPSS, TBS, Train Control, COMM Room, Power Control, etc. will require adequate radio communications coverage to each room or space within these facilities to which MTPD, emergency responders, or WMATA employees can access the above ground simulcast radio system. Larger wayside facilities may require the design and installation of Off-The-Air BDA Radio Repeater System(s) or the installation of individual desk radios for very small rooms.

27.9.5.3 (AG) Rail End-Of-Line Terminals and Yard Towers

The WMATA Rail End-Of- Line Terminal Supervisor's Radio Subsystem facility that provides two-way voice communications between all Terminal Supervisor's Office and WMATA personnel (usually train operators) within the passenger station interfacing with the existing WMATA Simulcast radio system. An End-Of-Line Terminal Supervisor's mobile radio shall be designed, furnished, and installed in the end-of-line passenger station. All Block houses, Guard Booths and Yard towers shall also include a mobile radio system to communicate over the above ground Comprehensive Radio Communication System (CRCS). The Mobile Radio shall consist of a Mobile Radio, Desktop Cabinet and Desk Microphone, Antenna and Coax cable for external mount.

27.9.5.4 (AG) Buildings and Structures

All above ground facilities to Include Yard Buildings, S&I shops and Service buildings will require adequate radio communications coverage to each room or space within these facilities to which MTPD, emergency responders, or WMATA employees can access the above ground simulcast radio system. The design and installation of Off-The-Air BDA Radio Repeater System (s) or Fiber fed BDA systems shall be used for proving coverage. Within these structures, a Distributed Antenna System (DAS) will be tied to the BDA repeater.

27.9.6 Below-Ground (BG) Design Objective

The below ground Comprehensive Radio Communication systems (CRCS) radio system shall provide DAQ 3.4 quality with 95/95% reliability in rail vehicles in the tunnels and in station (both public & non-public locations) with the radio mounted on the hip. Radio coverage is provided by a DAS (Distributed Antenna System) installed throughout the underground. The DAS is fed by a redundant radio frequency (RF) donor system, which distributes the above ground RF signal using fiber-optic links to a number of UHF bi-directional amplifiers (BDAs) installed along the right of way.

27.9.6.1 (BG) Station Distributed Antenna System (DAS)

All Below-Ground Rail stations are required to have radio coverage in all station public areas and to extend coverage to station service rooms and other non-public areas that are part of the station as defined in station drawings. This coverage shall be designed to cover all areas identified above and where possible integrate to the existing station antenna system provided by the neutral host project. This enhance radio coverage will be engineered to tap into the existing below ground

CRCS RF uplink and downlink signal feed.

The system design and implementation shall be able to satisfactorily support operation in the Public Safety 700 MHz and 800 MHz bands. Leaky coax, antenna, coax cables, passive devices and other RF components used should be in compliance with the frequency range.

27.9.6.2 (BG) Tunnel Distributed Antenna System (DAS)

All new and existing design for tunnel segments including Cut& Cover, Sound Box Cover and Yard Lead partially below ground will require CRCS coverage. All CRCS radios in these areas shall communicate via a 50-ohm slotted leaky coaxial cable antenna system. Installation and specification shall follow design details outlined under the neutral Host project.

27.9.7 Public Safety Radio System (PSRS)

Multiple local jurisdictions have installed 800MHz Public Safety Radio System (PSRS) in the underground. These systems provide two-way voice communications between control center facilities of local Fire Departments, Police Departments, and Emergency Medical Services (EMS) authorities and their corresponding portable radios.

Typically, these Public Safety Radio Systems (PSRS) are a frequency modulated voice radio system operating in the 850 MHz portions of the frequency band. Each of the three networks (Fire, Police, and Emergency Medical Services) shall operate, each with its individual radio equipment, control logic frequency(s), and portable radios. The following jurisdictions have underground PSRS within WMATA's Below-Ground Stations and tunnels:

- Washington DC
- Prince Georges County, MD
- Montgomery County, MD
- Fairfax County, VA
- Arlington County, VA
- City of Alexandria, VA
- Loudoun County, VA (future)

27.9.7.1 (BG) Station Distributed Antenna System

All Below ground Rail stations are required to support Public Safety Radio System (PSRS) radio coverage in all station public areas. This coverage shall be designed to cover all areas identified above and where possible integrate to the existing station antenna system provided under the neutral host project. This enhance radio coverage will be engineered to tap into the existing belowground PSRS -800 MHZ RF uplink and downlink signal feed.

27.9.7.2 (BG) Tunnel Distributed Antenna System (DAS)

All new and existing design for tunnel segments will require PSRS coverage. Areas including Cut & Cover, Sound Box Cover and Yard Lead partially below ground will be able to support PSRS coverage. All radios operating in the PSRS band in these areas shall share communication on the 50-ohm slotted leaky coaxial cable antenna system provided for CRCS under the Neutral Host project. Installation and specification shall follow design details outlined under the neutral Host project.

27.9.8 Subscriber Units

Subscriber units will be required in a variety of different configuration packages: mobiles, portables, control stations, vehicular adapters, remote desk sets, and vehicular repeater systems. All cables (antenna, battery, control head[s], chargers, etc.), mounting hardware, antennas, electrical protection, installation and programming services, and accessories shall be provided as a completely functional subscriber unit. When required, as accessories provided should be compatible with the existing CRCS Radio network.

Mobile radios shall be installed on busses, revenue rail vehicles, non-revenue rail vehicle (yellow iron), MTPD Scout cars, and miscellaneous non-revenue autos. Mobile radios shall be provided with the following components and accessories: Transceiver, Control head, Palm Microphone, Speaker, cabling, Antenna and Mounting Hardware.

27.9.9 Frequencies

The following frequencies listed in section 27.9.9.1 to section 27.9.9.5 are in use throughout the WMATA rail system:

27.9.9.1 WMATA CRCS Frequencies

Assignment	TX Frequency (MHz)	RX Frequency (MHz)	Operating Mode
1	490.8625	493.8625	Mixed Mode (A/D)
2	490.7875	493.7875	Mixed Mode (A/D)

3	496.4375	499.4375	Mixed Mode (A/D)
4	496.5375	499.5375	Mixed Mode (A/D)
5	496.6125	499.6125	Mixed Mode (A/D)
6	496.5625	499.5625	Mixed Mode (A/D)
7	496.4875	499.4875	Mixed Mode (A/D)
8	496.3375	499.3375	Mixed Mode (A/D)
9	490.9625	493.9625	Mixed Mode (A/D)
10	490.9125	493.9125	Mixed Mode (A/D)
11	490.8875	493.8875	ASTRO Only (D)
12	490.8375	493.8375	ASTRO Only (D)
13	489.5375	492.5375	ASTRO Only (D)
14	489.5125	492.5125	ASTRO Only (D)
15	496.5875	499.5875	ASTRO Only (D)
AVL 1	496.4625	499.4625	Orbital Data (A)
AVL 2	489.0875	492.0875	Orbital Data (A)

Assignment	TX Frequency (MHz)	RX Frequency (MHz)	Operating Mode
AVL 3	489.1625	492.1625	Orbital Data (A)
AVL 4	490.7625	493.7625	Orbital Data (A)
MTPD	490.9375	493.9375	Mobile Data
SMNT	496.5125	499.5125	Paging (D)

27.9.9.2 Montgomery County Underground Frequencies

Channel No.	Mobile Tx Freq	Base Tx Freq
	Base Rx	Mobile Rx
719	806.2125	851.2125
TBD	806.2750	851.2750
724	806.3375	851.3375
730	806.4875	851.4875
TBD	806.6500	851.6500
784	807.8375	852.8375
786	807.8875	852.8875
787	807.9125	852.9125
795	808.1125	853.1125
797	808.1625	853.1625
TBD	808.2750	853.2750
805	808.3625	853.3625

806	808.3875	853.3875
808	808.4375	853.4375
815	808.6125	853.6125
816	808.6375	853.6375
818	808.6875	853.6875
825	808.8625	853.8625
826	808.8875	853.8875
828	808.9375	853.9375

27.9.9.3 Arlington County Underground Frequencies

Assignment	TX Frequency (MHz)	RX Frequency (MHz)
1	**860.4375**	**815.4375**
2	**859.9375**	**814.9375**
3	**859.7625**	**814.7625**
4	**859.4375**	**814.4375**
5	**858.9375**	**813.9375**
6	**858.7625**	**813.7325**
7	**858.4375**	**813.4375**
8	**857.9375**	**812.9375**
9	**857.7625**	**812.7625**
10	**856.9375**	**811.9375**
11	**856.7625**	**811.7625**

12	**856.4375**	**811.4375**
13	**866.7125**	**821.7125**
14	**852.1875**	**807.1875**
15	**851.8125**	**806.8125**
16	**852.675**	**807.675**
17	**860.9375**	**815.9375**
18	**860.7625**	**815.7625**

27.9.9.4 DC Fire Underground Frequencies

Channel Number	Pre - Rebanding FIRE 800 MHz		Post - Rebanding FIRE 800 MHz	
	TX	RX	TX	RX
CH 01	852.6125	807.6125	854.8625	809.8625
CH 02	852.6375	807.6375	856.1875	811.1875
CH 03	852.6625	807.6625	856.5875	811.5875
CH 04	852.6875	807.6875	857.1875	812.1875
CH 05	852.7125	807.7125	857.5875	812.5875
CH 06	852.7375	807.7375	858.5875	813.5875
CH 07	852.7625	807.7625	859.0375	814.0375
CH 08	852.7875	807.7875	859.0875	814.0875
CH 09	855.2125	810.2125	855.2125	810.2125
CH 10	855.2375	810.2375	855.2375	810.2375
CH 11	855.4625	810.4625	855.4625	810.4625

CH 12	856.9875	811.9875	856.9875	811.9875
CH 13	857.9875	812.9875	857.9875	812.9875
CH 14	858.9875	813.9875	858.9875	813.9875
CH 15	859.9875	814.9875	859.9875	814.9875
CH 16	860.9875	815.9875	860.9875	815.9875

27.9.9.5 Prince George's County Underground Frequencies

Channel Number	Emergency Medical Svcs. Freqs (MHz)	
	Transmit	Receive
CH 17	**851.2250**	**806.2250**
CH 29	**851.3750**	**806.3750**
CH 145	**852.9000**	**807.9000**

27.10 KIOSK SYSTEM

27.10.1 Purpose

The purpose of the Kiosk System is to provide the Kiosk with the equipment needed to monitor and control passenger station Communications

Systems, Fire and Intrusion Alarm Systems, wire and cabling interconnections from parking garage booth's unified fare technology (UFT) and fare collection equipment, elevators and escalators, and to provide an effective communications interface with the public (passengers). At least one Kiosk is located in each passenger station of the Washington Metropolitan Area Transit Authority (WMATA) Rail Rapid Transit System. It is the focal point of activity at each passenger station.

27.10.2 Design

The design shall provide all facilities necessary to monitor and control the passenger station systems. It shall include the Kiosk cabinets, system interface panels, cabling and cable termination facilities and monitoring and control panels for the various systems, facilities and equipment in the passenger stations. It shall include fire and intrusion facilities for protection of the Kiosk and electrical power facilities for the panels, monitors and control.

27.10.2.1 Major System Components

As a minimum, the design shall include cabinet facilities for the following items:

- Telephone Instruments
- Public Address System Panel
- Video Surveillance Viewing System
- Fire Alarm Annunciator
- Call-For-Aid Control Panel
- Elevator Monitor and Control Panel
- Escalator Monitor and Control Panel
- Kiosk Attendant/Passenger Intercom System

27.10.3 Interfaces

The design shall include interface between the various panels, monitors and controls and their respective system central control facilities.

27.10.4 Performance

The design shall ensure that the system performance of each panel, monitor and control is in compliance with the system performance requirements of the system of which it is a part. The design of the kiosk and the placement of equipment shall be optimized for serviceability

27.10.5 Kiosk Construction

It has been the Authority's past practice to include the construction and installation of the station Kiosk in the Communications Contract. The detailed specifications and drawings pertaining to this portion of the work will be supplied by the Authority to the Communications Designer. These drawings and specifications shall be incorporated into the Kiosk & Communications Systems procurement documents.

27.11 CNG DETECTION

27.11.1 Purpose

The purpose of the CNG detection system is to detect the presence of explosive gasses and open doors and energize exhaust fans to clear the air of explosive gasses.

27.11.2 Design

The gas detection system will be solely dedicated to detect dangerous gas concentrations in the range from 1% LEL to 100% LEL. The gas detection system will trigger an audible, visual and remote (e-mail/phone) notification prior to the event becoming a hazardous situation for personnel in the immediate area, personnel in neighboring areas, assets and the environment. The gas detection system will also be capable of actuating building automation such as garage doors, exhaust fans, make-up air units (MAU's) and HVAC equipment.

Installation of the gas detection system equipment will be considered to be intrinsically safe and comply with the National Electrical Code definition of hazardous locations to the class I, Div 2, Group D specifications. Installed devices will particularly need to comply with the NEC code, in the area where a hazardous gas can accumulate to a depth of 18 inches.

Turnover rate calculations by the system designer for gas evacuation will need to be developed so that proper operation of the building automation detail can be configured, programmed and executed during an alarmed event.

Factory acceptance testing (FAT) should be provided by the manufacture to WMATA prior to installation within the facility.

When available all Building Automation software servers, backup servers, Data Historians and remote workstations should be compliant with WMATA IT specifications or an acceptable equivalent as determined by WMATA IT.

Extensive equipment naming convention (e.g. North, South, NE, SW, etc.) and point configuration in the software will correspond to field devices and equipment naming and labeling convention. The naming convention will be submitted to WMATA for review prior to final programming and labeling.

All programming, equipment configuration detail, code sequences, configurable interfaces, and design configuration will be developed such that qualified WMATA personnel will be able to intuitively manipulate the program structure to resolve real-time and off-line trouble-shooting issues and provide in-house system enhancements of the complex algorithms, operation sequences, install and remove devices at the configuration level, and manipulate HMI's and data historians that will be developed by the supplier. Sequences of Operations will be submitted to WMATA for review prior to installation for review and approval. Historic and real-time Data for all sensors and equipment monitored or actuated by the gas detection system will be available on demand by preconfigured trends. Storage Capacity for trended data will be provided to maintain retrievable data for up to ten years.

Labeling within the developed cabinets will be identical to the naming convention in the field and in the programming software.

SOP documentation shall be provided for the operation of the system and how the overall system (i.e. horns, lights, buzzers, doors, MAU, HVAC, shunt trip, page out, email etc. etc.) should respond to an event as evaluated by the system.

Programming within the system shall be available to disable a device that has gone 'out of service' without the need to take the entire system off-line.

Provide delay timers to prevent nuisance alarms as well as return to normal alarms to notify personnel that a gas alarm has been restored to normal conditions.

Provide device failure alarms, network communication failure alarms that will notify management and supervisors.

Actionable gas alarms shall be passed to the existing fire detection system to alert personnel in other locations as specified. The following alarms will be defined within the fire detection system as actionable: low alarm, high alarm and shunt trip.

The gas detection system shall include the capability of being expandable in the future by adding more sensors, alarms, I/O panels and automatic calibration stations, if applicable.

27.11.3 Major System Components

The CNG Detection system shall consist of the following components:

- Gas Detectors
- Annunciator Panel
- Control Panel

- Calibration System
- Audible Alarm
- Visual Alarm

27.11.4 Basis of Design

The basis of design for the CNG Detection system is as follows:

- Gas Detectors - Scott
- Annunciator Panel - Wonderware

27.11.5 Interface

The CNG detection system shall interface with the following systems:

- Fire Alarm System
- Garage Roll Up Doors
- HVAC System
- BAS System

27.12 OPERATIONS CONTROL CENTER - COMMUNICATIONS

27.12.1 General

The Jackson Graham Building houses the headquarters and associated offices of the management, administration and operations of the Washington Metropolitan Area Transit Authority (WMATA).

Located in this building is the Operations Control Center from which is exercised the centralized control of the Rail Rapid Transit System (METRORAIL) and the WMATA Bus System (METROBUS) and the train control and communications systems necessary to support these operations.

Located in the Communications Equipment Area of this building is the equipment that provides the hub of the system-wide communications network. Radiating from this centralized equipment the communication service extends throughout the transit property to trains, buses, administrative, transportation, maintenance and security vehicles, passenger stations, yards, ancillary buildings, wayside areas, security and transit police.

The central control facility contains a control computer, a hot backup computer, and an additional computer for software development which also serves as another level of backup for the main computer. The control computer receives and transmits messages between the operations control center and station locations via the Carrier Transmission System (CTS) to the Data Transmission System's remote terminal units (RTUs) in the field locations. The central control computer communicates with the central control operator by providing displays on a large scale display and video monitors (CRTs) and accepting operator input from the consoles.

The control computer performs schedule adjustments by changing dwell times and inter-station run times, both of which are sent over communications channels to the station RTUs via the DTS. The telephone system provides the means for console operators to contact needed personnel or to report to management.

The general communications functions provided to aid the central control operators are detailed below.

27.12.2 Public Address Display and Control System

The central control facility for the Public Address System is equipped with an electronic switching system, stand-alone central electronics equipment, and touch screen displays. Through the touch screen displays the operator can make an assortment of pre-recorded announcements.

27.12.2.1 Description

The Public Address (PA) consoles are installed in the Rail OCC Passenger Operations consoles. The PA consoles are an integral part of the Public Address Control System. Each PA console is comprised of the following components:

- PA console Central Processor Unit (CPU)
- Touch screen CRT
- Mouse
- Headset
- Foot switch
- Microphone
- Console speaker panel
- Keyboard

27.12.2.2 Basis of Design

The basis of design for the PA head end system is Penta.

SECTION 28 – SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)

28.1 GENERAL

28.1.1 SCADA design criteria include functional and design requirements for the Supervisory Control And Data Acquisition (SCADA) systems for all electrical and mechanical facilities which service the Rail Rapid Transit System Washington Metropolitan Area Transit Authority (WMATA) System.

28.1.2 SCADA systems provide control and monitoring of the electrical and mechanical equipment and systems serving the mission critical loads. These SCADA design criteria shall apply to all facilities that will be operationally interconnected to the Rail Operation Control Center (ROCC) and reflect the high reliability required for those facilities, it shall also be used as a reference for similar systems in other facility types.

28.1.3 The design of the Power SCADA System shall be coordinated compatible with the design of Rail Operation Control Center ROCC, for control and status indications and the requirements of communication networks. In addition, any new facility shall provide for the monitoring and control of equipment through the SCADA system design described in this document.

28.2 SCADA SYSTEM OVERVIEW

28.2.1 The original WMATA SCADA architecture provided status and control functions of Traction Power, Station power and a variety of mechanical systems (tunnel ventilation, chillers, drainage pumps, etc.) to the Operations Control Center (OCC) ROCC through Remote Terminal Units (RTUs) located in Automatic Train Control (ATC) rooms using utilizing Data Transmission System (DTS) cables. This architecture limited the SCADA system's capability to the signals received at OCC and provided no additional did not include the capability for advanced diagnostics of the electrical and mechanical equipment, critical to WMATA engineering and maintenance personnel in responding to issues associated with equipment malfunction and repairs.

28.2.2 The new Power SCADA system is designed to fulfill the requirement of the safe, reliable and economic operation of the Rail Operation Control Center. The new design employs a distributed SCADA architecture, where ROCC and Automatic Energy Management Systems (AEMS) communicates directly to modern RTUs located in the respective ancillary rooms. OCC Front End Processor (FEP) communicates with the remote RTUs the facility RTU using Distributed Network Protocol (DNP3) over Fiber-Optical cables.

28.2.3 Mechanical Industrial Process (MIP) server and the Building Automation Systems (BAS) server communicate directly to the facility systems using Modbus and BACnet protocols for non-critical applications.

28.2.4 Simplified diagrams of the Power and Mechanical systems SCADA system is shown in Figure 28.1, 28.2 and 28.3. The components of the SCADA system function are closely coordinated to provide a variety of essential services. These components are described in these criteria.

28.3 SCOPE

28.3.1 This design criteria document establishes the primary functional and engineering requirements for the SCADA systems. The fundamental concepts of control systems, system architecture, network communication methods, reliability considerations, operator interfaces, and commissioning are covered by in this section of the SCADA design criteria. The following SCADA systems shall be designed, installed and commissioned to monitor and in some instances have control of facilities. These include but not limited to the following facilities throughout the WMATA system:

28.3.1.1 Traction Power Systems

28.3.1.2 Electrical Power Systems (All facilities)

28.3.1.3 Emergency Power Systems

28.3.1.4 Escalators and Elevators Systems

28.3.1.5 Heating, Ventilating and Air Conditioning Systems

28.3.1.6 Pumps (drainage, sewage, etc.)

28.3.1.7 Wayside systems (ETS & Third Rail Heaters)

28.3.1.8 Parking Facilities

28.3.1.9 Jackson Graham Building (JGB)

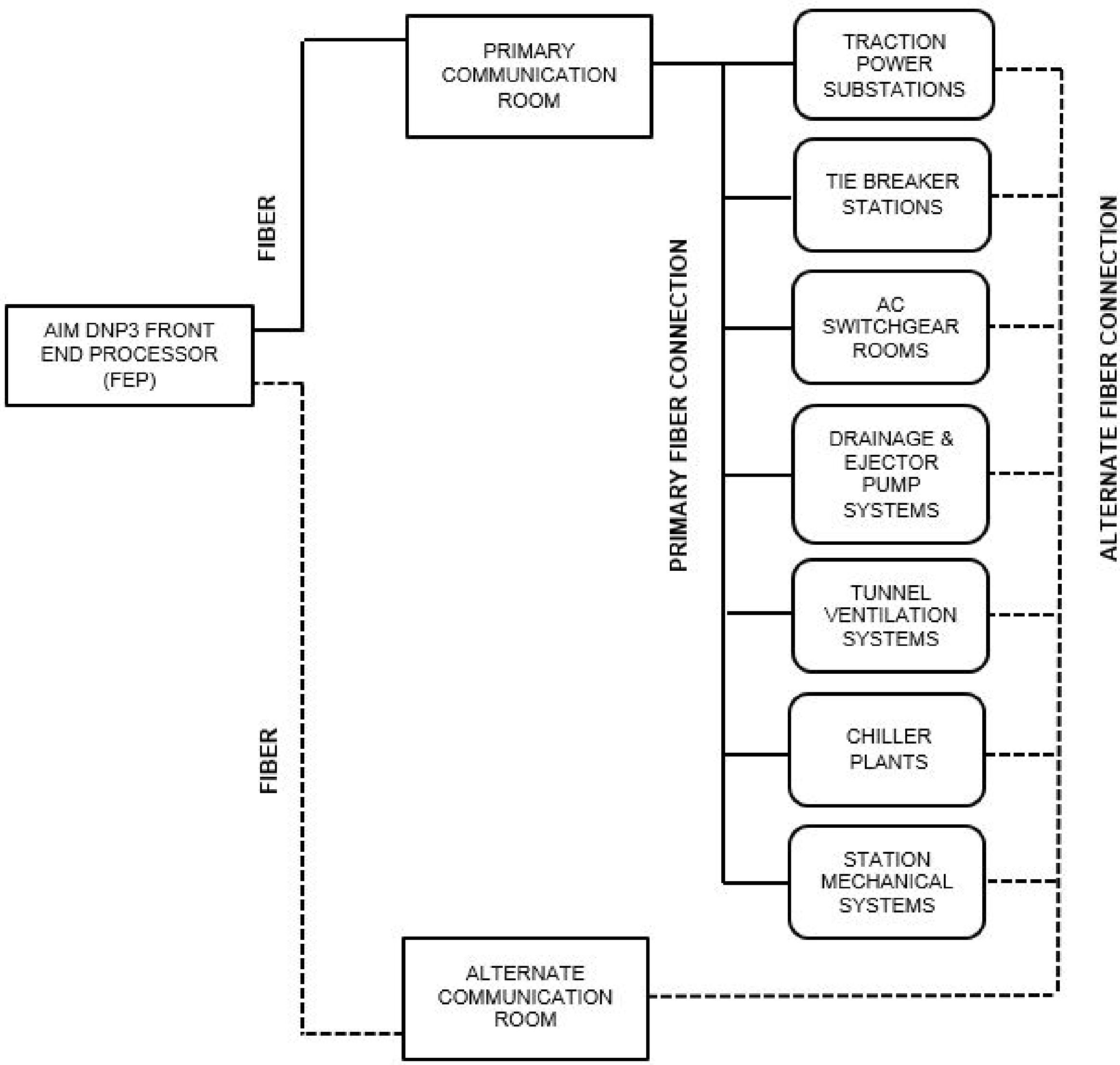
28.3.1.10 Carmen Turner Facility (CTF)

28.3.1.11 Ancillary Buildings

28.3.1.12 Mechanical systems at Bus Garages, Rail Stations and Ancillary Facilities

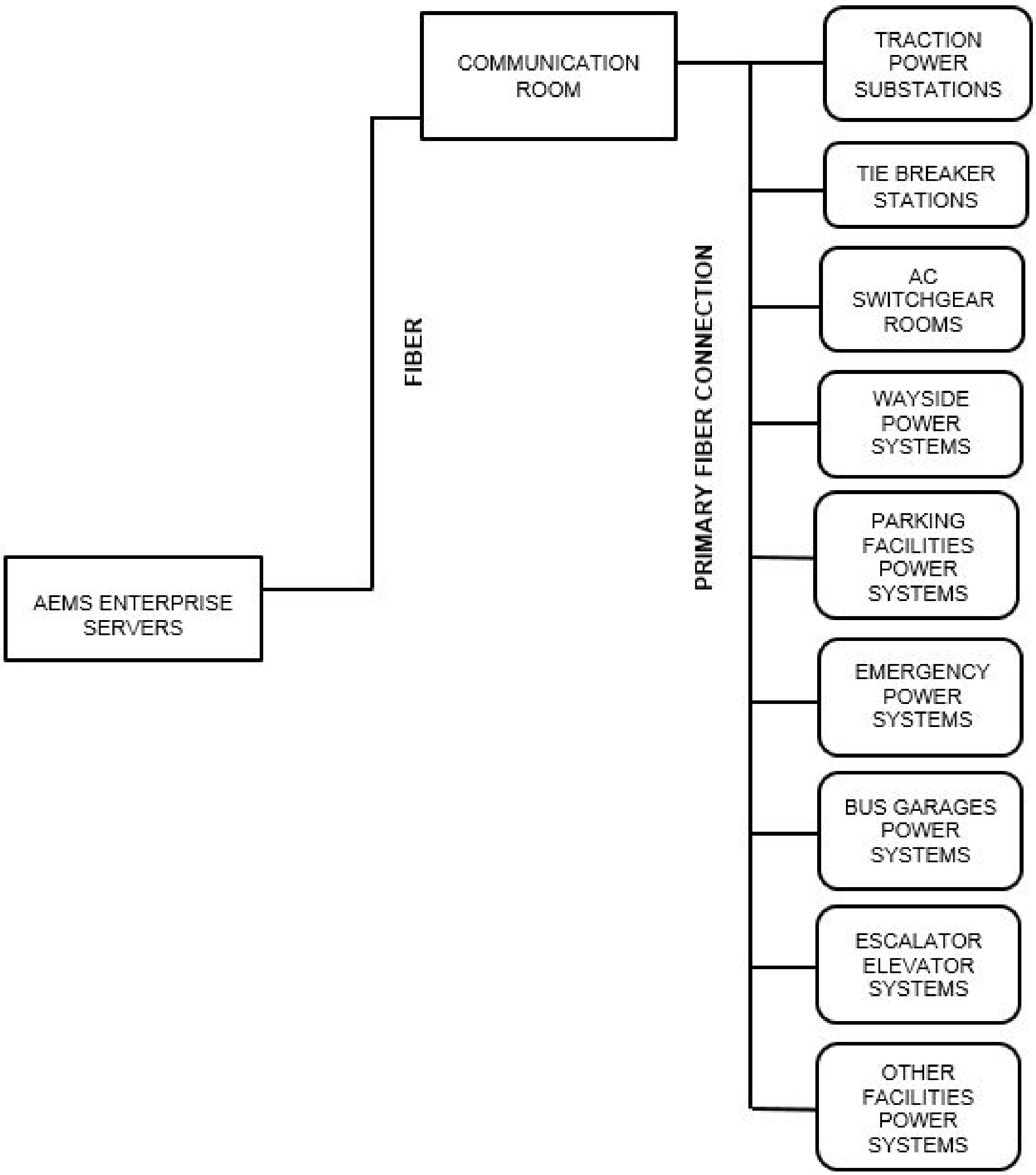
RAIL SCADA SYSTEM BLOCK DIAGRAM

FIGURE 28.1



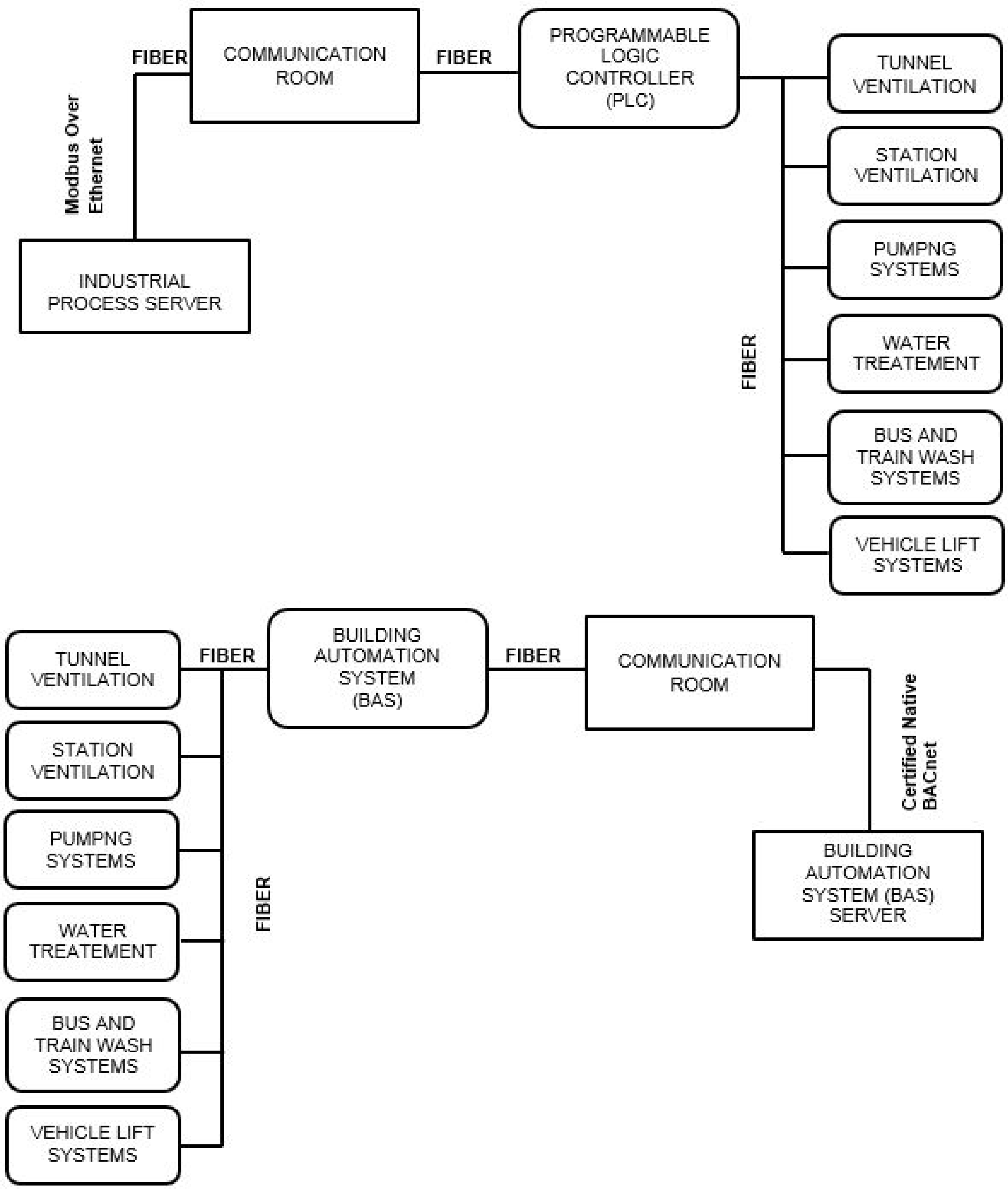
NON-CRITICAL POWER SYSTEMS SCADA BLOCK DIAGRAMS

FIGURE 28.2



NON-CRITICAL MECHANICAL SYSTEMS SCADA BLOCK DIAGRAMS

FIGURE 28.3



28.4 SCADA SYSTEMS DESIGN REQUIREMENTS

28.4.1 The intent of this section is to ensure that each new or renovated building or equipment location is designed and constructed to be properly interconnect and operate compatible with the Authority's WMATA's SCADA system. This section also further describes the level of support that must be provided to successfully interconnect and enable remote monitoring and control of low and medium voltage electrical switchgear, transformers, and associated equipment installed at the Traction Power Substation, Tie Breakers Stations, Passenger stations electrical rooms and other electrical equipment facilities throughout the WMATA system the existing system and equipment in facilities listed.

28.4.2 Rail Operations Control Center (ROCC)

28.4.2.1 This SCADA design criteria does not include criteria for the WMATA Rail Operation Control Center (ROCC). Refer to Section 26.2.1 for an overview of the computer System portion of the ROCC criteria.

28.4.2.2 To handle the specialized data transmission, the ROCC central computers are connected to communicate with the distributed RTU's at various facilities via Fiber-Optic Cables to the various field RTUs and permit the transfer of data to and from the central control computer. The FEPs receive the raw data from the field and forward change information to the central processors. The FEPs communicate with the SCADA RTUs for control and indications using Distributed Network Protocol (DNP3).

28.4.3 General Requirements

28.4.3.1 The SCADA system shall incorporate microprocessor based modular system components that are modern and the design shall adhere to proven designs available to provide the highest degree of safety, security, efficiency, and reliability.

28.4.3.2 All equipment and systems shall be designed and constructed with consideration given to physical and electrical environments such as temperature and humidity, range of operation, vibration and shock, dust and weather, electric and magnetic fields, electromagnetic coupling of conductors, pairs and cables, transient peaks of electrical grounding, and voltage and current.

28.4.3.3 The physical configuration of equipment shall allow ease of inspection and replacement of system components without the need to remove or dismantle complete assemblies.

28.4.3.4 Electrical test points, adjustments, fuses, equipment alarms, and indication shall be provided at front panels wherever possible.

28.4.3.5 Each new or renovated electrical station and substation shall be designed and built to integrate with the established SCADA system and shall support remote monitoring of all designated equipment including mechanical support systems and the remote control of circuit breakers through the SCADA system.

28.4.3.6 The SCADA system communication network design shall use optical fiber communication will utilize fiber-optic communication medium to transmit information between the Rail Operation Control Centers ROCC and terminal RTU locations along the WMATA right-of-way.

28.4.3.7 To provide maximum reliability, the design shall provide PRIMARY, SECONDARY and REDUNDANT networks arranged to connect the terminal from the facility's network switches to two adjacent communication rooms at all times. This design shall provide reliable and efficient network protection from cable cuts or node failures.

28.4.3.8 The Fiber-Optic PRIMARY and REDUNDANT medium shall Network will have sufficient bandwidth and cable runs with sufficient optical fiber-pairs necessary for simultaneous data transmission, in both directions of transmission, and shall accommodate sufficient spares for future use.

28.4.3.9 The Fiber-Optic cables shall be installed in conduits, cable ducts and cable troughs along the right-of-way and within all Passenger Stations. Inner ducts shall be provided when optical fibers are installed inside conduits.

28.4.3.10 At all facilities all equipment for the Fiber-Optics Network System at the facilities shall be mounted on racks inside cabinets and there shall be adequate filtered air ventilation.

28.4.3.11 The design shall provide Fiber-Optics termination cabinets that includes Fiber Splice Panels and Fiber Patch Panels and provide for optical fibers for fiber terminations and splice panel organizers for the splicing of fibers that "pass through".

28.4.3.12 In facilities, the Local Area Network (LAN) serves as a communication medium between station devices such as protective/metering devices, Programmable Logic Controller (PLC)s, Human Machine Interface (HMI), distributed I/O and the station SCADA RTU.

28.4.3.13 In facilities, Fiber-Optic cables, communication cables and SCADA control cables shall be installed on utilizing communication cable trays. Fiber-Optics cable inner ducts shall be used where approved. The design shall provide Fiber-Optics termination Fiber Patch Panels for terminations at the Network Switch cabinet side and at the equipment side.

28.4.3.14 Each Internet Protocol (IP)Device in the station connects with the Wide Area Network (WAN) through the station's main N network S switch for security and to provide remote control and monitoring from the ROCC or/and Yard Control Tower and remote monitoring from Engineering/Maintenance consoles.

28.4.3.15 Fiber-optic cable shall be use to connect each Intelligent Electronic Device (IED) to the SCADA when the option is available from the device manufacturer.

28.4.4 Supervisory Control and Data Acquisition of Electrical Systems

28.4.4.1 The Electrical Supervisory Control and Data Acquisition (SCADA) System shall monitor and, in some instances, have control of the traction power and other electrical and mechanical equipment necessary for the continuous operation of the system. The following is included in the design of this system. Refer to TABLES 28.3 and 28.4:

28.4.4.1.1 Facilities requiring control and supervision by ROCC: Traction Power Substations, Tie Breaker Stations and Fan Shafts, except in yards and service and inspection shops and Fan Shafts.

28.4.4.1.2 Facilities requiring monitoring supervision by ROCC: Passenger station AC Switchgear room (aka AC Switchboard room), electrical equipment, AC power unit substations, Carmen Turner Facility (CTF) and Jackson Graham Building (JGB) electrical equipment.

28.4.4.1.3 Yard facilities requiring control and supervision by Yard Control Tower: Yard Traction Power Substation, Yard Tie Breaker Stations, Yard Service and inspection shops Traction Power Substation and Yard power disconnect Switches.

28.4.4.1.4 Yard facilities requiring supervision by Yard Control Tower: Electrical equipment and AC power unit substations.

28.4.4.1.5 Other facilities requiring monitoring by others: Mechanical systems, Escalator and Elevators systems, Parking Garages and Bus Garages.

28.4.4.1.6 All facilities require monitoring by SCADA Engineering, Power Engineering, Mechanical Engineering, Power System Maintenance and Plant Maintenance.

28.4.4.2 STANDARDS

28.4.4.2.1 Supervisory Control and Data Acquisition SCADA for electrical systems shall use Microprocessor Based systems which provide the highest degree of safety and reliability. Whenever applicable, d Design of equipment for the SCADA functions shall be in accordance with ANSI, NEMA and IEEE Standards and Technical Specifications. The functional principles of these specifications shall also be maintained where new devices or techniques are developed and the specification are revised.

28.4.4.2.2 Because SCADA systems make extensive for process control shall use PLC's for the primary basis of operation. HMI shall be provided to each mechanical system to allow local and remote monitoring, data logging, web server functionality and system manipulation. Modbus communication protocol shall be used for communication.

28.4.4.2.3 SCADA systems for facilities and HVAC systems shall use Building Automation Systems (BAS) technology that can have a very short technological cycle, recommendations regarding specific types of hardware, software, communications protocols, etc. may no longer represent the state of for all non-process control systems. The BAS shall use Certified Native BACnet compatible communications protocol and devices.

28.4.4.2.4 SCADA systems for process control, facilities and HVAC systems shall be interfaced to remote their respective servers for data collection, dissemination, and system monitoring and control.

28.4.4.2.5 SCADA systems for process control, facilities and HVAC systems shall be interfaced with the state-of-the-art at the time of project implementation. AC room Power SCADA RTU for all remote monitoring and Control by ROCC.

28.4.4.2.6 Selection of SCADA systems must assure that the newer state-of-the-art technologies considered being offered comply with the principles identified in these design criteria for reliability and threat-resistance and have a demonstrated history in field service adequate to assure the attainment of design reliability and security criteria of the SCADA system. The SCADA system design and equipment shall conform to the following standards:

28.4.4.2.6.1 Institute of Electrical and Electronic Engineers (IEEE)

28.4.4.2.6.2 IEEE C37.1, IEEE Standard for SCADA and Automation Systems

28.4.4.2.6.3 IEEE 37.90.1, IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems

28.4.4.2.6.4 IEEE 1613, IEEE Standard Environment and Testing Requirements for Communications Networking Devices Installed in Electric Power Substations

28.4.4.2.6.5 National Electrical Manufacturers Association (NEMA)

28.4.4.2.6.6 NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum)

28.4.4.2.6.7 Telecommunications Industry Association (TIA/EIA)

28.4.4.3 EQUIPMENT AND SYSTEM INTERFACES

28.4.4.3.1 Control Center Console

28.4.4.2.6.1 The Control Center located in the ROCC shall contain an Electrical Display and Control Console which shall give provides immediate alarm and visual indication of the equipment status changes, faults, failure of microprocessor devices or other abnormal conditions associated with traction power substations, tie breaker stations, and AC switchboard rooms, tunnel ventilation systems and drainage pumping stations. This Control Console shall be is further equipped to provide the operating attendant ROCC operate with the capability to control or adjust electric power systems (as indicated in Tables 28.3 and 28.4) serving within the transit facilities, to maintain supporting continuous rapid transit operation.

28.4.4.2.6.2 Additional functions of the Control Console are described in subsequent sections of these criteria. This equipment is designed and installed under the Train Control and Communications contracts.

28.4.4.3.2 SCADA Master Stations

28.4.4.3.2.1 Redundant SCADA system servers shall be provided at JGB and CTF ROCC. The system shall be capable of being configured with up to four (4) fully synchronized SCADA system servers, which support automatic, prioritized, fail-over to standby servers of all gateway/RTU Communication, printer driver and operator console services with no manual assistance or intervention.

28.4.4.3.2.2 The SCADA Master Station shall consist of central database and communication server(s) which maintain the core SCADA system database and communication software on a secure server platform.

28.4.4.3.2.3 The Automatic Energy Management System (AEMS) system collects all the SCADA data and arranges it for use by the various applications and systems that depend on the data. Data validation is done by the AEMS system to ensure that the SCADA data is being received correctly and reliably. The AEMS system does not provide control of field power system breakers. The communications protocol used by AEMS servers is DNP3 and approved RTU manufacturer proprietary protocol.

28.4.4.3.2.4 Redundant AEMS Master Stations, software, all other hardware and software shall be designed for a functional operating SCADA system to support the monitoring of the passenger station (AC Switchboard Room), Traction Power Substations (TPSS), Tie-breaker Stations (TBS), Fan Shafts, Drainage Pumping Stations (DPS) and all equipment that is currently monitored/controlled by the Automated Energy Management System (AEMS) in JGB OCC.

28.4.4.3.2.5 Hardware and software of the AEMS Master Stations shall be sized to accommodate all SCADA points in service at existing locations, plus 30% to account for future expansion.

28.4.4.3.2.6 Redundant Data Historian Servers shall contain a record of selected SCADA data and system data for retrieval at a later date. The data historian shall allow the viewing of data trends over long periods of time. Viewing format shall be through web browsers. Some of the uses of this data are: review of system events, sequence of events. Historian servers shall automate the archiving of past data to long-term storage available for quick access when needed.

28.4.4.3.2.7 Redundant Digital Trace Record (DTR) server shall store streamed data from remote DTRs for real time viewing as well as retrieval of stored data at a later date. The DTR server shall allow the viewing of data trends over long periods of time. Digital trace servers shall automate the archiving of past data to long-term storage available for quick access when needed. Some of the uses of this data are: review of system events, determination of fault current, voltage, peak loads, forecasting using load flow records, and trending.

28.4.4.3.2.8 Redundant Web servers shall be provided to allow the access of the SCADA system data, displays by WMATA engineers and maintenance personnel.

28.4.4.3.3 SCADA Communication Network

28.4.4.3.3.1 Communication services shall be provided to all electrical and mechanical facilities. Backbone communication services for the SCADA system between facilities and communication rooms shall be through Fiber-Optic Cable.

28.4.4.3.3.2 WMATA's Information Technology (IT) and Cyber Security team shall be responsible for the design of the SCADA Wide Area Network (WAN) and Security Architecture by implementing strategy that includes:

28.4.4.3.3.2.1 Implementing a network topology for SCADA that has multiple layers with the most critical communications occurring in the most secure and reliable layer.

28.4.4.3.3.2.2 Providing logical separation between the corporate and SCADA networks or as defined by WMATA.

28.4.4.3.3.2.3 Employing Firewalls and DMZ network architecture that prevents direct traffic between the corporate and SCADA networks.

28.4.4.3.3.2.4 Ensuring that critical facilities (Traction Power Substations, Tie Breaker Stations and Passenger Station Electrical Switchgear Rooms, Tunnel Ventilation Systems and Drainage Pumping Stations) are provided with redundant fiber cable networks.

28.4.4.3.3.2.5 Disabling unused ports and services on SCADA devices after testing to assure this will not impact SCADA operation.

28.4.4.3.3.2.6 Restricting SCADA user privileges to only servers located on the DMZ network.

28.4.4.3.3.2.7 SCADA protocols, such as MODBUS/TCP, EtherNet/IP, and DNP3 are critical for communications to most control devices. These protocols were designed without sufficient built in security features and typically do not require sufficient authentication during remote execute commands on a control device. These protocols should only be allowed within the SCADA network and not allowed to cross into the corporate network.

28.4.4.3.3.2.8 AEMS, Historian and Digital Trace Recorder servers that are access by SCADA users shall be located in the DMZ.

28.4.4.3.3.2.9 The design of the SCADA system and the communication infrastructure must be performed with consideration to overall system resilience to ensure the highest level of availability for the SCADA system and associated control and protection equipment. Redundant Fiber-Optic circuits are required for all facilities monitored and/or controlled by OCC.

28.4.4.3.3.2.10 Secured Ethernet switches with firewall /VPN The secure SCADA network, designed to reliably connect and safeguard SCADA equipment from attacks shall be specified by WMATA's IT department. The specified Ethernet switches will meet current IT/NCS network and equipment standards as defined in the "Department of IT Technology Standards Guide" and shall be suitable for harsh environment, immune to typical environmental conditions including electrical and radio frequency interference found in Traction Power Substation and in a medium voltage station environment.

28.4.4.3.3.2.11 The Switch shall SCADA LAN/WAN networks will use highly secure firewall to monitor application traffic and stop unauthorized and potentially damaging activities.

28.4.4.3.3.2.12 Ethernet switches shall be installed in locked cabinets with adequate ventilation and air filtration.

28.4.4.3.3.2.13 Communication Network block diagram for communication troubleshooting purposes detailing the communication path from communication room connection point to the RTU or other device that is communicating with the electrical equipment in the field shall be provided. For security purposes device addressing shall not be provided on these diagrams.

28.4.4.3.3.2.14 Cable and connectors should be color-coded and labeled so that the WAN and LAN networks are clearly delineated and the potential for an inadvertent cross-connect is reduced. Cable runs should be installed so that access is limited to authorized personnel only.

28.4.4.3.3.3 WMATA's IT/NCS SCADA Engineering shall be responsible for the design of SCADA Local Area Network (LAN) Architecture.

28.4.4.3.4 Remote Terminal Unit (RTU)

28.4.4.3.4.1 Each Traction Power Substation, Tie Breaker Station, Passenger station Electrical switchgear Rooms, Parking Garages, Bus garages and Chiller Plant shall be equipped with a Remote Terminal Unit (RTU) of the appropriate type and size to communicate with SCADA masters and field devices. The RTU is a highly customized device designed for indoor installation inside substations and stations, performs a number of critical functions including: communication with the ROCC master stations, AEMS master stations, local HMI and field devices. The RTU is a data concentrator for the local SCADA database; and provides protocol conversion (between the master station SCADA and numerous field devices); and communication with the IEDs installed within the substations.

28.4.4.3.4.2 Remote Terminal Units shall be furnished, installed, programmed and tested by the contractor or as specified in the contract.

28.4.4.3.4.3 RTU shall be connected to the Remote Master Stations via a network switch (gateway) installed at each facility.

28.4.4.3.4.4 For all fan shafts, vent shafts, drainage/pumping stations, and chiller plant, satellite RTU or Distributed Input Output module (DIO) or Programmable Logic Controller (PLC) shall be located in respective equipment room. Fiber-Optic cable shall use to connect these devices IEDs to the nearest Passenger station AC switchboard rooms, network switch or RTU.

28.4.4.3.4.5 For Passenger station Escalator and elevator, Programmable Logic Controller (PLC) shall be located in in the Passenger station AC switchboard room or in escalator and elevator equipment room. Ethernet cable shall connect the PLC to the AC room Network Switch.

28.4.4.3.4.6 Redundant AC and DC Power supply shall be provided to the RTU.

28.4.4.3.4.7 RTU installed in substations and stations shall be designed to operate on 125V DC.

28.4.4.3.4.8 To assure security for the SCADA system, each RTU shall communicate with the SCADA master stations over a virtual private network (VPN) or as specified by the Authority. RTU shall communicate with the master stations using DNP3 protocol and approved RTU proprietary protocol.

28.4.4.3.4.9 Each RTU shall be designed to interface and communicate with local IEDs (meters, Microprocessor Relays, Programmable Logic Controllers (PLCs), controllers, etc.,) using as a minimum the following common open network communication protocols; Modbus, DNP3 and IEC61850.

28.4.4.3.4.10 Physical communications where IP communication is not available at the edge devices, physical communication with RTU shall be overRS-485 communications links or discrete wires.

28.4.4.3.4.11 For each IED monitored by the RTU, communication protocol, register number, point name, scaling shall be provided for successfully interfacing with the IEDs.

28.4.4.3.4.12 Adequate wall space shall be identified and reserved within the substation and station to install the RTU.

28.4.4.3.4.13 The RTU shall be compatible with the Authority's WMATA's master station located at the ROCC. RTU's shall be provided in traction power substations, and AC Switchboard Rooms. RTU point counts and wiring requirements are listed in Table XX 28.1. The master station database shall be able will have the capability to be create automatically created from a RTU file using an intermediate conversion program.

28.4.4.3.5 System Functions

28.4.4.3.5.1 The field response equipment in the remote zone control units shall permit the traction power substation functions to be supervised or controlled remotely from the ROCC.

28.4.4.3.5.2 Field equipment shall be designed to permit supervision, control and monitoring as specified.

28.4.4.3.5.3 Tables 28.3, 28.4 list the various locations, supervisory control and monitoring functions for traction power substations and auxiliary electrical equipment respectively. Local and supervisory control functions for these systems and for other equipment shall be as shown on electrical and mechanical design and standard drawings.

28.4.4.3.6 SCADA For Traction Power Systems

28.4.4.3.6.1 The SCADA system inside Mainline and Yard Traction Power Substation (TPSS) and Tie Breaker Station shall control and/or monitor as applicable High voltage AC switchgear, Rectifier Transformer units, Auxiliary transformers, DC switchgear, Digital trace recorders, Low Voltage AC switchgear, u Uninterruptible p Power s Supplies (UPS), battery cycle monitor, negative switchboards, emergency trip system, contact rail heating system, feeder cable shield monitor, and ancillary equipment installed inside the substation.

28.4.4.3.6.2 All Microprocessor based devices shall be provided with support, at a minimum, Fast Ethernet/Full-Duplex 802.3u communications over Fiber-Optic cable shall connect to the network switches and shall communicate using DNP3, Modbus or IEC61850 protocol. The devices shall also include web servers accessible from standard web browsers.

28.4.4.3.6.3 Tables 28.3 and 28.4 list the various locations and supervisory control point lists for traction power substations and auxiliary electrical equipment respectively. Local and supervisory control functions for these systems and for other equipment shall be as shown on electrical, mechanical and train control design and standard drawings.

28.4.4.3.6.4 AC or DC power systems when applied, load shedding schemes, Load transfer schemes, transfer trip schemes shall use protected and dedicated communication link. SCADA network shall not be used

28.4.4.3.6.5 Human Machine Interface (HMI):

28.4.4.3.6.5.1 Human machine interface (HMI) for SCADA systems shall provide the functions of status indication, alarm reporting, event logging, and operator intervention in control action.

28.4.4.3.6.5.2 HMI shall use graphical screens displays to communicate system status and alarm conditions. Screens shall be configured for system overview, subsystem, and equipment screens for all major components of the facility. Remote manual control and supervisory control shall be performed at the HMI.

28.4.4.3.6.5.3 HMI event and alarm log records shall be maintained on-site for a minimum of 5 years.

28.4.4.3.6.5.4 HMI WEB server shall use open-source web technologies to build interactive screens accessible from standard web browsers.

28.4.4.3.6.6 AC Switchgear:

28.4.4.3.6.6.1 Each utility supply feeder breaker shall have a utility grade Power Quality Metering (PQM) installed to measure and report energy utilization to SCADA.

28.4.4.3.6.6.2 Each medium voltage feeder breaker shall have a microprocessor based protective relay programmed for remote monitoring by SCADA.

28.4.4.3.6.6.3 Each utility supply breaker, rectifier-transformer breaker, bus tie Breaker, and feeder breaker shall have its status monitored by and control functions through the SCADA system. Distributed Input-Output (DIO) modules communicated to the RTU shall be provided for the circuit breaker status and controls.

28.4.4.3.6.6.4 Potential Transformer (PT) Throw-over circuit that changes the voltage source for the metering and relay functions for circuit breakers shall be provided and connected to all protective relays, Power Quality Meters and Digital Power Meters.

28.4.4.3.6.6.5 Each Substation Transformer shall be provided with microprocessor based transformer monitor. The transformer monitoring device shall include Dissolved Gas Analysis (DGA) device for oil filled transformers

28.4.4.3.6.6.6 Each Substation Rectifier shall be provided with microprocessor based device to monitor the rectifier health and annunciate the following specified indications:

28.4.4.3.6.6.6.1 Diode failure alarm for each diode

28.4.4.3.6.6.6.2 1st stage diode failure alarm

28.4.4.3.6.6.6.3 2nd stage diode failure alarm

28.4.4.3.6.6.6.4 1st stage rectifier over temp alarm

28.4.4.3.6.6.6.5 2nd stage rectifier over temp alarm

28.4.4.3.6.6.6.6 Rectifier door open alarm

28.4.4.3.6.6.6.7 Heat sink stack temperature per diode string

28.4.4.3.6.6.6.8 Negative disconnect switch position

28.4.4.3.6.6.6.9 Rectifier

28.4.4.3.6.7 DC Switchgear:

28.4.4.3.6.7.1 Each DC Cathode and feeder breaker shall have a microprocessor based protective relay programmed for remote monitoring by SCADA.

28.4.4.3.6.7.2 Each feeder breaker relay shall measure its associated third rail voltage and indication shall be provided to ROCC.

28.4.4.3.6.7.3 Each DC Cathode and feeder breaker shall have its status monitored by the SCADA system, through the Distributed Input-Output modules shall be provided for the circuit breaker status and controls.

28.4.4.3.6.7.4 Cable Shield Monitoring systems for track feeders shall be microprocessor based and shall connect directly to the Network Switch by Fiber-Optic cable.

28.4.4.3.6.7.5 Each substation shall be equipped with a complete, properly operating, microprocessor controlled Digital Trace Recording (DTR) System which shall monitor, record, stream in various prescribed formats, the status of DC Cathode and feeder breaker currents, DC switchgear bus voltage, DC negative return currents and Rail to ground voltages continuously. The DTR system shall be accurate, user friendly, versatile in output formats, easy to troubleshoot and maintain, and shall meet all of the following basic minimum requirements:

28.4.4.3.6.7.5.1 Analog Inputs: 11 DC inputs minimum. Current supplied by transducers with 0-2mA range.

28.4.4.3.6.7.5.2 Streaming Data: minimum 50 samples per sec. per channel streamed to TCP/IP network.

28.4.4.3.6.7.5.3 Status Inputs: minimum 32 inputs.

28.4.4.3.6.8 Emergency Power System

28.4.4.3.6.9.1 Uninterruptible Power Supply (UPS) system provided shall include communication module connected to SCADA for remote monitoring. Alarms points monitored by OCC shall be hardwired to the RTU.

28.4.4.3.6.9 Battery Monitor

28.4.4.3.6.9.1 Stationary battery monitor designed for use in industrial applications shall be provided and shall have remote monitoring capability with remote access via Ethernet. All battery parameters including individual cell parameters shall be measured and continuously monitored.

28.4.4.3.6.10 Contact Rail De-icing System

28.4.4.3.6.10.1 Each substation is provided with a microprocessor based master (Zone) zone controller that interfaces with track heater controllers and the substation RTU for control and indications. Zones are track 1, track 2 and track 3 if applicable.

28.4.4.3.6.10.2 The zone heater controller shall be connected to the substation network switch using Ethernet Fiber Fiber-Optic cable.

28.4.4.3.6.10.3 The zone heater controller shall include web server functionality for status through Internet browser. The webpages shall include as a minimum the following:

28.4.4.3.6.10.3.1 Zone heater On/off indications and local/remote switch indication.

28.4.4.3.6.10.3.2 Trackside controller contactor On/Off indication, relays On/Off indications and local/remote switch indication.

28.4.4.3.6.10.4 The zone controller at the RTU location shall provide an active "Zone Heaters Off" indication to the RTU when any of the current relays of any trackside heater controller of the same zone is not detecting at least the minimum current flow.

28.4.4.3.6.10.5 Each trackside heater control panel shall include a controller that interfaces to a zone controller at the RTU location over a single multi-drop RS485 serial link.

28.4.4.3.6.10.6 Each trackside heater controller panel shall include a single rugged and hermetically sealed contactor with high efficiency DC coil capable of switching two 30 amp DC load circuits at voltages up to 1000VDC.

28.4.4.3.6.10.7 Each trackside heater controller panel shall include two current relays, one per circuit. Each current relay shall have an adjustable current threshold that can be set between 1 amp and 10 amps to determine that the heater has been powered on.

28.4.4.3.6.10.8 The trackside heater controller panel shall derive its 24 VDC control system power from the third rail, using a 240W DC-DC converter that is housed in the Trackside controller enclosure.

28.4.4.3.6.10.9 Track side heater controller shall be rugged, compact and designed to withstand EMI, RFI, shock and vibration.

28.4.4.3.6.10.10 Room Temperature Monitor

28.4.4.3.6.10.10.1 Facility Room Thermostat shall be connected to SCADA for monitoring. Room temperature shall be displayed on the facility HMI main screen.

28.4.4.3.6.10.11 Battery Room Exhaust Fan

28.4.4.3.6.10.11.1 Battery room exhaust fan and hydrogen level, where required by the local jurisdiction, alarms shall be monitored by ROCC

28.4.4.3.6.10.12 ETS Relay Monitoring

28.4.4.3.6.10.12.1 A normally open (NO) contact from each ETS relay shall be connected to the RTU for monitoring. ETS activation shall be alarmed on the HMI annunciator. Upon reset of the relay, the alarms is are cleared only by an acknowledgement on the HMI.

28.4.4.3.7 SCADA For Yard Control Tower

28.4.4.3.7.1 Yard tower shall be provided with control and monitoring systems for remote control and supervision of Power equipment, the display of Yard Contac Rails, isolation switches, TPSS and TBS One-line diagrams on a 46" or larger digital screen.

28.4.4.3.7.2 The system shall allow the operator at the yard control tower to trip control and monitor breakers from the Power HMI panel only.

28.4.4.3.7.3 The system shall permit "Yard Isolation" from the mainline and vice-versa through the HMI, which in turn operates the dc positive and negative tie breakers in accordance with interlocks provided.

28.4.4.3.7.4 Yard Master Trip shall be hardwired for direct tripping of the breakers. SCADA shall monitor the activation of the yard master trip switch.

28.4.4.3.7.5 Circuit breaker status shall be monitored and displayed on the digital display panel and on the HMI.

28.4.4.3.7.6 Audible alarm shall be provided on the HMI for critical alarms.

28.4.4.3.7.7 Yard electrification single line diagram shall be displayed on the digital screen.

28.4.4.3.7.8 Third rail energization shall be displayed on the digital display panel.

28.4.4.3.7.9 Utility Feeder energization shall be displayed on the digital display.

28.4.4.3.7.10 Third Voltage shall be displayed on both the HMI and digital display panel.

28.4.4.3.7.11 The status of trackside disconnect switched shall be monitored and displayed on the digital display panel.

28.4.4.3.7.12 Additionally, the yard tower has a second HMI connected to the train wash PLC, via the ethernet communication, dedicated to trail wash functionally.

28.4.4.3.8 Mechanical Systems

28.4.4.3.8.1 HMI shall be provided and connected to the train wash PLC, via the Ethernet communication, dedicated to train wash functionally.

28.4.4.3.8.2 The train wash HMI shall monitor the temperature in the train wash and shall alarm the tower if freezing is eminent. Status to the train wash doors is critical and part of the HMI functions.

28.4.4.3.9 SCADA For Auxiliary AC Electrical Systems

28.4.4.3.9.1 The SCADA system inside Auxiliary AC Electrical facilities shall monitor Medium Voltage AC switchgear, Transformer units, Low Voltage AC switchgear Main breakers, Tie breakers and Feeder breakers rated 150A or higher, Human Machine interface (HMI), PLC, uninterruptable power supplies (UPS), battery cycle monitor, room temperature, battery room exhaust fan and hydrogen level, (where required by the local jurisdiction) escalator elevator system, Fan shaft systems, drainage pump stations and Chiller Plants.

28.4.4.3.9.2 All Microprocessor based devices shall be provided with will support, at a minimum, Fast Ethernet communication module for full-duplex (802.3u) communications over optic f Fiber-Optic cable, shall connect to the network switches and shall communicate using DNP3, Modbus or IEC61850 protocol. The devices shall also include web servers accessible from standard web browsers.

28.4.4.3.9.3 Tables 28.3 and 26.4 list the various locations and supervisory control point lists for traction power substations and auxiliary electrical equipment respectively. Local and supervisory control functions for these systems and for other equipment shall be as shown on electrical, mechanical and train control design and standard drawings.

28.4.4.3.9.4 Human Machine Interface (HMI):

28.4.4.3.9.4.1 Human Machine Interface (HMI) for SCADA systems shall provide the functions of status indication, alarm reporting, event logging, and operator intervention in control action.

28.4.4.3.9.4.2 HMI shall use graphical screens displays to communicate system status and alarm conditions. Screens shall be configured for system overview, subsystem, and equipment screens for all major components of the facility. Remote manual control and supervisory control shall be performed at the HMI for medium voltage breakers only.

28.4.4.3.9.4.3 HMI event and alarm log records shall be maintained on-site for a minimum of 5 years.

28.4.4.3.9.4.4 HMI WEB server shall use open-source web technologies to build interactive screens accessible from standard web browsers.

28.4.4.3.9.4.5 This HMI is a separate HMI from the HMI provided with the Low Voltage Switchgear for Main-Tie-Tie-Main operation.

28.4.4.3.9.5 Medium Voltage AC Switchgear:

28.4.4.3.9.5.1 Each utility supply feeder breaker shall have a utility grade Power Quality Metering (PQM) installed to measure and report energy utilization to SCADA.

28.4.4.3.9.5.2 Each medium voltage feeder breaker shall have a microprocessor based protective relay programmed for remote monitoring and controlled by SCADA.

28.4.4.3.9.5.3 The relay shall be interfaced to open and close its associated breaker and provide the status of the breaker.

28.4.4.3.9.5.4 Remote control of the Medium Voltage breaker is restricted to the Local HMI only.

28.4.4.3.9.6 Medium Voltage Transformers:

28.4.4.3.9.6.1 Each Substation Transformer shall be provided with microprocessor based transformer monitor.

28.4.4.3.9.7 Low Voltage Switchgear Programmable Logic Controller.

28.4.4.3.9.7.1 Each switchgear lineup (Switchgear 1 & 2) shall be equipped with a programmable logic controller and HMI for automatic Main-Tie-Tie Main load transfer operation and circuit breaker status indication.

28.4.4.3.9.7.2 The PLC system design shall include redundant hot standby programmable logic controllers.

28.4.4.3.9.7.3 Redundant controllers refer to Hot Standby configuration where both the controllers are reading inputs and processing them at the same time, however only one shall write the outputs. Both controllers are in close synchronization with each other and checking each other in each cycle. The transfer of control on outputs is bump seamless and no loss of functionality occurs. The controllers are directly linked to each other by fiber without any interfacing device to avoid "Common cause of failure".

28.4.4.3.9.7.4 Connections between the switchgear's two redundant PLCs shall be through dedicated optical fiber cables. The SCADA network shall not be used for communication between the two PLCs.

28.4.4.3.9.7.5 PLCs shall communicate their status and control to the OCC via the SCADA RTU over fiber as detailed on AC room SCADA system block diagram.

28.4.4.3.9.7.6 SCADA RTU connects to the MTTM PLC via the switchboard LAN to provide the following status to SCADA servers:

28.4.4.3.9.7.6.1 Breaker closed

28.4.4.3.9.7.6.2 Breaker open

28.4.4.3.9.7.6.3 Breaker Connected

28.4.4.3.9.7.6.4 Breaker Racked out

28.4.4.3.9.7.6.5 Breaker Bell alarm Lockout

28.4.4.3.9.7.7 Both lineups of the MTTM station shall be equipped with touch screen HMIs.

28.4.4.3.9.7.8 This HMI shall be programmed by the manufacturer of the switchgear and shall give the operator single point access to as much status, control and configuration capability as possible.

28.4.4.3.9.7.9 HMI shall include web server enabled and accessible from standard web browsers. Control or configuration changes through webpage shall be prohibited.

28.4.4.3.9.7.10 HMI Ethernet Port: Fast Ethernet connected to Ethernet switch.

28.4.4.3.9.8 Low Voltage switchgear Breakers

28.4.4.3.9.8.1 The main and tie breakers trip units shall use microprocessor-based technology to provide the basic adjustable time-current protection functions. The trip unit shall be equipped to permit communication to the LAN system provided in the equipment for remote monitoring. All monitored parameters shall be transmitted to SCADA.

28.4.4.3.9.9 Low Voltage switchboard Feeder Breakers

28.4.4.3.9.9.1 Feeder circuit breaker with plug rated 150A or higher trip unit shall be equipped to permit communication to the LAN system provided in the equipment for remote monitoring. All monitored parameters shall be transmitted to SCADA.

28.4.5 Testing and Commissioning

28.4.5.1 Commissioning activities shall be develop for each facility to verify and document that the installed SCADA system complies with and performs in accordance with the design intent, as defined in these criteria and SCADA specifications.

28.4.5.2 A factory acceptance test and demonstration shall be required in which the controller(s), I/O, and HMI hardware and software are verified to the extent possible without the actual field devices.

28.4.5.3 Hardware integration test shall be performed to ensure that the servers and RTU hardware, conforms to requirements.

28.4.5.4 Point Assignment Charts, aka Scan Sheet, shall be developed for each facility.

28.4.5.5 Site Acceptance Tests

28.4.5.5.1 The SCADA system shall be tested at the site. All hardware and software associated with the SCADA system along with all RTUs, HMIs, fiber networks and all field devices connected shall be tested under the field tests.

28.4.5.5.2 The equipment which has undergone the factory testing shall be installed at site and integrated with the RTU and HMI though the communication medium.

28.4.5.5.3 Functional performance test of all systems and subsystems shall be performed to verify all features of the SCADA hardware, software and monitoring point on the point assignment chart.

28.4.5.5.4 System availability tests shall be conducted before the End-to-End tests. The system availability test shall apply to the SCADA servers system (hardware and software) integrated with the RTUs. The SCADA system (hardware and software systems) shall be available for 99.5% of the time during the 360 hours (15 days) test period.

However, there shall not be any outage/down time during last 85 Hours of the test duration.

28.4.5.5.5 The final acceptance tests shall be an overall network verification test to include operations at the OCC and the Yard Control Tower as required. End-to-End test shall be conducted to verify:

28.4.5.5.5.1 Communication of RTUs with ROCC FEP and AEMS servers.

28.4.5.5.5.2 RTU communication channel monitoring by IT for dropped packets.

28.4.5.5.5.3 Mapping of ROCC and AEMS SCADA database with RTU for all RTU points.

28.4.5.5.5.4 Mapping of SCADA database with displays and reports.

28.4.5.6 Whenever all or part of a SCADA system is modified, repaired or replaced, re-commissioning the system is required will be commissioned to verify that the portions of the system affected function correctly and that the work has not affected other portions of the system. The extent of re-commissioning required should will be determined by WMATA based on the extent of the modifications.

28.4.6 SCADA System Maintenance

28.4.6.1 A comprehensive maintenance program is critical to attaining long-term reliable performance of SCADA systems. Periodic device calibration, preventive maintenance, and testing allow potential problems to be identified before they can cause mission failure. Prompt corrective maintenance assures reliability by minimizing downtime of redundant components.

28.4.6.2 SCADA system maintenance shall be part of the overall preventive maintenance (PM) program for the facility.

28.4.6.3 SCADA system and software maintenance shall be conducted by the SCADA technicians.

28.4.6.4 SCADA Technician Field Office: Provide an enclosed room, temperature and humidity controlled, for SCADA technician reporting office. The field office space design shall include space for two desks with computers, a test and repair bench and a storage space. Size of room shall be 15 by 20 feet minimum.

28.4.7 Abbreviations and Acronyms

28.4.7.1 Below is a listing of some of the technical abbreviations and acronyms used in this document. Terms not listed may be found in the current WMATA Manual of Design Criteria.

28.4.7.1.1 AEMS (Automated Energy Management System) - A system used to monitor and facilitate the safe, reliable and efficient operation of the electrical and mechanical systems.

28.4.7.1.2 AIM (Advanced Information Management) - The current Rail Operation Control Center software is the Advanced Information

Management software provided by the ARINC Corporation

28.4.7.1.3 DIO - Distributed Input/Output

28.4.7.1.4 DNP (Distributed Network Protocol) - A communication protocol designed to achieve open, standards-based interoperability between substation computers, RTUs (Remote Terminal Units), IEDs (Intelligent Electronic Devices) and master stations.

28.4.7.1.5 DTS (Data Transmission System) – Original WMATA SCADA architecture connects systems to ATC RTU through DTS cables.

28.4.7.1.6 DTR (Digital Trace Record) - DTR is a device installed at the Traction Power Substation and Tie Breaker Station for DC switchgear load flow and trending.

28.4.7.1.7 FEP (Front End Processor) - The ROCC software FEPs communicate and receive real time data from Power systems RTUs.

28.4.7.1.8 ETS - Emergency Trip Station

28.4.7.1.9 HMI - Human-Machine Interface

28.4.7.1.10 IED (Intelligent Electronic Device) - Any device incorporating one of more processors with the capability to receive or send data/control from or to an external source (e.g., electronic multifunction meters, digital relays, controllers).

28.4.7.1.11 I/O - Input/Output

28.4.7.1.12 MOC - Maintenance Operation Center

28.4.7.1.13 MTTM - Main-Tie-Tie-Main

28.4.7.1.14 OCC - Operations Control Center

28.4.7.1.15 PLC - Programmable Logic Controller

28.4.7.1.16 RTU (Remote Terminal Unit) - In SCADA systems, RTU is a device installed at a remote location that collects data, codes the data into a format that is transmittable and transmits the data back to a central station, or master. RTU also collects information from the master device and implements processes that are directed by the master. RTUs are equipped with input channels for sensing or metering, output channels for control, indication or alarms and a communications port.

28.4.7.1.17 SCADA (Supervisory Control and Data Acquisition) - used in the transit environment usually refer to systems that provide the remote control and monitoring of field equipment located in the transit passenger stations, power substations and other miscellaneous buildings in the transit environment.

28.4.7.1.18 TBS - Tie Breaker Station

28.4.7.1.19 TPSS - Traction Power Substation

28.4.8 RTU Point Counts and Wiring Requirements Shall be as follows:

TABLE 28.1

RTU CONNECTION POINT REQUIREMENTS

RTU Location	Control Points		Status Points	Analog Points		Accum Points
	Momentary	Latching		0-1m-A	4-20mA	
Traction Power Substation	8	8	24	16	16	8
Passenger Station (AC SWG Room)	16	16	40	16	16	8
S&I Shop (AC SWG Room)	16	16	40	16	16	8
Tie Breaker Station	8	8	24	16	16	8
Bus Garage (AC SWG Room)(t	8	8	24	16	16	8
Parking Garage	8	8	24	16	16	8

TABLE 28.2

WIRING REQUIREMENTS

FUNCTION	WIRE TYPE DESCRIPTION	NUMBER of CONDUCTORS INTERFACE TYPE	MINIMUM SIZE
Power	Stranded Copper	3	No. 12 AWG
Meter Pulse Accum	Stranded Copper	6	No. 14 AWG
Communication Type 1	Fiber		
Communication Type 2	Category 6		
Analog	Stranded Copper Shielded	2	No. 16. AWG
Ground	Bare Stranded Copper	1	No. 12 AWG
PULSE ACCUMULATOR POINTS (Contact Closure)	Utility Switchgear Power Meter	KWH	
EQUIPMENT STATUS POINTS (Contact Closure)	Exterior Lighting*	ON/OFF	
	Unit Heaters over 10 KW		
HOA SWITCH STATUS POINTS (Contact Closure)	Exterior Lighting*	AUTO/HAND	
	Unit Heaters over 10 KW		
CONTROL POINTS (Contact Clousure)	Exterior Lighting*	ON/OFF	
	Unit Heaters over 10 KW		

*Parking lot, garage, site, exterior platform and mezzanine

28.4.9 Control of Traction Power Substations and Tie Breaker Stations

28.4.9.1 The control and operation of a typical traction power substation and tie breaker station is described below. For schematic control diagrams refer to Electrical Design Drawings.

TABLE 28.3

LOCAL AND REMTE INDICATION AND CONTROL FUNCTIONS FOR TIE BREAKER STATIONS AND TRACTION POWER SUBSTATIONS

FUNCTIONS	CONTROL			INDICATION			WEB ACCESS
	Local HMI	ROCC	AEMS	Local HMI	ROCC	AEMS	
AC Incoming Line Breakers	X	X		X	X	X	
AC Tie Breakers				X	X	X	
AC Rectifier Transformer Feeder Breakers	X	X		X	X	X	
AC Auxiliary Transformer Feeder	X	X		X	X	X	
Power Quality Meters				X		X	X
Power Quality Meters Comm. Failure				X		X	
Microprocessor Protective Relays				X		X	X
Microprocessor Protective Relays Failure				X	X	X	
AC Incoming Line 27/59				X	X	X	
AC Breaker Control Power Failure				X	X	X	
AC SWG DIO Comm Failure				X	X	X	
AC Breaker Position				X	X	X	
AC Breaker In Local Position				X		X	
AC Incoming Line Breakers (86L) (Lockout)				X	X	X	
AC Tie Breakers (Lockout) (86BT)				X	X	X	

FUNCTIONS	CONTROL			INDICATION			WEB ACCESS
	Local HMI	ROCC	AEMS	Local HMI	ROCC	AEMS	
AC Rectifier Transformer Feeder Breakers (Lockout) (86R)				X	X	X	
AC Auxiliary Transformer Feeder Breakers (Lockout) (86R)				X	X	X	
AC Over current (50/51, 50N,51N, 51A & 51B)				X	X	X	
DC Cathode Breakers	X			X	X	X	
DC Cathode Breaker Microprocessor Protective Relays				X		X	
DC Cathode Breaker Microprocessor Protective Relays Failure				X		X	
DC Cathode Breaker Control Power Failure				X	X	X	
DC Cathode Breaker DIO Comm Failure				X	X	X	
DC Cathode Breaker Position				X	X	X	
DC Cathode Breaker In Local Position				X		X	
DC Switchgear 86 Lockout Relay				X	X	X	
DC Feeder Breakers	X	X		X	X		
Third Rail Voltage (Each Feeder Breaker)				X	X	X	
DC Feeder Breakers Microprocessor Protective Relays				X		X	X
DC Feeder Breakers Microprocessor Protective Relays Failure				X	X	X	
DC Feeder Breakers Control Power Failure				X	X	X	
DC Feeder Breakers DIO Comm Failure				X	X	X	

DC Feeder Breakers Position				X	X	X	
DC Positive Tie Breaker	X	X		X	X		
DC Positive Tie Breaker Microprocessor Protective Relays				X		X	X
DC Positive Tie Breaker Microprocessor Protective Relays Failure				X		X	
DC Positive Tie Breaker Control Power Failure				X	X	X	
DC Positive Tie Breaker DIO Comm. Failure				X	X	X	
DC Positive Tie Breaker Position				X	X	X	
DC Negative Tie Breaker Control Power Failure				X	X	X	
FUNCTIONS	**CONTROL**			**INDICATION**			**WEB ACCESS**
	Local HMI	**ROCC**	**AEMS**	**Local HMI**	**ROCC**	**AEMS**	
DC Negative Tie Breaker DIO Comm. Failure				X	X	X	
DC Negative Tie Breaker Position				X	X	X	
DC Switchgear, Grounded Structure (64DY)				X		X	
DC Switchgear, Hot Structure (64DX)				X		X	
Positive Digital Trace Recorder				X		X	X
DC Cathode Breaker Current				X		X	
DC Feeder Breaker Current				X		X	
DC Bus Voltage				X		X	
Negative Digital Trace Recorder				X		X	X
DC Negative Return Current				X		X	

Rail to Ground Voltage				X		X	
Battery Monitor -Battery Voltage				X	X	X	X
Transformer Monitor Comm. Failure				X	X	X	X
XFMR 26T1 Top Oil Temp Alarm (Stage1)				X	X	X	X
XFMR 26T2 Top Oil Temp Alarm (Stage2)				X	X	X	X
XFMR 26T1 Bottom Oil Temp Alarm (Stage1)				X		X	X
XFMR 49T1 Winding Temp Alarm (stage 1)				X		X	X
XFMR 49T2 Winding Temp Alarm (stage 2)				X	X	X	X
XFMR System Failure				X	X	X	X
Transformer Low Oil (63QL)				X	X	X	X
XFMR 63SPX Sudden Pressure Alarm				X	X	X	X
XFMR 63MRX Pressure Relief Alarm				X	X	X	X
Rect. XFMR Dissolved Gas Fault				X		X	X
Auxiliary Transformer Comm. Failure				X	X	X	X
Auxiliary 49T1 Transformer Over-Temp (Stage 1)				X	X	X	X
FUNCTIONS	**CONTROL**			**INDICATION**			**WEB ACCESS**
	Local HMI	**ROCC**	**AEMS**	**Local HMI**	**ROCC**	**AEMS**	
Auxiliary 49T2 Transformer Over-Temp (Stage 2)				X	X	X	X
Rectifier Monitor Comm. Failure				X	X	X	
Rectifier Over-Temp 1st Stage (26RT1)				X	X	X	

Rectifier Over-Temp 2nd Stage (26RT2)				X	X	X	
Rectifier Diode Failure (95) Stage 1				X	X	X	
Rectifier Diode Failure (95) Stage 2				X	X	X	
Rectifier Diode Failure				X		X	
Rectifier Energized Structure (64C)				X		X	
Rectifier Grounded Structure (64X)				X		X	
Rectifier Door Open (Dev 33)				X		X	
Rectifier Negative Switch Open (Dev 89N)				X		X	
Rectifier Diode Heat Sink Temp				X		X	
AC Surge Protection Fuse & Micro switch (Dev 99AC)				X		X	
DC Surge Protection Fuse & Micro switch (Dev 99DC)				X		X	
Cable Shield Monitor -Cable Fault				X	X	X	X
Battery Charger Failure				X	X	X	
Inverter Output Failure				X	X	X	
UPS Transfer Switch Position				X	X	X	
Battery Room Exhaust Fan				X	X	X	
Third Rail Heater On	X	X	X	X	X	X	X
Third Rail Heater OFF	X	X	X	X	X	X	X
ETS Failure				X	X	X	
Amber Light ON	X	X	X	X	X	X	
Amber Light OFF	X	X	X	X	X	X	
Room Temperature				X		X	
Substation DC Load (MW)				X		X	

DC Stray Current				X		X	X
Fire Alarm				X	X	X	
FUNCTIONS	**CONTROL**			**INDICATION**			**WEB ACCESS**
	Local HMI	**ROCC**	**AEMS**	**Local HMI**	**ROCC**	**AEMS**	
Unauthorized Entrance				X	X	X	
HMI				X			X
Utility Meter (RS-232 Dial-up)						X	

TABLE 28.4

LOCAL AND REMOTE INDICATION AND CONTROL FUNCTIONS

FOR AUXILIARY ELECTRICAL EQUIPMENT

FUNCTIONS	CONTROL			INDICATION			WEB ACCESS
	Local HM	ROCC	AEMS	Local HM	VROCC	AEMS	
AC Incoming Line Breakers (86 Lockout)				X	X	X	
Power Quality Meters				X		X	X
Power Quality Meters Comm. Failure				X		X	
Microprocessor Protective Relays				X		X	X
Microprocessor Protective Relays Failure				X	X	X	
AC Incoming Line 27/59				X	X	X	
AC Breaker Control Power Failure				X	X	X	
AC Over current (50/51, 50N & 51N)				X	X	X	
AC Transformer Over-Temp 1st Stage				X	X	X	X
AC Transformer Over-Temp 2nd Stage				X	X	X	X
AC Transformer Comm. Failure				X	X	X	
Secondary Main Breaker	X			X	X	X	
Secondary Main Breaker Load and Parameters				X		X	
Secondary Tie Breaker	X			X	X	X	

Secondary Tie Breaker Load and Parameters				X		X	
Feeder Breaker Load and Parameters				X		X	
LV PLC				X		X	X
LV HMI				X		X	X
Battery Charger Failure				X	X	X	
Inverter Output Failure				X	X	X	
UPS Transfer Switch Position				X	X	X	
Battery Room Exhaust Fan				X	X	X	
Battery Monitor -Battery Voltage				X	X	X	

FUNCTIONS	**CONTROL**			**INDICATION**			**WEB ACCESS**
	Local HM	**ROCC**	**AEMS**	**Local HM**	**VIROCC**	**AEMS**	
Room Ambient Temperature				X		X	
Fare Collection Intrusion				X	X	X	
Fire Alarm				X	X	X	
Unauthorized Entrance				X	X	X	
Station Elevators						X	X
Station Escalator						X	X
Site Lighting		X	X		X	X	
Platform Lighting		X	X		X	X	
Mezzanine Lighting		X	X		X	X	
Tunnel Ventilation Fan		X			X	X	
Pumping Station					X	X	
Utility Meter (RS-232 Dial-up)						X	

Under Platform Exhaust Fan (UPE)		X			X	X	
Dome Exhaust Fan		X			X	X	