REQUIREMENTS
MANUAL

Revision 1
August 2024

FOREWORD

The Requirements Manual is for use by Sound Transit engineering personnel and design consultants. It provides design policies and technical guidance for developing the design of new facilities and improvements to the existing system in Pierce, Snohomish, and King Counties. This Manual does not, however, supplant or eliminate the need for independent engineering and judgment that must always be applied when designing Sound Transit projects.

Sound Transit is committed to delivering cost-effective, environmentally conscious, quality designs. The intent of this manual is to provide required and preferred criteria, as appropriate, for design elements associated with facilities and stations.

Updating the Requirements Manual is an ongoing process and revisions are issued regularly. Comments, questions and improvement ideas are welcomed. Please send all comments to: PSO Engineering Technical Standards & Requirements Director.

REQUIREMENTS MANUAL REVISION RECORD			
Document Title	**Revision No.**	**Date**	**Comments**
Sound Transit Requirements Manual	0	06/30/2023	
Sound Transit Requirements Manual	1	08/16/2024	Updates to all Requirement Sets and added new Requirement Set 1101

Set 001 - General

- Updated definitions and classifications list.

Set 007 – Noise and Vibration

- No changes

Set 010 – Operations

- Updated definitions and classifications list.
- Updated design headway requirements.
- Clarification on de-energization of electrical equipment.
- Clarification on special trackwork requirements.
- Updates to handover to and acceptance by operations and maintenance requirements.
- Updates to At-Grade/Elevated Guideway Mileage Sign dimensions.
- Updates to Tunnel Mileage Sign dimensions.
- New Storage Track Identification Sign.

Set 120 – At-Grade Crossings

- Clarified the provision for future design for at-grade crossing.
- Updated station vicinity at-grade crossing to include automatic pedestrian gates instead of manual swing gates.
- Updated swing gates as a secondary option for ped at-grade crossing based on diagnostics review.
- Updated figures to better illustrate the pavement marking for swing gates.

Set 123 – Train Control – Link Light Rail

- Added requirement for system interface to maintenance center database. This will allow equipment with the capability to do so, to automatically report maintenance data.
- Requirement added from STRM Recommendations for System Requirements Specifications that explains system software and interfaces. Operations department was especially interested in this item.
- Requirement added from STRM Recommendations for Customer Requirement Specifications to be provided.
- Updated language for “as approved by Sound Transit”, “or approved Sound Transit alternate”, and “or approved equivalent where not needed.
- Changed backup power requirement from 90 minutes to 4 hours as suggested by STRM Recommendations. Current requirement is 90 minutes, but data shows most train bungalows on new extensions get close to 4 hours.

Set 125 – Link Train Control Block Design

- Updated definition for “Headway” to make it match usage in rest of the requirements manual.
- Updated signal system design headway definition to match usage in the rest of the requirements manual and to delineate between the signal system design

headway and the general headway. Signal system headway does not match the overall headway of the system, but we want signal system headway to allow more trains than is possible so the signal system isn't a cause for reduction in overall headway.
- Corrected reference to "standard" drawing.
- Changed potentially confusing generic description to reference exact sections of the railroad as defined in section 010.3.5.2.
- Changed potentially confusing generic description to a reference of exact sections of the railroad as defined in section 010.3.5.3.

<u>Set 220 – Traction Power</u>
- Changed standard for step and touch potential to IEEE 2720.
- Added requirement for a resume of past projects for LFA.
- Added requirement to use worst case vehicle in the LFA.
- Added requirement that yard and shop TPSSs cannot be in the same building.
- Added requirement preventing TPSS's where potential water intrusion issues may occur.
- Clarified that prefabricated TPSS are required and only built-in-place TPSS are only allowed in a passenger station facility building and with ST approval.
- Added solar reflective index requirement for the TPSS building.
- Corrected shop TPSS rectifier circuit number.

<u>Set 221 – Overhead Contact System</u>
- Removed requirement for motorized sectionalizing switches.
- Added requirement for spare conduits to accommodate an upgrade to motorized sectionalizing switches.
- Added requirement to coordinate OCS poles with station structural grids.
- Added requirement prohibiting the use of OCS poles for lighting, signals, and CCTV on the mainline.
- Removed requirement restricting yard OCS poles to be used for signage.
- Removed "without prior written approval of Sound Transit Traction Power" from the requirement preventing contact or messenger wire splices.

<u>Set 222 – Stray Current Corrosion Control</u>
- No changes

<u>Set 301 – Network Communications Infrastructure</u>
- Clarified monitoring for isolated networks.
- Clarification of cable ratings.
- Added supported PoE by ST.
- Clean up of some acronym from BMS to FBMS
- Clarified requirement for conduit use.
- Clarified time synchronization, availability and architecture requirements.
- Clarified UPS requirements when there is a generator.
- Update copper spare requirements.

Set 302 - Telephony

- Updated to provide requirements for public bathrooms.
- Updated to provide requirements for public security offices interfacing with the public.
- Updated ETEL requirement to include pocket for a phone directory.
- Removed potentially confusing language about what networks specific phones are on.
- Clarified intent for new phone systems to integrate with existing platforms.
- Clarified requirements for installation of phones.
- Clarified definition of “off hook” for phone types.
- Added detail to Table 302-1 to show summary of PET location requirements and who requires it. Removed two entries covered elsewhere.
- Added exception path for specific ETELs required but not maintainable or in dangerous locations. Also added requirements for ETELs to be maintainable and accessible areas. Added ETEL enclosure cover requirements.
- Clarified Table 302-3 for CES location requirement summary.
- Clarified network requirements and coordination.
- Clarified design drawing requirements.
- Simplified coordination with ST.

Set 303 – Radio

- Fixed figure references and list.
- Fixed references to Directive Drawings for Standard Drawings.
- Corrected header and footer text.

Set 304 – Audio Systems

- Clarification of how PA system must be designed during emergency and non-emergency modes and how must meet code requirements.
- Added additional option to implement required code as acceptable by AHJ.
- Added use of Platform microphone and when they were required.
- Added guidelines to better meet noise code and requirements to lessen public issues with speaker volumes.
- Updated PA zoning requirements with minimum of eight zones.
- Specify intelligibility requirements meeting OSHA and NFPA 72 codes.
- Added some additional devices on identification of wiring.

Set 324 – SCADA

- Added acronyms for clarity.
- Removed elevators and escalators from BMS SCADA.
- Minor updates to language for clarity.

Set 520 – Vehicle Clearances and Track Spacing

- Removed reference to directive drawings.

Set 521 – Track Geometry

- Minor updates to acronyms and definitions.
- Updated Link rail track milepost labeling distance in tunnels.
- Removed reference to Sound Transit Signage Manual.
- Minor edits and clarifications to Vertical Curve requirements.

Set 522 – Track Construction

- Minor updates to language.
- Updated code references, abbreviations, and definitions.
- Update language for standard and guidance drawing.
- Minor clarification to emergency guard rail (EGR) and restraining rail.
- Removed requirements on wood ties on derails.
- Updated requirements for Special Trackwork Type and Speed
- Modified requirements for ballasted track underdrains.
- Changed the track grade crossing types to commentary.
- Deleted commentary for sand pits and “skate” bumping posts.
- Removed duplicated requirement for high resilient fasteners in DF tunnels and at-grade DF Track locations.
- Updated commentary for signal equipment placement within guideway.
- Deleted requirements for commuter rail walkway.
- Clarified LRV delivery track requirements.

Set 530 – Track Clearance and Spacing - Commuter Rail

- Updated code references and acronyms.

Set 532 – Track Construction - Commuter Rail

- Updated code references and acronyms.
- Removed reference to Set 122.

Set 601 – Fire / Life Safety

- Procedures added for determining physical addresses.
- Clarifies pedestrian safety gates at track crossing that serve as an exit must meet IBC means of egress requirements.
- New language to prevent slip/trip from conduits and other obstructions along the emergency walkway.
- Added means of egress dead-end length limitations for trainways.
- Fire/smoke dampers position must be monitored by the BMS for LINK stations.
- Smoke control weekly self-test programming is clarified.
- Monitor power to fans on standby (normally not running) that provide required

ventilation for rooms with hydrogen detection systems (e.g., UPS rooms).

- Schedule 40 painted black steel pipe is permitted as an alternate to Schedule 40 galvanized pipe for dry-pipe and pre-action systems.
- Licensed engineer required to perform preliminary calculation to determine if a fire pump is required, or not.
- Blue lens required for clean agent system visual notification devices.
- Fire hazard analysis required when the guideway extends over permanent structures.
- Clarity to omit standpipes from at-grade and limited access guideways unless required by the AHJ.
- Provide a fire hose valve in tunnel cross passages when required by the AHJ.
- Provide fire separation for energy storage system rooms when required.
- Pressure transient analysis and one fan out analysis required for tunnel and enclosed station emergency ventilation.
- Ventilation shaft design to ensure laminar flow and noise criteria is met.
- Monitoring for fan vibration and bearing temperature added.
- Clarifies when tunnel emergency ventilation is intended to be used besides fire/smoke events.
- Factory testing requirements added for fans, dampers actuators, and sound attenuators.
- Emergency ventilation system test plan requirement is added and review of test results.
- Clarifies safe access needs to fans, dampers, and other equipment.
- OMF LRV storage yard fire break and fire access requirements added.
- Self-certification requirement added for facilities constructed in WSDOT ROW when local AHJ does not have authority.

Set 701 – Geotechnical Engineering

- Added the space of tunnel borings using AASHTO Specification Table.
- Added the soil sulfate content test to determine the sulfate exposure classes using ACI Table.
- Added the soil sample storage period and condition.
- Added the landslide monitoring requirements.
- Minor changes – Added some references.

Set 720 – Building Structures

- Minor changes to language
- Changed “mezzanine” to “concourse”
- Minimum precompression for floor decks increased.

- Clarifies requirements for minimum PT reinforcement in slabs for temperature and shrinkage.
- Clarifies requirements for minimum mild reinforcement in slabs for temperature and shrinkage.
- Added requirements for transverse reinforcement detailing in beams.

Set 721 – Bridges and Elevated Structures

- Minor changes to language.
- Clarifies requirement of code version used be current by 30% design.
- Added requirements for Designer of Record to provide O&M Manuals for non-typical bridge components.
- Refers to WSDOT Bridge Design Manual and AASHTO for material unit weights.
- Added requirements for DOR to perform a load rating on commuter rail bridge following design completion.
- Clarifies that General Design conforms to WSDOT BDM only where specified.
- Moved requirements for Rail Rotation to its own section.
- Added requirement that a load rating must be performed on a pedestrian bridge if a construction vehicle in excess of the design maintenance vehicle were to access the bridge.
- Added requirement that concrete stress limits for superstructures under final conditions in the pre-compressed tensile zone is limited to zero under service loads
- Added requirement that steel deck must not be used as a composite system or stay-in-place form.
- Added allowance for polygonal shapes for pier column use.

Set 722 – Tunnel and Underground Structure Design

- Minor changes to the language.
- Added ST's approval submittal requirements for steel fiber to be used in final shotcrete lining.
- Added requirement that precast concrete lining must have mild reinforcement.
- Added requirement on the usage of the bentonite water proofing system.
- Added ST's approval submittal requirements for the shotcrete to be used as the final lining.
- Added more durability requirement for the precast lining gasket.

Set 801 – Architectural Materials, Elements, and Furnishings

- Minor changes to language and referenced codes.
- Added slip resistance requirement for expansion joint covers.

- Added requirement to enlist fall protection design expert.
- Modified glass size to allow for up to 4 by 8 feet dimension.
- Added requirement for anti-graffiti film in elevator shaft glass.

Set 802 – Landscaping

- Minor changes to language.
- Added requirements to minimize heat island effect.
- Added requirements to maintain drought-resistant soil.
- Added requirements to improve irrigation efficiency.
- Added requirements to monitor plants for heat stress during construction period.
- Added language to choose flood-resistant plants were applicable.

Set 803 – Sustainability

- No changes

Set 804 – Fall Protection

- Minor changes to language and referenced codes.
- Added requirement to minimize need to switch between different fall protection mechanisms when changing areas.
- Added requirements around ladder tie-offs.

Set 805 – Vertical Transportation

- Minor changes to language and referenced codes.
- Added requirements around passenger experience focusing on relationship between vertical transportation elements, fare paid zone, and circulation between different floors.
- Added requirements for maintenance equipment access.
- Provided option to reduce public stair width to 60 inches when between two escalators.
- Added requirement to provide unique numeric identifier for each stair.
- Added requirement for APTA-rated escalators.
- Clarified material requirements adjacent to escalators.
- Added requirement to not locate escalators over public right of way.

Set 806 - Signage

- Minor changes to language and referenced codes.
- Added additional signage types to Sound Transit Signage table.
- Added reference to At-Grade Crossings.
- Clarified VMS signage quantities and locations.

- Added requirement to coordinate off-site PA and VMS signs adjacent to stations.

Set 807 – Bike Program

- Minor changes to language and referenced codes.
- Clarified passenger experience needs.
- Added references to safety, visibility, passenger flow, and ease of access.
- Added references to Station Experience Design Guidelines.
- Added prohibition of charging in bicycle parking areas.

Set 808 – Sound Transit Art Program (STart)

- Minor changes to language.
- Added requirement to design artwork for ease of inspection.

Set 815 – Telecommunication Spaces

- Added reference to UL Lightning Protection Guide.
- Updated reference to BICSI TDMM from 14th Edition to 15th Edition recently released.
- Updated references to TDMM chapters under new edition.
- Updated pointers to coordination with other disciplines.

Set 820 – Facility Area Planning

- Minor changes to language and referenced codes.
- Added requirement for detectable warnings where no other physical barrier, curb, or landscaping is provided between pedestrian and vehicle circulation.
- Added and clarified paratransit requirements.
- Added requirement to coordinate driver comfort stations as required at bus layover facilities.

Set 821 – Station Layout – Commuter Rail

- Minor changes to language.

Set 822 – Station Layout – Light Rail

- Minor changes to language.
- Added requirements for clear space on either side of fare paid zone.
- Added requirements to coordinate and minimize cross bracing on platform canopies.
- Added requirement related to maintenance access heights and height limits at which a scissor lift is required to be provided at stations.
- Added requirement to provide toeboard adjacent to track access.
- Added requirement to prevent water dripping between canopies and directly adjacent walls.
- Added requirement to close small spaces behind windscreens when they are

unable to be maintained.
- Removed requirement for backs on benches when they are accessible from both sides.
- Added language to provide security glazing at key back-of-house spaces.
- Added requirements around fare ambassador hub locations and programming.
- Added requirements to protect raceways and receptacles in public areas.
- Removed duplicate CCTV location information.

<u>Set 830 – Parking Facilities Layout</u>
- Minor changes to language.
- Added requirement for vehicle barrier at ends of stalls where there is a ledge.
- Added requirements around CCTV locations.
- Added requirements for edge protection of garage levels to ensure objects do not roll over.
- Added requirements around “main pedestrian entry” to garage.

<u>Set 836 – Operations & Maintenance Base/ Facility – Light Rail</u>
- Minor changes to language.
- Clarified fire department access requirement.

<u>Set 901 – Storm Drainage</u>
- Clarified usage of WSDOT Highway Runoff Manual and WSDOT Hydraulics Manuals where AHJ criteria is absent.
- Clarified some wording for better understanding.

<u>Set 902 – Utilities</u>
- Removed commentary for Sound Transit Utility relocation guidelines as there is no such document.
- Added maintenance need for locating assets and equipment for minimal service disruption.
- Added safety need for locating Fire Department Connection which must not impede egress operation.
- Clarified some sentences/wording for better understanding.
- Removed deviation languages.

<u>Set 903 – Fencing</u>
- Clarified the requirements for diagnostics report in compliance with EP-13.
- Updated requirements for inter-track fencing to include material type.
- Updated and clarified throw-protection fencing height requirements for installing on existing and new public aerial structures.
- Updated and clarified pedestrian fencing height requirements.

<u>Set 904 – Grading</u>
- No change

Set 905 – Survey

- Updated field books' general notations' requirements.

Set 906 – Roadways and Non-Motorized Facilities

- Updated requirements for repairing/replacing existing non-motorized facilities to comply with AHJ requirements instead of in-kind.
- Updated non-ST owned facilities' pavement replacement requirements to comply with AHJ requirements.

Set 1002 – Mechanical – Plumbing

- Updated and clarified procedure to designer when encounters cases of special designs not covered by this criteria.
- Updated abbreviations and acronyms list.
- Revised "ICIP" to "Sound Transit Integration Process" throughout this set.
- Reliability, Availability and Maintainability Needs, updated and clarified procedure to demonstrate provision to remove or service equipment.
- Water Service, clarified main shut-off valve assembly location.
- Drainage and Vent:
    - Updated underground, concealed and embedded in structural slabs soil and waste pipe, and minimum pipe size.
    - Delete floor drains and area drain grating in public spaces statement.
    - Delete minimum underground and embedded waste pipe minimum diameter.
- Piping and Fittings:
    - Updated piping system.
    - Updated piping hydrostatic test.
- Added "BMS interface:" throughout this set to all items connected to BMS.
- Floor Drain, updated grating.
- Area and Trench Drains, updated grating.
- Roof, updated and clarified downspout and gutters material.
- Traps, moved waterless trap primers to first item in Traps section.
- Subsurface Drainage, added "Tunnel and Below Grade Level of Parking Garages," provide separate description of tunnel drainage facilities and below grade garages to the paragraph.
- Pumping Station: Added pumping station for parking garages.
- Plumbing Pumps: Added BMS interface statement for pumps.

Set 1003 – Mechanical – HVAC

- Updated abbreviations and acronyms list.
- Added "BMS interface:" throughout this set to all items connected to BMS
- Updated Auxilliary Rooms, BMS to monitor HVAC system only.
- HVAC Conditioning Systems Equipment:

    - Added fault detection and diagnostic (FDD) function as required by code.
    - Added clarification of refrigerant for HVAC conditioning equipment.
- Deleted refrigerant requirement from packaged compressor and condensing units, central chiller and heat pump, and distributed heat pumps and variable refrigerant flow.

Set 1004 – Building Monitoring and Control

- Removed references for interface between BMS and Vertical Transportation (elevators and escalators). Monitoring of vertical transportation will no longer be a function of BMS, with ST electing to utilize a 3rd party monitoring software called Knaq.
- Clarified language concerning desktop workstations and HMI's as they relate to operational needs.
- Clarified language regarding delineation of networks (TCN/EFN) as they related to EVS and BMS.
- Updated references to systems standard drawings for BMS and EVS points lists.
- Added information regarding interface between BMS and AC Switchgear.
- Clarified reference information for interface between Utility Submeters and BMS.
- Expanded language regarding requirements for Control Narrative.

Set 1005 – Electrical Power

- Updated utilization voltages for communications and video equipment.
- Clarified BMS monitoring for generators.
- Added equipment types to the NEC 110 requirement for dedicated equipment space.
- Deleted allowance for use of stationary generator to carry minimum runtime for inverters.
- Added requirement for lightning risk assessment.

Set 1006 – Electrical Raceway

- Clarified spare raceway requirements.
- Table 1006-3: clarified use of EMT.
- Table 1006-3: added requirement for fire rated circuit installation to conform to UL 2196 as a rated FHIT system.
- Added coordination requirement for subsystems with a network connection.
- Deleted specific reference to rainwater harvesting system.

Set 1007 – Electrical Lighting

- Minor changes to the language.
- Added glare rating for interior.
- Added additional requirements for Exit Sign in Lighting Strategy and Layout and Circuiting sections.
- Added additional requirements for UL 924.

- Clarified requirement for approved luminaires as part of Basis of Design.
- Added and revised the Light Loss Factor Table 1007-3.
- Added and revised Table 1007-4, Table 1007-5, and Table 1007-6.
- Clarified the height requirement for nonlight pole luminaires.
- Clarified the requirement for surface mount fixture in Parking Garage.
- Added fastener requirement for Light Poles.
- Added tunnel lighting in the Exterior section.
- Added Flagpole as part of the requirement.
- Added glare rating of G=1 in the Exterior section.
- Added diffuser, lens and glare shielding in the Exterior section.

Set 1101 – Common Technology

- New requirement set

Set 1102 – Passenger Information Management Systems (PIMS)

- No change

Set 1103 – Fare Vending

- No change

Set 1201 – Cybersecurity

- Refined Scope
- Added requirements for software licensing.
- Addressed System Hardening requirements by having default passwords removed form system.
- Removed product names of applications when describing application functions
- Required more frequent audits of user accounts.
- Added NIST requirements for Secure Coding.

Set 1202 – Closed-Circuit Television (CCTV) and Track Intrusion Detection System (TIDS)

- Refined scope
- Added language for coordination.
- Removed requirement for CCTV coverage of refuse receptacles.
- Added restricted for mounting CCTV cameras near the ledges.

Set 1203 – Access Control Systems

- Add further definition of ISO 14443 and 15963.
- Added prohibition for Access Control Panel location in elevator machine room.
- Added alarm reporting points.
- Added prohibition for integrated locksets.
- Clarified Alarms vs. Alerts vs. “sounders.”

REQUIREMENTS MANUAL

APPLICABILITY

For projects that have not yet commenced Final Design as of August 1, 2024.

East Link Bel-Red

Contract No.	Title	DCM Revision	Design Status
E320	South Bellevue (I-90 to East Main Station)	3	Completed
E330	Downtown Bellevue Tunnel	3	Completed
E335	Downtown Bellevue to Spring District (East Main Station to 124th)	3*	Completed
E340	Bel-Red (124th to NE 20th)	3*	Completed
E360	SR 520 to Overlake Transit Center Station	3	Completed

Downtown Redmond Link Extension

Contract No.	Title	DCM Revision	Design Status
R200	Downtown Redmond Link Extension	5	Completed

East Link I-90 Segment

Contract No.	Title	DCM Revision	Design Status
E110	Central Link Interface and Turn Back Track at IDS	3	Completed
E120	Gravity and Seismic Retrofits of WSDOT Structures – WSDOT BDM	N/A Will use WSDOT manual	Completed
E130	Seattle to South Bellevue	3 (WSDOT for WSDOT Structures Retrofit)	Completed
E140	Mechanical/Electrical Work in WSDOT Tunnel Facilities –	3	N/A (see E130)
E160	I-90 Track Bridge System and Prototype Project	2	Completed

Eastlink - Systems

Contract No.	Title	DCM Revision	Design Status
E750	Northgate and Eastlink Systems	3	Completed

Federal Way Transit Expansion

Contract No.	Title	DCM Revision	Design Status
F200	Federal Way Link Extension	5	Completed

Central Corridor Projects

Contract No.	Title	RM Revision	Design Status
TBD	Ballard to Downtown Link Extension	1	CE
TBD	West Seattle to Downtown Link Extension	1	PE

Tacoma Dome Link Extension

Contract No.	Title	RM Revision	Design Status
TBD	Tacoma Dome Link Extension	1	CE

Operations and Maintenance Facilities - South

Contract No.	Title	RM Revision	Design Status
TBD	OMFS	1	CE

Operations and Maintenance Facilities - North

Contract No.	Title	RM Revision	Design Status
TBD	OMFN	1	CE

Everett Link Extension

Contract No.	Title	RM Revision	Design Status
TBD	Everett Link Extension	1	CE

Infill Station Projects

Contract No.	Title	RM Revision	Design Status
TBD	Graham St	1	CE
TBD	Boeing Access Rd	1	CE

Bus Rapid Transit/ST Express

Contract No.	Title	Stride RM	Design Status
TBD	Bus Capital Enhancements for Speed, Reliability and Convenience along Pacific Avenue	0	CE
BT001	Bus Operations and Maintenance Facility	0	FD
TBD	Capital Enhancements to Improve Bus Speed and Reliability between East Pierce County Cities and Sumner Sounder Station	0	CE
TBD	King County Metro Rapid Ride C and D and Madison Street Capital Improvements	0	CE
TBD	North Sammamish Park-and-Ride	0	CE
BTS305 BTS306 BTS307	Northeast 145th Street and SR 522 Bus Rapid Transit	0	FD
X500005	ST Express Bus Base project	0	CE

Other Projects

Contract No.	Title	DCM Revision	Design Status
X500020	Midday Bus Storage	3	Completed
S35251	South Tacoma and Lakewood	4	Completed

Sounder

Contract No.	Title	DCM Revision	Design Status
S300035, S300040	Kent and Auburn Station Access Improvements	5	FD
S300004	Sounder Maintenance Base	TBD	CE
S300011	Positive Train Control (PTC)	N/A	D/B

* ST to provide Consultant Design Team selected Rev 4 changes

CE - Conceptual Engineering

PE - Preliminary Engineering

FD - Final Design

TABLE OF CONTENTS / MODE APPLICABILITY

Requirement sets that will be applicable to multiple modes (denoted as Common under the Set Type column in the below table) will be developed in an upcoming effort to incorporate the remaining modes.

Set #	Set Name	Set Type	Current Applicability				
			Light Rail	Commuter Rail	Bus Rapid Transit	URV	OMF
808	Sound Transit Art Program (STart)	Common	X	X		X	X
815	Telecommunication Spaces	Common	X	X		X	X
820	Facility Area Planning	Common	X	X		X	X
821	Station Layout – Commuter Rail	Application		X			
822	Station Layout - Light Rail	Application	X				
830	Parking Facilities Layout	Common	X	X			X
836	Operations & Maintenance Base / Facility – Light Rail	Application	X				X
901	Storm Drainage	Common	X	X			X
902	Utilities	Common	X	X			X
903	Fencing	Common	X	X			X
904	Grading	Common	X	X			X
905	Survey	Common	X	X			X
906	Roadway and Non-Motorized Facilities	Common	X	X			X
1002	Mechanical - Plumbing	Common	X	X		X	X
1003	Mechanical - HVAC	Common	X	X		X	X
1004	Building Monitoring and Control	Common	X	X		X	X
1005	Electrical Power	Common	X	X		X	X
1006	Electrical Raceway	Common	X	X		X	X
1007	Electrical Lighting	Common	X	X		X	X
1101	Common Technology	Common	X	X		X	X
1102	Passenger Information Management System (PIMS)	Common	X	X		X	
1103	Fare Vending	Common	X	X		X	
1201	Cybersecurity	Common	X	X		X	X
1202	Closed-Circuit Television (CCTV) and Track Intrusion Detection System (TIDS)	Common	X	X		X	X
1203	Access Control System	Common	X	X		X	X

001 GENERAL

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SET - 001 TABLE OF CONTENTS

TABLES

SET - 001 GENERAL

001.1 INTRODUCTION

001.1.1 Document Scope

001.1.1.1 This set establishes criteria for the conceptual engineering, preliminary engineering, final design, and construction of the light rail transit system (Link) and the commuter rail system (Sounder), including projects at existing facilities.

001.1.1.2 Link, for the purpose of these requirements, denotes a system utilizing overhead electric power distribution to coupled, motorized vehicles traveling on steel wheels, through streets and arterials, elevated guideways, and tunnels.

001.1.1.3 Sounder, for the purpose for these requirements, denotes the commuter rail service operated across the existing freight railroad corridor on behalf of Sound Transit.

001.1.1.4 The material contained in these requirements sets provides a uniform basis for design and must be used during conceptual engineering, preliminary engineering, final design, construction, and testing, including modification of existing facilities.

001.1.1.5 Unless specifically stated otherwise in these criteria, the latest edition of the code, regulation, standard, manual, or specification that are applicable at the time the design is initiated must be used.

001.1.1.6 Where the Agency, AHJ, state, and federal regulations have differing requirements, comply with that which is most stringent, as determined by Sound Transit.

001.1.1.7 Where these requirements sets and referenced state and federal regulations have differing requirements, comply with that which is most stringent, as determined by Sound Transit.

001.1.1.8 Where these requirements sets and referenced standards have differing requirements, notify Sound Transit of the differences and comply with that which is most stringent, as determined by Sound Transit.

001.1.1.9 The engineer/architect is responsible for preparation of designs that fully meet all current applicable codes, whether or not such codes are noted and/or referenced in these criteria. These criteria do not substitute for engineering judgment and sound engineering practice.

001.1.1.10 The designers are responsible for identifying any departure from the criteria contained in this document and bringing them to the attention of Sound Transit. All changes to and/or deviations from the criteria must be approved by Sound Transit prior to use in design. Application for change of criteria, addition to the criteria, and other questions must be submitted in writing to Sound Transit in accordance with Sound Transit's Engineering Design Procedures.

001.1.1.11 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Sound Transit Design Requirements Set 001 owner to determine the technical source for the design criteria.

001.1.2 Regulations, Codes, Standards, and Guidelines

001.1.2.1 International Regulations, Codes, Standards, and Guidelines

001.1.2.1.1 International Code Council (ICC) A117.1 Accessible and Usable Buildings and Facilities.

001.1.2.1.2 International Plumbing Code (IPC).

001.1.2.1.3 International Fire Code (IFC) with local amendments.

001.1.2.1.4 International Building Code (IBC) with local amendments.

001.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

001.1.2.2.1 ANSI/ASSE Z359.1 Fall Protection Code.

001.1.2.2.2 OSHA/WISHA Standards.

001.1.2.2.3 NEMA (National Electrical Manufacturers Association).

001.1.2.2.4 MUTCD (Manual of Uniform Traffic Control Devices).

001.1.2.2.5 ADA Standards for Transportation Facilities (Department of Transportation [DOT], 2006) (ADA Standards).

001.1.2.2.6 National Electrical Code (NEC) with local amendments.

001.1.2.2.7 National Fire Protection Association (NFPA).

001.1.2.2.8 Code of Federal Regulations (49 CFR Part 625) Transit Asset Management.

001.1.2.2.9 Department of Transportation (DOT) - Hazard Analysis Guidelines for Transit Properties - DOT-Federal Transit Administration (FTA)-MA-26-5005-00-01.

001.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

001.1.2.3.1 Washington Administrative Code (WAC).

001.1.2.3.2 Washington State Building Code.

001.1.2.3.3 Washington State Department of Transportation (WSDOT).

001.1.2.3.3.1 Standard Plans – For Road, Bridge and Municipal Construction.

001.1.2.3.3.2 Design Manual for Roadway Design.

001.1.2.3.3.3 Standard Specifications for Road, Bridge, and Municipal Construction.

001.1.2.3.3.4 Highway Runoff Manual.

001.1.2.3.3.5 WSDOT Pedestrian Facilities Guidebook.

001.1.2.3.3.6 WSDOT – Design Manual – Bridges and Structures.

001.1.2.3.4 Municipal and Special District Codes and Standards.

001.1.2.3.4.1 Municipal Codes and Comprehensive Plans, as applicable.

001.1.2.3.4.2 Municipal and District Roadway, Utility, and Surface Water Standards.

001.1.2.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

001.1.2.5 Other Jurisdictions

001.1.2.5.1 Precedence of Design Codes Standards Manuals and Specifications.

001.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines (Not Used)

001.1.2.6.1 Station Experience Design Guide (SEDG).

001.1.3 Abbreviations and Acronyms

001.1.3.1 AASHTO–American Association of State Highway and Transportation Officials

001.1.3.2 AREMA–American Railway Engineering and Maintenance-of-Way Association

001.1.3.3 AHJ–authority having jurisdiction

001.1.3.4 CIP–cast-in-place

001.1.3.5 DOR–designer of record

001.1.3.6 DOT–Department of Transportation

001.1.3.7 EIS–Environmental Impact Statement

001.1.3.8 FONSI–finding of no significant impact

001.1.3.9 FMECA–failure modes, effects, and criticality analyses

001.1.3.10 FTA –Federal Transit Administration

001.1.3.11 IBC–International Building Code

001.1.3.12 LCP–lighting control panel

001.1.3.13 Link–Link light rail transit system

001.1.3.14 MOW–maintenance of way

001.1.3.15 MIA–master implementation agreement

001.1.3.16 MDE–maximum design earthquake

001.1.3.17 MCBF–mean cycles between failures MTBF–mean time between failures

001.1.3.18 MTBSF–mean time between service failures

001.1.3.19 MTTR–mean time to repair

001.1.3.20 MOA–memorandum of agreement

001.1.3.21 ODE–operating design earthquake

001.1.3.22 OWF–other wayside factor

001.1.3.23 NEPA–National Environmental Policy Act

001.1.3.24 NFPA–National Fire Protection Agency

001.1.3.25 ROD–record of decision

001.1.3.26 SCR–smart card reader

001.1.3.27 STart–Sound Transit Art Program

001.1.3.28 Sounder–Sounder commuter rail system

001.1.3.29 SEPA–State Environmental Policy Act

001.1.3.30 SCADA–supervisory control and data acquisition

001.1.3.31 SSMP–Sound Transit's Safety and Security Management Plan

001.1.3.32 TPSS–traction power substation

001.1.3.33 UPS–uninterrupted power supply

001.1.3.34 WAC–Washington Administrative Code

001.1.3.35 WSDOT–Washington State Department of Transportation

001.1.4 Definitions and Classifications

001.1.4.1 Apron (area): The paved area outside of a designated building for parking, loading, and unloading.

001.1.4.2 Access portal: A passageway through which a person or vehicle must pass from one space into a more controlled or restricted space, in which only authorized persons are allowed.

001.1.4.3 Ancillary space: Non-public areas that are only accessible by, and visible to, Sound Transit or authorized personnel, including hallways or spaces used to access the non-public area.

001.1.4.4 Aspect, roadway: The appearance of a roadway signal conveying an indication as viewed from the direction of an approaching train.

001.1.4.5 At-grade crossing: The crossing or intersection of a railway track and a vehicular roadway or pedestrian and/or bicycle pathway at the same elevation.

001.1.4.6 At-grade crossing treatment, active: A warning device used at an at-grade crossing that has an active operating feature and is activated by a train's approach, (e.g., flashing lights, gates, bells, and horns).

001.1.4.7 At-grade crossing treatment, passive: Treatments used at an at-grade crossing such as pavement markings, signs, raised medians, and detectable warning surfaces. These are static and do not change in some mechanical or other physical way at the approach of a train.

001.1.4.8 At-grade crossing, pedestrian: A separate designed sidewalk or pathway where pedestrians, but not vehicles, cross railroad tracks. Sidewalk crossings contiguous with, or separate but adjacent to, public highway-rail grade crossings are not considered pedestrian at-grade crossings (49 CFR 222.9).

001.1.4.9 At-grade crossing, private: An at-grade crossing that includes a private roadway or pathway with limited vehicular and/or pedestrian use and no general public access.

001.1.4.10 At-grade crossing, public: An at-grade crossing that includes a public roadway or pathway.

001.1.4.11 At-grade guideway: A segment of the guideway that is not elevated or in a tunnel.

001.1.4.12 Authority having jurisdiction: The organization, office, or individual responsible for enforcing the requirements of a code or standard, for approving drawings, equipment, materials, an installation, or a procedure and issuing a permit or other official approval within its jurisdiction.

001.1.4.13 Automatic block signal system: A method of controlling train movements by utilizing wayside signals that give indications to operators based on right-of-way conditions.

001.1.4.14 Availability, communication systems: The proportion of time that a system or network must provide service. Availability is the probability that a network is in service and available to users at any given instant in time.

001.1.4.15 Back of house area: Same as ancillary space.

001.1.4.16 Ballast: The select crushed granular material placed as the top layer of the track substructure in which the ties are embedded.

001.1.4.17 Ballasted track: A track structure consisting of rail, tie plates or fastenings, cross ties, and the ballast/subballast bed supported on a prepared subgrade.

001.1.4.18 Bandwidth, communication systems: Indicates how much data, in bits or bytes, flows between two points in a given time, it is actually a transfer rate. The capacity of a data link is representative of the total amount of information that can be transmitted at any one time.

001.1.4.19 Battery/UPS Room: Equipment room where backup battery/ UPS equipment is stored. Typical equipment includes UPS and battery bank, maintenance bypass panel – quantities and weights to be confirmed as part of design.

001.1.4.20 Below-grade guideway: A segment of the guideway located below ground within a structure, such as a retained cut or tunnel.

001.1.4.21 Between-car barrier: Device or system that prevents, deters, or warns individuals from stepping off the platform between cars (FTA).

001.1.4.22 Bicycle facility: Equipment or spaces intended to be used by cyclists, including bike lockers; racks; and the area around the lockers and racks. This does not include the bike lanes, paths, cycle tracks, or other bike infrastructure used to access the station.

001.1.4.23 Block: A length of track of defined limits, the use of which by trains is governed by block signals, cab signals, or both.

001.1.4.24 Block, absolute: A block in which no train is permitted to enter while it is occupied by another train.

001.1.4.25 Bond, track: A metallic connection attached to adjoining rails to ensure electrical conductivity.

001.1.4.26 Bridge plate: Spans the gap between the train and the mini-high platform and is deployed by the conductor.

001.1.4.27 Building envelope: Including water penetration barriers, thermal performance measures, air and vapor barriers, condensation control measures, acoustical treatments, and roofing systems.

001.1.4.28 Buff barrier: Any of various devices or pieces of material for reducing shock or damage due to contact.

001.1.4.29 Bumping post: A steel frame device placed at the end of stub end tracks to prevent a moving rail vehicle from rolling off the end of the track.

001.1.4.30 Cast-in-place concrete: A construction technique that utilizes a temporary formwork to shape the concrete slurry until it hardens.

001.1.4.31 Capital projects: Includes facilities for Sounder and Link stations, Sound Transit Express park-and-ride lots, transit centers, and freeway stations.

001.1.4.32 Centerline, track: The centerline between two running rails in a track with standard gauge. In a gauge-widen curved track, the amount of widen gauge is always added to the outer rail side, but the track centerline still keeps the same distance as to the tangent track from the inner rail.

001.1.4.33 Centerline radius, track: The distance from the center of curvature to the centerline of the curved circular track.

001.1.4.34 Centralized traffic control: A term applied to a system of railroad operation by means of which the movement of trains over routes and through blocks on a designated section of track or tracks is directed by signals controlled from a designated point without requiring the use of train orders and without the superiority of trains.

001.1.4.35 Chorded wall method: Use short and straight wall formworks to construct a curved structure.

001.1.4.36 Chorded wall construction factor: A factor related to the increased clearance to the track caused by using short and straight wall formworks to construct a wayside curved structure.

001.1.4.37 Circulation path: An exterior or interior way of passage provided for pedestrian travel, including (but not limited to), walks, hallways, courtyards, plazas, elevators, escalators, platform lifts, ramps, stairways, mezzanines, and landings (ADA DOT).

001.1.4.38 Clearance point: Location on a switch or turnout beyond which rail vehicles must be placed to clear the dynamic envelope of rail vehicles running on the track from which the switch or turnout diverges.

001.1.4.39 Clearance envelope: Required space for the safe passage of trains and maintenance vehicles free of obstructions. The clearance envelope is composed of the vehicle dynamic envelope plus the effects of other wayside factors, including construction and maintenance tolerances for track and various facilities, plus running clearances.

001.1.4.40 Communications room: Communications room containing communications equipment, including servers, panels, and necessary support equipment for cooling and lighting.

001.1.4.41 Commuter rail: A transit mode that is an electric or diesel propelled railway for urban passenger train service consisting of local short distance travel operating between urban areas primarily used for transit to and from work locations during common working hours.

001.1.4.42 Concourse: Intermediate area connecting a station platform(s) to a public way via stairs escalators, or corridors.

001.1.4.43 Concrete tie track: Ballasted railroad track constructed with concrete cross ties and approved elastic fastening system.

001.1.4.44 Consider, considered: The associated recommended provisions must be evaluated, and the reasons and analyses used to decide whether or not to implement the recommended provisions must be documented.

001.1.4.45 Consist: A lineup or sequence of railroad cars and/or locomotives that form a unit.

001.1.4.46 Construction tolerances: The allowed variation in a dimension, construction limit, or physical characteristic of a material in the finished construction work.

001.1.4.47 Constant warning time detection: A means of detecting rail traffic that provides relatively uniform warning time for the approach of trains.

001.1.4.47.1 Constant warning time only applies to Sounder.

001.1.4.48 Contingency, communication systems: The activity of activating a backup element or process upon failover from the primary failed element. Depending on the context, a contingency can take on various forms. It can represent a backup component, system, network link or path, service provider, or a recovery data center or hot site.

001.1.4.49 Continuous welded rail: A number of rails joined together into a continuous string by the electric flash butt or thermite processes.

001.1.4.50 Control operator: An employee who directs train traffic by the use of the Direct Traffic Control Block System.

001.1.4.51 Control track: When viewing the alignment looking ahead station (outbound), the track on the viewer’s right must be designated as the control track.

001.1.4.52 Cross level, track: The measurement of the difference in elevation (height) between the top surface of the two rails at any point of railroad track.

001.1.4.53 Crossover: A pair of turnouts that connect two tracks, enabling a train to direct its travel from one pair of tracks to the other.

001.1.4.54 Crossover, universal: A pair of crossovers allowing trains to move from either main track to the other, in either direction, without changing direction of movement, that does not utilize a diamond.

001.1.4.55 Crossover, scissors/diamond: A more condensed pair of crossovers that uses a diamond.

001.1.4.56 Crosswalk: A portion of the roadway between the intersection area and a prolongation or connection of the farthest sidewalk line or in the event there are no sidewalks then between the intersection area and a line 10 feet therefrom, except as modified by a marked crosswalk (RCW 46.04.160).

001.1.4.57 Delay, communication systems: The duration of time from when a signal is transmitted to when it is received.

001.1.4.58 Derail: A device built on or attached to track for the purpose of causing rail cars, locomotives, and on-track equipment to run off the rails.

001.1.4.59 Design life: The design life of a structure, building, component, or system is the period of time during which its designers expect the asset to provide the desired function with a specified level of maintenance established at the design stage.

001.1.4.60 Designer of record: The party responsible for preparing designs that comply with Sound Transit requirements and regulations from the AHJ.

001.1.4.61 Detectable warning: A standardized surface feature built in or applied to walking surfaces or other elements to warn of hazards on a circulation path (ADA DOT).

001.1.4.62 Direct fixation track: A ballastless track structure in which the track is mounted on direct fixation fasteners that in turn are anchored to an underlying concrete slab or plinth.

001.1.4.63 Diversity, communications systems: The implementation of multiple redundant elements or versions in which the elements and versions are deliberately made to be different. The key goal served by diversity is avoidance of fate sharing amongst critical network elements. Diversity increases resilience by providing alternatives. Diversity requires geographic separation.

001.1.4.64 Double break circuit: A term used to describe the method of design in which both the positive and negative wires to the controlled device are opened by contacts of controlling device(s).

001.1.4.65 Duct bank: Groups of conduit designed to protect and consolidate cabling. In a duct bank, data and electrical cables are laid out within conduit that are bundled together. Often these bundles are protected by concrete or metal casings.

001.1.4.66 Dynamic envelope: The clearance required for light rail trains and maintenance vehicles due to any combination of loading, lateral motion, or suspension failure.

001.1.4.67 Electrical closet: Closet for electrical equipment, including (but not limited to) panels, disconnect(s), and lighting control panel (LCP) - quantities and weights to be confirmed as part of design.

001.1.4.68 Electrical distribution room: Electrical equipment room, including (but not limited to) the following: panels (two to eight), low voltage transformer (one to four), disconnects, fused switches, LCPs (one to two), fire alarm control panel, and photovoltaic inverter.

001.1.4.69 Electrical room (main): Primary electrical equipment room housing the following equipment typically: main switchgear, DC battery, main switchboard, panel (two to eight), and low voltage transformer.

001.1.4.70 Elevated guideways: Sections of track infrastructure between stations that are raised above grade or street level.

001.1.4.71 Elevator machine room: Room housing elevator equipment, including (but not limited to) hydraulic elevator - elevator power unit, and elevator hydraulic fluid cooler. Traction elevator - controller and motors - quantities and weights to be confirmed as part of design.

001.1.4.72 Emergency guard rail: See restraining rail.

001.1.4.73 Embedded track: A type of track that is completely encased in CIP concrete – except for the tops and gauge sides of the rails - within pavement.

001.1.4.74 Equipment: Including roof safety anchors, fall-arresting systems, and window washing equipment.

001.1.4.75 Error, communications systems: A general term that refers to data that has been altered in some fashion during transmission such that when it is received at a destination, it is different from what was originally sent. Error rates, particularly bit error rates, are typically stated as a percentage of the transmitted traffic. Errors usually arise out of some problem along the transmission path and are usually characterized by corrupted data or out-of-sequence packets.

001.1.4.76 Escalator control room: Room containing the controls for the escalator - typical controller weighing 1,000 pounds.

001.1.4.77 Evaluate, Evaluated, Address, or Addressed: The associated issue must be evaluated or addressed through detailed analysis and the results documented.

001.1.4.78 Eyewash Station: Portable or plumbed fixture that flushes eyes with a continuous supply of water for emergency purposes.

001.1.4.79 Failover, communication systems: The process of switching to a backup component, element, or operation while recovery from a disruption in undertaken. There are several types of failovers. Hot or immediate failover requires a running duplicate of the production system as a backup to provide immediate recovery. Cold failover, on the other hand, is the least complex to implement but likely results in some disruption until the backup is able to initiate service. Warm failover uses a backup system that is not provided with state information on the primary system until a failover takes place.

001.1.4.80 Failure rate, communication systems: Defined to express failure frequency in terms of failures per unit time, say percentage of failures per 1,000 hours.

001.1.4.81 Fan control room: Room housing electrical devices and controls for the operation of emergency ventilation fans. Electronic and controls infrastructure to support control and functionality of emergency ventilation system are often housed in the same space

001.1.4.82 Fan room: For tunnel stations, a room housing large emergency ventilation fans for the purpose of controlling smoke due to a fire event in the tunnel. Fans can range in size, dependent upon sizing needs for airflow, but can include the fan, attenuator, ductwork, and dampers. For garages, a room with that provide removal of vehicle exhaust for subgrade and fully enclosed levels that do not have adequate natural ventilation.

001.1.4.83 Fare paid zone: Area at a Link station entrance that delineates the start of the paid area. Overhead signage, detectable floor surface, and smart card readers (SCRs) must indicate extent of the fare paid zone. For all other modes, fare paid zone is the threshold of the vehicle.

001.1.4.84 Floating track slab: A track structural slab adding the highest possible mass above the track spring to form a system with a very low resonance frequency to reduce train vibration transmission and help vibration energy dissipation.

001.1.4.85 Foreign carrier, track: Freight cars, train that is from different companies and agency.

001.1.4.86 Frog: A track device used at the intersection of two running rails to provide support for wheel treads and passageways for wheel flanges, thus permitting wheels traversing either rail to cross the other.

001.1.4.87 Gauge, track: The spacing of the rails on a railway track and is measured between the inner faces of the load bearing rails. (The standard gauge is 4 feet 8-1/2 inches).

001.1.4.88 Geotextile: Permeable woven or non-woven synthetic textile material used to increase soil stability, provide erosion or aid in drainage.

001.1.4.89 Girder: Girders are main horizontal support members of structures. They are also known as beams, but all beams are not girders. They usually have a cross section like an "I", with two flanges and a web.

001.1.4.90 Girder bridge: A bridge that uses girders as the means of supporting its deck.

001.1.4.91 Guard Rail system (WAC) and Guard (IBC):

001.1.4.91.1 WAC: A barrier erected along an unprotected or exposed side, edge, or other area of a walking-working surface to prevent employees from falling to a lower level (WAC 296-880-4005). Term is applicable to describe the barrier installed on the edge of an elevated guideway and other areas where employees work.

001.1.4.91.2 IBC: A building component or a system of building components located at or near the open sides of elevated walking surfaces that minimizes the possibility of a fall from the walking surface to a lower level. Equivalent to guard referenced in the IBC. Generally applicable to stations and other facilities per IBC.

001.1.4.92 Guidance drawing: Refers to Sound Transit guidance drawings, conveying uniform standards for the design, fabrication, installation, and construction of specific items of work for the transit system. The DOR is responsible for validating and incorporating the design on the guidance drawings for inclusion into project final design.

001.1.4.93 Guideway: For FTA or general Sound Transit purposes: A public transportation facility using and occupying a separate right-of-way for the exclusive use of public transportation, including buildings and structures dedicated for the operation of transit vehicles. The guideway does not include passenger stations, transfer facilities, bus pull-ins, or train control systems (e.g., cab signaling and train control). For NFPA purposes: That portion of the fixed guideway transit or passenger rail system included within right-of-way fences, outer lines of curbs or shoulders, tunnels and stations, cut or fill slopes, ditches, channels, and waterways, including all appertaining structures.

001.1.4.94 Handrail: A horizontal or sloping rail intended for grasping by the hand for guidance or support.

001.1.4.95 High Security Areas: As defined in Set 801 Architecture Materials, Elements, and Furnishings.

001.1.4.96 High-rail Vehicle: A roadway maintenance vehicle that is manufactured to meet Federal Motor Vehicle Safety Standards and is equipped with retractable flanged wheels so that the vehicle may travel over the highway or on railroad tracks.

001.1.4.97 Hunting Force: Dynamic lateral load by vehicle in motion.

001.1.4.98 Indication: The information conveyed by the aspect of a signal.

001.1.4.99 Industry track: A section of track serving the needs of a commercial industry, including warehouses, mills, mines, and factories.

001.1.4.100 Insulated joint: A rail joint that ensures electrical insulation to adjacent rails to limit a track circuit.

001.1.4.101 Interchange track: The practice of railroads conveying freight cars from other companies and agencies over their lines.

001.1.4.102 Interlocking: An arrangement of signals, generally including switches, and with or without other signal appliances, which are so interconnected by means of electric circuits that their movements must succeed each other in proper sequence, train movements over all routes being governed by signal indication.

001.1.4.103 Intertrack fencing: A fence installed between tracks to prevent passengers from crossing multiple tracks between two station platforms.

001.1.4.104 Integrated automation: Including building management systems, heating, ventilation, and air conditioning controls, and backup power supplies.

001.1.4.105 Jitter, communication systems: Refers to variation in latency or delay.

001.1.4.106 Joining of rail: Connect the rails so that they act as a continuous girder with uniform surface and alignment.

001.1.4.107 Joint bar: A metal bar that is bolted to the ends of two rails to join them together in a track.

001.1.4.108 kN Redundancy, communication systems: Type of redundancy replicates N resources k times (i.e., 2N, 3N, 5N, etc.), resulting in a 1 to 1 (1:1) redundancy.

001.1.4.109 Ladder track: A single lead track with many tracks branching off to form a classification yard.

001.1.4.109.1 This definition only applies to Sounder.

001.1.4.110 Latency, communication systems: The time it takes for a particular signal, often in the form of a data packet or voice signal, to get from a network origin point to a destination point, measured in units of time (usually milliseconds). In essence, latency is the cumulative delay posed by all of the network elements in a transmission path. In an IP network, for example, it is the time it takes for data packets to go from a client to an intended server. Contributors to latency include the following: encryption and decryption propagation, latency, network hops, peer points (POP sites) routers and firewalls, impedance mismatch.

001.1.4.111 Layover track: A temporary storage track generally used for one or more of the following: recover for delays, provide breaks for the driver, daily service, and inspection activities. This includes pocket tracks and tail tracks.

001.1.4.112 Lead track: A track connecting a railroad yard or facility with a main line or running track. Lead tracks are considered as mainline tracks, unless otherwise specified.

001.1.4.113 Lean rail: Bench alternative for passengers waiting at stations, bus loops, and other waiting areas – also at pedestrian bridge locations.

001.1.4.114 Light rail vehicle: Vehicles used for carrying passengers on a light rail transit system. Typically driven electrically with power being drawn commonly from an overhead contact system.

001.1.4.115 Link light rail transit system: A system utilizing overhead electric power distribution to coupled, motorized vehicles traveling on steel wheels, through streets and arterials, elevated guideways, and subways.

001.1.4.116 Locking: The combination of one or more electric locks and controlling circuits by means of which levers of an interlocking machine, or switches, or other units operated in connection with signaling and interlocking, are secured against operation under certain conditions.

001.1.4.117 Locking, approach: Electric locking effective while a train is approaching, within a specified distance, a signal displaying an aspect to proceed, and which prevents, until after the expiration of a predetermined time interval after such signal has been caused to display its most restrictive aspect, the movement of any interlocked or electrically locked switch, movable point frog, or derail in the route governed by the signal, and which prevents an aspect to proceed from being displayed for any conflicting route.

001.1.4.118 Locking, indication: Electric locking that prevents the manipulation of a lever that would result in an unsafe condition for a train movement if a signal, switch, or other operative unit fails to make a movement corresponding to that of its controlling lever, or that directly prevents the operation of a signal, switch, or other operative unit, in case another unit, which operate first, fails to make the required movement.

001.1.4.119 Locking, route: Electric locking, effective when a train passes a signal displaying an aspect for it to proceed, which prevents the movement of any switch, movable point frog, or derail underneath or in advance of the train within the route entered. It may be so arranged that as a train clears a track section of the route the locking affecting that section is released.

001.1.4.120 Locking, time: A method of locking, either mechanical or electrical, which, after a signal has been caused to display an aspect to proceed, prevents, until after the expiration of a predetermined time interval after such signal has been caused to display its most restrictive aspect, the operation of any interlocked or electrically locked switch, movable point frog, or derail in the route governed by that signal, and which prevents an aspect to proceed from being displayed for any conflicting route.

001.1.4.121 Locking, traffic: Electric locking which prevents the manipulation of levers or other devices for changing the direction of traffic on a section of track while that section is occupied or while a signal displays an aspect for a movement to proceed into that section.

001.1.4.122 Loss, communication systems: Loss (of data or packets) can arise out of network congestion or transmission problems. Loss would occur in the case of a buffer overflow in a device where overflowed data is discarded altogether, versus fragmenting it prior to retransmission. Loss can also occur when two or more devices attempt to simultaneously seize a network interface, trunk, or link (collisions in Ethernet networks).

001.1.4.123 Lubricator, track: A system used to reduce noise emission, reduce wear on rail, switches, and wheel.

001.1.4.124 Mainline track: A section of track that is used for through trains or is the principal artery of the system from which the branch lines, yards, sidings, and spurs are connected.

001.1.4.125 Masonry wall: A built−up construction or combination of building units of such materials as clay, adobe, shale, concrete, glass blocks, gypsum, or stone that is set in mortar or plain concrete.

001.1.4.126 Maintainability: The provision of facilities, tools, diagnostics, fall protection, and access to enable Maintenance to be conducted to enable inspection and maintenance.

001.1.4.126.1 Access is to be understood to include both personnel and the tools and equipment necessary to conduct such maintenance.

001.1.4.127 Maintenance: The action of Sound Transit, or a Contractor employed for that purpose, to perform routine, planned, unplanned, or emergency inspection, cleaning, testing, lubrication, adjustment, refurbishment, or repair of Sound Transit-owned facilities.

001.1.4.127.1 This definition is also considered to include activities, such as weed abatement, planting control, tree trimming, graffiti abatement, and trash removal.

001.1.4.127.2 This definition is also considered to include such activities performed by, or on behalf of, third-party facility owners, over or through which Sound Transit operates.

001.1.4.127.3 Such activities are not to be assumed or construed to occur exclusively during non-revenue periods, except where, for safety reasons, this is not otherwise possible.

001.1.4.128 Maintenance tolerances, Track: Limits of variability of various parameters pertaining to track geometry.

001.1.4.129 Maintenance facility: Maintenance facility where mechanics, machinists, and other maintenance personnel perform preventative maintenance, daily service, and inspection, and/or corrective maintenance activities on revenue vehicles to keep them in-service (FTA definition). This includes buildings and adjacent yard properties.

001.1.4.130 Maintenance-of-way: Refers to the maintenance, construction, and improvement of rail infrastructure, including tracks, ballast, grade, and lineside infrastructure, such as signals and signs.

001.1.4.131 Maintenance-of-way Facility: Maintenance facility that houses equipment and personnel responsible for the service of wayside elements not related to track or vehicles.

001.1.4.132 Maintenance walkway: A surface designated for a transit employee traveling on foot in a non-public area adjacent to a track at yard.

001.1.4.133 Maximum design earthquake: An earthquake event that has a return period of 2,500 years. The probability of exceedance for MDE is approximately 4 percent during the 100-year facility design life.

001.1.4.134 May: The associated provisions are recommended, but alternative methods or approaches that are consistent with the intent of the provisions are acceptable.

001.1.4.135 Mean time between failures, communication systems: A metric that conveys the mean or average life of a system based on the frequency of system outages or failures.

001.1.4.136 Mean time to failure, communication systems: A metric that is often used to characterize the operating life of a system. It is the amount of time from the placement of a system or component in service until it permanently fails.

001.1.4.137 Mean time to recovery, communication systems: Sometimes referred to as mean time to repair or restore. In either case, it means the same thing. It is the time required to restore operation in a component that has stopped operating or that is not operating to a satisfactory performance level. It includes the total time it takes to restore the component to full operation. It could include things like diagnosing, repairing, replacement, reboot, and restart.

001.1.4.138 Mean time to repair: The mean active repair time required, after arrival of the maintenance team, to locate and isolate the fault, make repairs, and perform a functional checkout to verify that the equipment has been restored to operational status. MTTR is calculated as follows:

001.1.4.138.1 MTTR = T (t) / f (t)

001.1.4.138.2 Where T (t) = total active repair time (i.e., excluding time to travel to site), and f (t) = the total number of failures occurring in time (t)

001.1.4.139 Man gate: A movable barrier, usually hinged, for closing an opening in a wall, fence, etc. to allow passage into or out of an enclosed place.

001.1.4.140 Mechanical equipment room: Room housing mechanical equipment, including air conditioning unit serving communication room, compressor unit (exterior, usually roof mounted), or a self-contained unit.

001.1.4.141 Metrics, communication systems: Quantitative measures of system or network behavior.

001.1.4.142 Micromobility: Small, lightweight, wheeled, low-speed, human- or electric-powered vehicles designed for individual use such as scooters, skateboards, personal transporters, etc., which are often used to travel short distances.

001.1.4.143 Mini-high accessibility platform: Provides a level train boarding surface at the rail car door height for individuals with mobility restrictions. The mini-high consists of ramps and elevated loading sections, while meeting the slope requirements for accessibility to connect to the low-level platform.

001.1.4.144 Mezzanine: A low story between two others in a building, typically between the ground and first floors.

001.1.4.145 Must: The associated provisions must be used. There is no acceptable alternative.

001.1.4.146 N + K Redundancy, Communication Systems: In situations where kN redundancy is not economical, resources can be spared in an N + K arrangement. N + K redundancy involves having K spare resources for a set of N resources. The K spare resources can load share traffic or operate on a hot, warm, or cold standby basis. If one of the N resources removes, fails, or degrades, one of the K spares takes over. N + K arrangements can be applied within kN arrangements, offering different granularities of protection. A kN arrangement can have K sets of resources, each having an N + K arrangement to ensure a higher degree of reliability within a set.

001.1.4.147 Non-public areas: Areas only accessible by Sound Transit or authorized personnel.

001.1.4.148 Openings: Including doors and frames, access doors and panels, overhead coiling grills, vertical lift gates, and door hardware, including locks.

001.1.4.149 Operating design earthquake: An ODE event that has a return period of 150 years. The probability of exceedance of this level of event is approximately 50 percent during the 100-year facility design life.

001.1.4.150 ORCA: Smart card-based electronic fare system for public transportation agencies serving King, Kitsap, Pierce, and Snohomish counties. ORCA is a durable, plastic smart card that contains a microprocessor.

001.1.4.151 Other track material: An appurtenance that connects the rails to each other and connects the rails to the ties. Including (but not limited to) spikes, tie plates, joint bars, track bolts, and track clips.

001.1.4.152 Other wayside factors: Other wayside factors is a part of clearance envelope. OWF is considered for certain construction and maintenance tolerances (CT+MT) plus a chorded wall construction factor to account for the effects of chorded wall construction.

001.1.4.153 Overhead contact system: The part of the train traction electrical system comprising the overhead conductors (or single contact wire), aerial feeders, direct suspension system, supports, foundations, balance weights and other equipment and assemblies, that delivers electrical power to electric vehicles.

001.1.4.154 Overhead communication systems: Includes conditions that must be factored in to convey the actual payload capacity of a network (may not be applicable for connectionless networks, such as Ethernet). The following are some of the variables that need to be considered in overhead: Duplexing Collisions, Duty Cycle, Impedance Mismatch, Protocol Overhead.

001.1.4.155 Pantograph: An apparatus mounted on the roof of an electric train, tram, or electric bus to collect power through contact with an overhead line.

001.1.4.156 Passenger: A person who is using, intends to use, or has used the transit system and is on Sound Transit's right-of-way.

001.1.4.157 Pedestrian: A person traveling on foot or with a mobility device.

001.1.4.158 Pedestrian walkway: An exterior prepared surface for pedestrian use, including pedestrian areas, such as plazas and courts.

001.1.4.159 Pocket track: A layover track capable of holding at least one full-length train in between main tracks.

001.1.4.160 Polarized circuit: An electrical path in which the polarity of electric current is reversed under certain conditions.

001.1.4.161 Positive train control: A system that meets the requirements of 49 CFR Part 236 that is designed to enforce braking on trains to prevent overspeed derailments, running through misaligned switches, incursions into established work zones, and train-to-train collisions.

001.1.4.162 Precurving: Precurving rail requires stretching the rail beyond the elastic limit of the steel so that it cannot spring back to its original straight configuration.

001.1.4.163 Preemption: The transfer of normal operation of a traffic control signal to a special control mode of operation.

001.1.4.164 Preemption, advanced: The notification of approaching rail traffic that is forwarded to the highway traffic signal controller unit or assembly by the railroad or light rail transit equipment in advance of the activation of the railroad or light rail transit warning devices.

001.1.4.165 Preemption, simultaneous: Notification of approaching rail traffic is forwarded to the highway traffic signal controller unit or assembly and railroad or light rail transit active warning devices at the same time.

001.1.4.166 Primary track: A section of track constructed for trains in revenue service. Term includes main line tracks, leads to main lines, sidings, pocket, and station tracks.

001.1.4.167 Progressive maintenance track: Track that can accommodate equipment for routine train maintenance and is constructed to accommodate a gauge width pit, a drop table, and a wheel truing machine, and is an embedded and posted-rail design.

001.1.4.168 Public area: Includes all areas used by, and visible to, the public including exterior plazas, general public areas of stations, pedestrian at-grade crossings, and emergency exit paths within Sound Transit right-of-way.

001.1.4.169 Pump room: Pump room containing pumps and associated equipment. Confirm weights and equipment as part of design.

001.1.4.170 Quiet zone: A segment of a rail line, with one or a number of consecutive public highway-rail grade crossings at which locomotive horns are not routinely sounded per 49 CFR Part 222.

001.1.4.171 Rail fixed guideway system:

001.1.4.171.1 For FTA purposes: A light, heavy, or rapid rail system that: (1) is not regulated by the Federal Railroad Administration; and (2) is included in FTA's calculation of fixed guideway route miles or receives funding under FTA's formula program for urbanized areas or (3) has submitted documentation to FTA indicating its intent to be included in FTA's calculation of fixed guideway route miles to receive funding under FTA's formula program for urbanized areas. (49 CFR 659.5)

001.1.4.171.2 For NFPA purposes: An electrified transportation system, utilizing a fixed guideway, operating on right-of-way for the mass movement of passengers within a metropolitan area, and consisting of its fixed guideways, transit vehicles, and other rolling stock, power systems, buildings, stations, and other stationary and movable apparatus, equipment, appurtenances, and structures.

001.1.4.172 Rail grinding: Rail grinding is a process that is usually performed by railbound machines. These machines remove metal from the rail using rotating grinding wheels (stones). The volume of metal removed is dependent upon the number and arrangement of stones on each rail, the characteristics and condition of the abrasive in the stones, the application pressure on the grinding stones, the forward speed of the machine and the hardness of the rail surface being worked on.

001.1.4.173 Rail gauge side: The side of rail that is not contacted by the wheel flange.

001.1.4.174 Rail field side: The side of the rail that guides the wheel flange.

001.1.4.175 Rail polishing: Rail polishing is a process that is usually performed by railbound machines. Rail polishing used a finer grit stone than rail grinding to polish out the rail.

001.1.4.176 Rail, track: The point of contact with the vehicle wheel, the structural beam supporting the wheel load, and one location where noise generated.

001.1.4.177 Railing: A vertical barrier erected along exposed sides of stairways and platforms to prevent falls of persons.

001.1.4.178 Recovery: The activity of repairing a troubled component or system. Recovery activity may not necessarily imply that the element has been returned to back to its operational state. At the system level, recovery activities can include anything from automatic diagnostic or restart of a component or system, data restoration, or even manual repair.

001.1.4.179 Redundancy: A system architectural feature whereby multiple elements are used so that if one cannot provide service, the other will. Redundancy can be realized at many levels of a network in order to achieve continuity. Effective redundancy requires elimination of single points of failure, adequate failover process to the redundant element, redundant element providing an equivalent level of service, and diverse redundancy overall.

001.1.4.180 Reliability: Defined as the probability (or likelihood) that a system, network, or component must perform satisfactorily during a specified period of time. It is measured by how long it takes for a network or system to fail (i.e., how long it continues to function until it ceases due to failure).

001.1.4.181 Response time: Time from when a request is sent to when a response is received. Response time can be thought of as round-trip latency from the perspective of the user, or the sending device.

001.1.4.182 Restraining rail (also known as emergency guard rail): Rail, as specified in Set 522 Track Construction, installed along the low rail on curves of tighter radius, and opposite the frog in switches, to provide a uniform flangeway and provide wheel steering action using the back face of the flange of the wheel.

001.1.4.183 Resumption: Returns the repaired element back into operational service. It is the process of transferring operations over to the restored element, either gradually or instantaneously once a recovery activity is completed.

001.1.4.184 Running clearances: Running clearance is a part of the clearance envelope. To provide clear passage for a LRV, which has moved to the extreme position within the Dynamic Outline, the minimum horizontal clearance to any structure, or part of a structure, must always include a horizontal running clearance.

001.1.4.185 Running rail: The rail that carries a wheel, as differentiated from a guard rail or flange rail that carries no weight.

001.1.4.186 Sag: Vertical curve that is concave upwards.

001.1.4.187 Secondary track: A section of track where trains may be operated without timetable authority, train orders, or block signals.

001.1.4.188 Security fencing: Fencing placed to secure yards, vehicle service areas, maintenance areas, storage areas, and stormwater detention ponds.

001.1.4.189 Security operations center: The primary location from which security staff monitors the security systems related to Link, Sounder commuter rail, and other systems.

001.1.4.190 Semi-exclusive: Excluding all others except for the principal or a licensee of the principal.

001.1.4.191 Service and inspection track: Track that is used to perform daily vehicle maintenance, such as cleaning the interior of rail vehicles, refilling sand reservoirs, and check/fill fluid levels.

001.1.4.192 Service life: Service life represents the period for which a product or infrastructure element provides the desired function based on usage and expected maintenance assumptions. Usage and maintenance assumptions considered to achieve the anticipated service life must be described in the Basis of Design.

001.1.4.193 Shop track: Track within mechanical limits used to park vehicles for repair or maintenance, not limited to within a structure.

001.1.4.194 Should: The associated provisions must be used unless strong justification is available and provided based on well-established regional or national practice, and if supported by well accepted results.

001.1.4.195 Shunt shop track: A by-path in an electrical circuit.

001.1.4.196 Sidewalk: A property between the curb lines or the lateral lines of a roadway and the adjacent property, set aside and intended for the use of pedestrians or such portion of private property parallel and in proximity to a public highway and dedicated to use by pedestrians. (RCW 46.04.540)

001.1.4.197 Siding: An auxiliary track located adjacent to a main line allowing a train to move out of the way of an oncoming train. Sidings are also used to store trains or to add or subtract rail cars.

001.1.4.198 Simple circular curve: A curve consists of a single arc with a constant radius connecting the two tangents.

001.1.4.199 Signal bungalow: A metal structure that houses signal and/or grade crossing equipment that has a door and is large enough for at least one person on the inside.

001.1.4.200 Signal case: A smaller metal case that houses signaling or grade crossing equipment.

001.1.4.201 Signal room: A room in a tunnel alignment that serves as a signal bungalow.

001.1.4.202 Signal, railway: A device that displays aspects to convey an indication to trains.

001.1.4.203 Single point of failure, communication systems: Any single isolated network element that, upon failure, can disrupt a network’s productive service.

001.1.4.204 Smart card readers: Electronic ORCA card readers used for fare collection and transfers.

001.1.4.205 Sounder commuter rail system (Sounder): A system characterized by diesel-electric locomotives transporting passengers within urbanized areas. Service routes use right-of-way owned by Sound Transit and by other freight railroad companies.

001.1.4.206 Special trackwork: Track elements where tracks converge, diverge, or cross one another. These elements include turnouts, crossings, and crossovers.

001.1.4.207 Soldier pile and lagging wall: A retaining structure used for the purpose of supporting excavation, especially where excavations run deep. Piles made of steel, and lagging made of timber is typically used. However, caissons, concrete, and circular pipes can also be used.

001.1.4.208 Spiral track: The spiral is a curve of varying radius from infinity to circular curve radius, which is used to gradually increase the curvature of a road or railroad.

001.1.4.209 Spur track: A stub track that diverges from main or other tracks, which provides access to industrial or commercial areas.

001.1.4.210 Standard drawings: Drawings established to ensure uniform design, fabrication, installation, and construction of the Sound Transit Systems. Standard drawings are final construction documents to be inserted into project contract documents.

001.1.4.211 Station: A place designated for the purpose of loading and unloading passengers, including passenger service areas, shelters, ticketing, and ancillary spaces.

001.1.4.212 Station platform: The area of a station immediately adjacent to the station track, used primarily for loading and unloading passengers onto a train.

001.1.4.213 Station track: A section of primary track adjacent to station platforms.

001.1.4.214 Subballast: Granular base material placed and compacted over the top of the entire embankment or roadbed to prevent penetration of the ballast into the subgrade. Common subballast materials include crushed stone, natural or crushed gravel and sands, or a mixture of these materials. The subballast layer must be of sufficient depth and shear strength to support and transfer the load from the ballast to the subgrade.

001.1.4.215 Subgrade: The finished surface of the roadbed below the subballast.

001.1.4.216 Summit: Vertical curve that is concave downwards.

001.1.4.217 Sump pump room: Room housing sump pump and pump control for collection of drainage for an underground facility. Room must typically house a sump pump or multiple sump pumps in sump below floor and the local controls and power infrastructure necessary for the operation of the system. Garages and grade-separated stations may have room housing sump pump and pump control for collection of drainage.

001.1.4.218 Superelevation, actual: The difference in inches the outer (higher) rail is rotated (raised) above the inner (low) rail while maintaining the inside rail at the profile grade. The rotated inner and outer rail base must be on the same plane and parallel to the top-of-rail plane.

001.1.4.219 Superelevation, equilibrium: The banking effect in which a rail vehicle can negotiate a curve in increased elevation of the outside rail of the track.

001.1.4.220 Superelevation, unbalanced: The superelevation that is the difference between the equilibrium superelevation and actual designed superelevation.

001.1.4.221 Surge zone: Spaces near entries and landings and at the base of stairs, escalators, and elevators that must be free of obstructions to accommodate large passenger surges.

001.1.4.222 Switch: A track feature that allows for trains to diverge from one track to another.

001.1.4.223 Switch, facing point: A switch, the points of which face approaching traffic. (diverging),

001.1.4.224 Switch, trailing point: A switch, the points of which face away from traffic. (converging),

001.1.4.225 Tacoma Urban Running Vehicle Transit System (Tacoma Link): A system operating with single-car trains powered by overhead catenaries located on mixed-traffic streets.

001.1.4.226 Tail track: A layover track that is an extension past the end of a terminal station platform that is capable of holding one full-length train.

001.1.4.227 Throughput, communications systems: The theoretical carrying capacity corrected for overhead and other factors.

001.1.4.228 Ticket vending machine: Automated machine device where passengers may purchase ORCA cards and purchase proof of payment tickets.

001.1.4.229 Tie, track: Can be wood or concrete used to support the rails in railroad track, transfer loads to the track ballast and subgrade, and keep the rail upright and maintain the rail gauge.

001.1.4.230 Top of rail plane: Plane connecting the tops of two running rails in a track.

001.1.4.231 Touch zone: Zone in public areas from floor level to 8 feet above floor level that is subject to abuse and willful damage. Elements in this zone must be especially resistant to damage and vandalism and must be easily repairable.

001.1.4.232 Track circuit: An electrical circuit that uses the rails in a track as part of the circuit utilized for train detection.

001.1.4.233 Track circuit, audio frequency: A track circuit that uses a coded, pulsed, audio frequency signal.

001.1.4.234 Track circuit, DC: A track circuit that uses DC voltage.

001.1.4.235 Track circuit, power frequency: A track circuit that uses an AC signal at a specific frequency utilizing phase shift detection.

001.1.4.236 Track gauge: The spacing of the rails on a railway track and is measured between the inner faces of the load bearing rails.

001.1.4.237 Track modulus: The supporting force per unit length of rail per unit vertical deflection of the rail. It is a measure of the vertical stiffness of the track foundation.

001.1.4.238 Track tolerance: Track tolerance is a permissible variation in measurement deriving from the base measurement during track design.

001.1.4.239 Train: One or more locomotives or LRVs, with or without cars.

001.1.4.240 Trainway: That portion of the system in which the rail vehicles operate (NFPA 130).

001.1.4.241 Turnback curve: A section of curved track connecting the end of turnout to the diverging track.

001.1.4.242 Turnout radius: Turnout radius is the curved closure rail section's radius, i.e., the radius of center line in AREMA definition.

001.1.4.243 Turnout, switch: An arrangement of switch points and a frog with closure rails, and appurtenances by means of which rolling stock may be diverted from one track to another.

001.1.4.244 Utilization, communication systems: Capacity utilization is a measure of congestion, workload, or usage of a network element.

001.1.4.245 Vehicle dynamic envelope: The vehicle dynamic envelope is a part of the clearance envelope and is the clearance required for the train and its vehicle's overhang due to combinations of loading, lateral motion, or suspension failure.

001.1.4.246 Vertical circulation: The provision of means within a facility, or the movement of persons within a facility, to increase or decrease in elevation. This may be in the form of active systems (such as escalator or elevator), or passive systems (such as ramp or stair).

001.1.4.247 Vertical transportation: An elevator and/or escalator.

001.1.4.248 Vital circuit: Any circuit the function of which affects the safety of train operation e.g., fail safe.

001.1.4.249 Vital relay: A relay, meeting certain stringent specifications, so designed that the probability of its failing to return to the prescribed state upon de-energization is so low as to be considered practically nonexistent.

001.1.4.250 Paved walkways: Paved areas for pedestrians to travel within a station area or inside of a tunnel

001.1.4.251 Wayside equipment: The signals, switches, and/or control devices for railroad or light rail transit operations housed within one or more enclosures located along the railroad or light rail transit right-of-way and/or on railroad or light rail transit property.

001.1.4.252 Wayside structures: Structural facilities located within an area of land immediately adjacent or close to a highway or railroad.

001.1.4.253 Wayside interface unit: A piece of equipment that connects existing wayside block signal equipment with the Positive Train Control System.

001.1.4.254 Wood Tie, track: Ballasted railroad track constructed with wood cross ties, cut spike, and tie plate or elastic fastening system.

001.1.4.255 Yard: A system of tracks that supports rail vehicle consists and the storage of rail vehicles and other rolling stock.

001.1.4.256 Yard track: Secondary track that is constructed for the purpose of switching, storing, or maintaining vehicles not in revenue service, and track sections not meeting the definitions of layover track and shop track.

001.1.5 References

001.1.5.1 The work governed by these requirements may be performed in municipal jurisdictions, state rights-of-way, tribal areas, or unincorporated county jurisdictions. There may be specific differences between codes and standards of these various jurisdictions. It is the express intent of Sound Transit for these requirements to be in substantial compliance with the codes and standards of the local jurisdictions.

001.1.5.2 Whenever the phrases “local jurisdiction,” “municipal jurisdiction,” “municipality,” or “authority having jurisdiction,” are noted, these terms must be understood to mean WSDOT, and all applicable counties, cities, and federal agencies, such as the AHJ. The codes and standards of these municipalities must govern design to the greatest extent possible, when not in violation of federal or state law.

001.1.5.3 In some cases, Sound Transit may believe that municipal or other jurisdictional codes and requirements are not in the best interest of the project or are excessive in either requirements or interpretation. Sound Transit reserves the right to petition or protest and seek code variances on certain issues whether or not these requirements or codes are referenced in these criteria.

001.1.5.4 The hierarchy of code enforcement must be federal (such as Environmental Protection Agency), state (such as WSDOT, SEPA), and then municipal. Where there is a difference between codes, the most restrictive must apply.

001.1.5.5 It is also Sound Transit’s express intent that design prepared under these requirements sets comply with all governing federal, state, and local safety codes and regulations. If there is an irreconcilable conflict between or among such codes and regulations, the designer is directed to inform Sound Transit of such conflict.

001.2 STAKEHOLDER NEEDS

001.2.1 Passenger Experience

001.2.1.1 Sound Transit's Station Experience Design Guidelines provides recommendations to the Agency's passenger experience expectations.

001.2.2 Operational Needs

001.2.2.1 Each rail route is part of the overall regional transportation system. Provide commuters and other travelers with the benefits of reliable and safe multimodal public transportation in a cost-effective, environmentally sensitive, and socially responsible manner.

001.2.3 Maintenance Needs

001.2.3.1 Design the Link and Sounder systems to use proven subsystems hardware and design concepts. All the major subsystems and their spare parts must be supplied by established manufacturers, with a documented operating history of previous and current usage.

001.2.3.2 All major subsystems must be able to integrate into the existing system.

001.2.3.3 The assets should be accessible and maintainable with minimal service disruption.

001.2.4 Safety Needs

001.2.4.1 SSMP provides the agency safety needs.

001.2.5 Security Needs

001.2.5.1 SSMP provides the agency safety needs.

001.2.6 Reliability, Availability, and Maintainability Needs

001.2.6.1 While reliability of all equipment is critical, it is intended that the reliability performance criteria established in this set must ensure procurement of reliable equipment capable of meeting Sound Transit's operational requirements.

001.2.6.2 Excessive maintenance costs and operating delays could be experienced by the Sound Transit system if adequate reliability controls are not imposed on system contractors and rigorously enforced.

001.2.7 Environmental and Sustainability Needs

001.2.7.1 Refer to Set 803 – Sustainability for detailed requirements.

001.2.7.2 Environmental Review Process

Commentary: The environmental review for a project under the NEPA and/or SEPA is typically completed during the preliminary engineering phase of the project and prior to commencement of final design. The environmental review is documented in a report or study, such as an EIS, environmental assessment, documented categorical exclusion, or environmental checklist.

For projects complying with NEPA, the environmental review process is completed with an environmental determination from the federal lead agency, normally a ROD or FONSI. These documents define the scope of the project, contain detailed information on the anticipated environmental consequences of the project, and identify potential mitigation measures and actions, which are intended to reduce the level of adverse effects resulting from implementation of the project.

001.2.7.2.1 Obtain copies of the relevant environmental documentation, including those referenced in the commentary above, for a particular project from the environmental lead for that project. If the configuration of the project changes after completion of the initial environmental review, notify the environmental lead. Additional environmental review may be necessary. Examples of these types of changes include:

001.2.7.2.1.1 Changes to the project scope (e.g., change in project “footprint”).

001.2.7.2.1.2 Changes in project impacts (including impacts to resources not identified in the previous environmental documentation) to one or more elements of the environment.

001.2.7.2.1.3 Added work outside the area evaluated in the original environmental documentation, including property acquisitions, and mitigation sites and construction staging sites that did not undergo environmental review.

001.2.7.2.1.4 Changes in environmental laws, regulations, or Endangered Species Act listings that have relevance to the project.

001.2.7.2.1.5 Changes that are required to be reviewed by an agency change control board.

001.2.7.2.1.6 Changes that are likely to be publicly controversial.

001.2.7.2.1.7 Changes that require new permits and/or approvals from another jurisdiction or agency.

001.2.7.2.1.8 Any other changes that could potentially raise environmental issues beyond the range of impacts and alternatives previously evaluated.

001.2.7.2.2 Environmental Mitigation Commitments

001.2.7.2.2.1 Designers must include mitigation measures and actions that are committed to as part of the project and are incorporated in the environmental determination or commitment list for the project.

Commentary: The environmental determination is normally a ROD or FONSI under NEPA or commitment list if only SEPA review is required.

001.2.7.2.2.2 The designers must follow the ROD or SEPA environmental commitment list that details all the agreed upon environmental mitigation measures and the means to monitor environmental compliance.

Commentary: On some projects, additional requirements may be required by third-party agreements, local, state, or federal permits, or special site conditions.

For light rail service between University of Washington station and University District station, Sound Transit and University of Washington executed an MOA that establishes the guidelines under which Sound Transit must have access to and use of university property. Appendix C of the MOA contains the agreed mitigation program. An MIA between Sound Transit and the University of Washington has also been executed to supplement the original MOA and provides additional environmental mitigation commitments and designers must include all aspects of the mitigation measures and actions into the design.

001.2.7.2.2.3 All design-related mitigation measures contained in the ROD, FONSI, SEPA commitment list, third-party agreements (UW MOA and MIA), and permits are incorporated into the design criteria by reference. Obtain copies of these additional documents from the environmental lead for the project. Mitigation commitments include actions that may affect the following Requirements Sets:

001.2.7.2.2.4 General (Set 001).

001.2.7.2.2.5 Noise and Vibration (Set 007).

001.2.7.2.2.6 At-Grade Crossings (Set 120).

001.2.7.2.2.7 Traction Electrification (Set Series 200).

001.2.7.2.2.8 Trackwork (Set Series 500).

001.2.7.2.2.9 Structures (Set Series 700).

001.2.7.2.2.10 Landscaping (Set 802).

001.2.7.2.2.11 Civil (Set Series 900).

001.2.7.3 Land Use Guidelines

001.2.7.3.1 The Link and Sounder Systems must be designed, where possible and desirable, to stimulate urban development and redevelopment while avoiding drastic changes that disrupt the public commerce or social interaction. Incorporate positive changes, such as street improvements, where there is opportunity to do so and where cost-sharing agreements can be made. Joint development of the transit right-of-way must be considered.

001.2.7.3.2 Minimize displacement of buildings and public activity areas. Protect retail establishments must from construction activities. Avoid creating physical barriers to land use functions and reducing traffic circulation capacity to the extent it is practicable to do so.

001.2.7.3.3 Maintain consistency with local and regional land use plans insofar as possible. Exceptions must be coordinated with the appropriate AHJ.

001.2.7.4 Urban Design Guidelines

001.2.7.4.1 The design of the Link and Sounder systems must consider the viewpoint of the user, the adjacent residential or business community, and the nearby pedestrian or motorist. In this regard, the items of concern include potential noise impacts and mitigation measures, historic preservation, visual intrusion, visual barriers, station access, continuity and transition of structures, separation of alignment, common system elements, and maintenance.

001.2.7.4.2 The Link and Sounder systems must be designed to minimize visual intrusion on public and private spaces. The system must neither obscure scenic views nor exert undue shade influence on adjacent land use. In addition, the design must comply with the requirements presented in the final EIS on environmental-related issues.

001.3 SYSTEM REQUIREMENTS

001.3.1 General Requirements

001.3.1.1 The basic goal of the Link light rail system and the Sounder commuter rail system is to connect more people to more places to make life better and create equitable opportunities for all. This will be achieved by providing commuters and other travelers passenger experience consistency, design efficiency and supportive station environments.

001.3.2 Design Life and Service Life

001.3.2.1 The Link and Sounder systems major guideway structures, including elevated guideways, tunnels, underground stations and shafts, retained cuts and fills, and under crossings, must be designed for a design life of 100 years. See Sets 701 Geotech Engineering, 721 Bridge and Elevated Structures, and 722 Tunnel and Underground Structures.

001.3.2.2 The Link and Sounder systems fixed facilities (station structures and buildings) must be designed for continued operation over a minimum period of 50 years before complete refurbishment or renovations are necessary from wear and tear and obsolescence. See Set 720 Building Structures.

001.3.2.3 Rail and trackwork must be designed for a design life of 20 years. See Set 522 Track Construction.

001.3.2.4 Major fixed mechanical and system equipment (such as substation hardware, shop machinery, light rail vehicles, and mechanical equipment) must be designed for a service life of a minimum of 30 years before major overhaul or complete replacement becomes necessary, assuming that approved maintenance policies are followed.

001.3.2.5 Components, products, materials, and parts must be designed for a design life that maximizes the long-term value of that element and a minimum service life of five years.

001.3.2.6 For additional information on design and service life requirements, refer to the corresponding requirements set.

001.3.3 Reliability, Availability, and Maintainability

001.3.3.1 While reliability of all equipment and systems is critical, the reliability performance criteria established in this set requires procurement of equipment and systems meeting the system operational requirements for the following systems:

001.3.3.1.1 Light Rail Vehicles. See also Set 421.

001.3.3.1.2 Train Control, including grade crossing equipment. See also Sets 120 and 123.

001.3.3.1.3 Communications, including Radio (Set 303), CCTV (Set 1202), Public Address (Set 304), Telephone Systems (Set 302), Passenger Information Management System (Set 1102), Access Control (Set 1203), and Network Systems (Set 301).

001.3.3.1.4 SCADA, including network devices connected thereto. See also Set 324.

001.3.3.1.5 Emergency Ventilation Equipment

001.3.3.1.5.1 In accordance with NFPA 130, Article 7.2.3, reliability must include, at a minimum, electrical, mechanical, and supervisory control elements of the emergency ventilation system.

001.3.3.1.5.2 This is understood to include fans, dampers, motors, motor control centers and starters, electrical feeders to motor control centers and starters, emergency management panels, and SCADA control systems thereto.

001.3.3.1.6 Traction electrification equipment, including traction power substations (Set 220) and overhead contact system (Set 221).

001.3.3.2 Reports, plans, and analyses required herein must be prepared by a certified reliability engineer.

001.3.3.3 Reliability Requirements Report

001.3.3.3.1 During final engineering, a study to determine the numerical values for the reliability of systems and components must be conducted and approved by Sound Transit. The requirements must be published in a report that includes, at a minimum:

001.3.3.3.1.1 Reliability allocations for all major system equipment and critical equipment components.

001.3.3.3.1.2 Model definitions and equations (if applicable).

001.3.3.3.1.3 Goals for reliability, including targets mandated by Sound Transit Requirements Sets and specific Project Contractual requirements.

001.3.3.3.1.4 Basis for the goals and numerical requirements

001.3.3.3.1.5 Goals must be defined in terms of MTBF

001.3.3.4 Reliability Plan

001.3.3.4.1 To ensure that the management and technical skills necessary to achieve Sound Transit System reliability objectives are applied in a coherent and organized manner, manufacturers of the system equipment listed in Section 001.3.3.1 must be required to establish and submit for approval by Sound Transit a Reliability Plan.

001.3.3.4.2 The Reliability Plan must include:

001.3.3.4.2.1 A detailed listing and description of each task.

001.3.3.4.2.2 The timing of each task and related milestones.

001.3.3.4.2.3 The organizational element responsible for each task.

001.3.3.4.2.4 Identification of reliability problems requiring resolution.

001.3.3.4.2.5 Procedures for recording reliability problem resolution.

001.3.3.5 Contractor/Supplier Reliability Analyses

001.3.3.5.1 Contractor/suppliers of the above-listed equipment must be required to prepare and submit for approval a reliability analysis that must include, as a minimum:

001.3.3.5.1.1 System definitions and related assumptions.

001.3.3.5.1.2 Functional block diagrams and reliability block diagrams.

001.3.3.5.1.3 Description of data base and any adjustment factors.

001.3.3.5.1.4 System and subsystem failure assumptions and predicted MTBF, MTBSF, MCBF, as appropriate.

001.3.3.5.1.5 Comparison of reliability predictions with allocations in the contract documents.

001.3.3.5.1.6 Impact of operating or design changes on predicted values.

001.3.3.5.1.7 Definitions of all interfaces, such that every part is identified as being part of a particular subsystem.

001.3.3.5.2 The designer of facilities and systems must verify that specific requirements for reliability analysis are included in the Issued for Bid/Issued for Construction documents.

001.3.3.6 Reliability Demonstration Testing

001.3.3.6.1 Contract documents must require the achievement and demonstration of reliability requirements both by analysis and demonstration testing.

001.3.3.6.2 The Reliability Demonstration Test Plan must include:

001.3.3.6.2.1 Criteria to be used for evaluating the equipment under test.

001.3.3.6.2.2 The failure reporting procedures to be used by the contractor.

001.3.3.6.2.3 The mathematical verification that the test must demonstrate the required mean time between failure and failure rates specified in contract documents.

001.3.3.7 Maintainability

001.3.3.7.1 To ensure that the management and technical skills necessary to achieve Sound Transit System maintainability objectives are applied in a coherent and organized manner, manufacturers of all project elements must be required to establish and submit for approval a Maintainability Plan.

001.3.3.7.2 Establish a maintainability program in support of the specified requirements. Features must be incorporated into the design of equipment to minimize the MTTR and preventive maintenance time. The subsystems and components must incorporate the following design features:

001.3.3.7.2.1 Accessibility: All routinely serviced subsystems and components must be readily accessible for service and inspection.

001.3.3.7.2.1.1 Accessibility of components must be proportional to frequency of maintenance and repair.

001.3.3.7.2.1.2 Active electrical or mechanical components that require maintenance must not be structurally embedded to hinder convenient access for repair or replacement.

001.3.3.7.2.1.3 Design equipment access with locations that minimize the need to implement fall protection and confined spaces.

001.3.3.7.2.1.4 If unavoidable, design must include fall protection.

001.3.3.7.2.2 Modular design: Modular design principles must be employed to the greatest extent practicable. Components must be packaged together in replaceable subassemblies according to the logical function that they perform. Components or subassemblies requiring occasional removal must preferably be plug-in units.

001.3.3.7.2.3 Adjustments: The need for adjustments must be avoided.

001.3.3.7.2.3.1 Where adjustment points cannot be avoided, they must be readily accessible, identified, and self-locking to prevent inadvertent adjustment or drift.

001.3.3.7.2.3.2 Adjustment points that disrupt service must be avoided unless approved by Sound Transit Operations.

001.3.3.7.2.4 Panels and openings: Panels and openings must be of quantity, size, and placement to permit ready access from normal work areas and positions and without needing to move other equipment. Adjustment controls, fittings, and such, must be directly accessible through panels and openings. Self-retaining fasteners must be used wherever possible. Special access opening tools must not be used unless considered necessary to prevent vandalism.

001.3.3.7.2.5 Lifting Assists: Handles, lifting lugs, or reviewed functional equivalents must be provided on components of 18 kilograms (40 pounds) or more.

001.3.3.7.2.6 Labeling: All test points, fault indicators, modules, wire junctions, pipes, tubes, wires must be identified by name plates, color coding, number coding, or other means to assist maintenance personnel. All ROMs, PROMs, and EPROMs must be labeled with the version and date of stored software.

001.3.3.7.3 Preventive Maintenance Plan

001.3.3.7.3.1 Develop a detailed preventive maintenance plan based upon the established maintainability requirements. The preventive maintenance plan must provide all preventive maintenance tasks needed to maintain each subsystem/equipment, supplied under this contract, as close as possible to new condition. The preventive maintenance task analysis must include all servicing, inspections, scheduled overhaul, or any task required on a scheduled basis. The elapsed time to perform specific tasks must be defined in the analysis, and in maintenance and servicing manuals. All tasks will be sorted and grouped by time interval (i.e., daily, weekly, monthly), as well as by subsystem.

001.3.3.7.3.2 Establish MTTR goals for each system. Comply with Sound Transit MTTR requirements, where established in these Requirements Sets.

001.3.4 Confined Spaces

001.3.4.1 Comply with WAC 296-809 – Confined Spaces.

001.3.4.2 Provide signage to identify the confined space that requires authorized access.

001.3.5 Sound Transit Art Program

Commentary: Sound Transit is committed to providing seamless integration of art, engineering, landscape architecture, signage, graphic design, and architecture in its facilities. The Sound Transit Board of Directors adopted Resolution 2010-21 that recommits the agency to the integration of public art in the implementation of the regional high-capacity transit system, and that supersedes the enabling public art Board Resolution 98-1.

001.3.5.1 Set 808 Sound Transit Art Program (STart) addresses the STart program in more detail.

001.3.5.2 Set 808 must be considered as a component of all other chapters in this manual.

001.3.5.3 Through a collaborative process with artists, engineers, and designers, art must be an important premise for this system in pursuit of its overall goals.

001.3.6 Non-Proprietary Materials and Buy America Requirements

001.3.6.1 Non-proprietary items must be used in the System to obtain competitive bids and comply with federal regulations. Proprietary items must be used only where established system wide products and materials have been identified by Sound Transit.

001.3.6.2 All materials must comply with Section 165 (49 U.S.C. § 5323) of the Surface Transportation Assistance Act of 1982 (commonly called the Buy America Act).

001.3.7 Characteristics of Systems and Facilities Testing and Commissioning

001.3.7.1 Design documentation must identify those tests and requirements used in each contract to verify that elements integrated in each contract perform as specified and as intended.

001.3.7.2 The designer of facilities and systems must verify that specific requirements for commissioning and testing are included in the Issued for Bid/Issued for Construction documents.

001.3.7.3 Designers must identify pre-requisite testing and commissioning activity (intra-contract and inter-contract).

001.3.7.4 All vertical transportation hold points must be adhered to. A Sound Transit Operations employee or Operations representative must inspect each hold point.

001.3.7.5 Comply with Sound Transit's General Testing and Commissioning Plan.

001.3.8 Characteristics of Systems Integration Testing

001.3.8.1 Design documentation must identify those start-up integration tests to be performed and the integration test requirements used in each contract to verify operation as an integrated system.

001.3.8.2 The design of facilities and Systems must verify that certain start-up tests are performed to verify operational readiness, the adequacy of personnel training, and the reliability, safety, and security of the system. The requirements of these start-up test must reside in the contract specifications.

001.3.8.3 Designers must describe the types of tests to be performed for verification of safety critical contractual tests, validation and demonstration of system performance, demonstration of safety and service characteristics for System Safety and Security Certification, and training of operations and maintenance personnel, and the integration of personnel, equipment, and procedures.

001.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

001.4.1 System Breakdown Structure

001.4.2 System Sites and Locations

001.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this Requirements Set and other requirement sets. These identified interface/coordination points are not meant to be an exhaustive list.

Table 1-1: Interface Between General Requirements and Other Disciplines

SET SERIES	SET NAME	SET 001 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	X
400	Vehicle	X
500	Track	X
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

001.5.1 Interface With Other Requirement Sets

001.5.1.1 This Set provides General Requirements that must be applied to all other Sets.

001.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

001.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

001.7.1 Interface and Integration Management

001.7.2 Design Management

001.7.3 Manufacturing and Construction Management

001.7.4 Installation Management

001.7.5 Inspection and Testing Management

001.7.6 Training, Pre-Revenue Operations

001.7.7 Certification Management

001.8 APPENDICES (NOT USED)

END SET - 001

007 NOISE AND VIBRATION

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TABLES

SET - 007 NOISE AND VIBRATION

007.1 INTRODUCTION

007.1.1 Document Scope

007.1.1.1 This set establishes the design criteria for noise and vibration. The introduction of light rail transit system (Link) may result in increased airborne noise and ground-borne noise and vibration to sensitive receivers adjacent to Link operations and facilities. This set defines limits of acceptable noise and vibration for the operation of the light rail system.

007.1.1.2 The limits are based on the noise and vibration criteria established in the FTA guidelines in Transit Noise and Vibration Impact Assessment, current edition, and from state and local noise regulations. Whenever projections of noise and vibration indicate that the goals established in this document must be exceeded, special noise and vibration control measures must be implemented to meet the project environmental commitments, FTA guidelines, local regulations, or local permitting conditions.

007.1.1.3 The Sound Transit Board adopted a Link Noise Mitigation Policy with Motion M2004-08. The Link Noise Mitigation Policy establishes Sound Transit policies that guide both the assessment and mitigation strategy, as appropriate, of noise impacts associated with Link light rail project components. These policies must be followed in the analysis of noise impacts and noise mitigation design for the light rail projects.

007.1.1.4 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 007 owner to determine the technical source for the design criteria.

007.1.2 Regulations, Codes, Standards, and Guidelines

007.1.2.1 International Regulations, Codes, Standards, and Guidelines

007.1.2.1.1 International Building Code (IBC).

007.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

007.1.2.2.1 Federal Highway Administration (FHWA) Standard 23 CFR 772 - Procedures for Abatement of Highway Traffic Noise and Construction Noise.

007.1.2.2.2 Federal Transit Administration (FTA) Regulations & Guidance in Transit Noise and Vibration Impact Assessment (VA-90-1003-06).

007.1.2.2.3 ASTM E413 - Classification for Rating Sound Insulation (Rating STC-60).

007.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

007.1.2.3.1 Washington State Department of Transportation (WSDOT) Policies.

007.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

007.1.2.4.1 Transit Cooperative Research Program's Track Design Handbook for Light Rail Transit Second Edition (TCRP Report 155).

007.1.2.5 Other Jurisdictions

007.1.2.5.1 Sound Transit Regulations, Codes, Standards, and Guidelines.

007.1.2.5.2 Sound Transit Link Noise Mitigation Policy with Motion M2004-08.

007.1.2.5.3 Sound Transit Master Implementation Agreement for Sound Transit Entry to the University of Washington Campus.

007.1.3 Abbreviations and Acronyms

007.1.3.1 dBA–A-weighted decibel

007.1.3.2 FTA–Federal Transit Administration

007.1.3.3 HVAC–heating, ventilation and air conditioning

007.1.3.4 Hz–Hertz

007.1.3.5 Leq–existing noise level

007.1.3.6 Ldn–average noise level

007.1.3.7 LRV–light rail vehicle

007.1.3.8 NRC–noise reduction coefficient

007.1.3.9 OMF–operations and maintenance facility

007.1.3.10 TPSS–traction power substation

007.1.4 Definitions and Classifications (Not Used)

007.1.5 References

007.1.5.1 U.S. Environmental Protection Agency (EPA) 1974. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," EPA/ONAC 550/9-74-004, March, 1974.

007.2 STAKEHOLDER NEEDS

007.2.1 Passenger Experience

007.2.1.1 The “as-finished” train operating under anticipated revenue service conditions on “as-built” trackwork must provide riding comfort.

007.2.2 Operational Needs

007.2.2.1 The operation and maintenance personnel and the community must be protected from noise and vibration impacts as required by environmental mitigation commitments.

007.2.3 Maintenance Needs

007.2.3.1 The design and construction of noise and vibration mitigation or permanent monitoring systems must enable servicing and maintenance either clear of the tracks during revenue hours or such that maintenance can be accommodated during regular track maintenance periods. Neither the design and construction of noise and vibration mitigation nor the permanent monitoring systems may impede servicing and maintenance of the tracks during regular track maintenance periods.

007.2.3.2 Provide maintenance manuals, maintenance training, and recommended spare parts lists.

007.2.3.3 If permanent noise and vibration monitoring systems are included as part of the project, provide instructions for the interrogation, downloading, and interpretation of noise and vibration data.

007.2.4 Safety Needs (Not Used)

007.2.5 Security Needs (Not Used)

007.2.6 Reliability, Availability, and Maintainability Needs (Not Used)

007.2.7 Environmental and Sustainability Needs

007.2.7.1 Comply with the recommendation of the project’s environmental impact statement and any related agreements.

007.2.7.2 The environmental mitigation commitments identify areas where noise and vibration mitigation must be implemented based on evaluation of the existing environment and the projected future environment.

007.2.7.3 During final design, the analysis of noise, ground-borne noise, and vibration in the environmental documentation must be updated to provide specific definition of the mitigation measures to be included in the final design. This includes updating as necessary the ambient noise levels, affected receivers, the Link trackway horizontal alignment and vertical profile, and locations of special trackwork, such as crossovers, during final design.

007.3 SYSTEM REQUIREMENTS

007.3.1 Criteria for Wayside Airborne Noise

007.3.1.1 The FTA criteria for wayside airborne noise from train operations are applicable to all Sound Transit light rail operations.

007.3.2 Noise Mitigation

007.3.2.1 Forecast year project noise levels that exceed the FTA criteria must require noise mitigation.

007.3.2.2 Sound Transit requires that mitigation measures be compliant with the Link Noise Mitigation Policy, adopted by Sound Transit Board Motion No. M2004-08, and compliant with applicable state and FTA guidelines.

007.3.2.3 The application of mitigation to the project for moderate and severe impacts under FTA criteria are summarized below:

007.3.2.3.1 Moderate impact: All FTA moderate noise impacts to noise sensitive receivers must be mitigated, compliant with FTA criteria.

007.3.2.3.2 Severe impact: All FTA severe noise impacts to noise sensitive receivers must be mitigated. If mitigation is not implemented, a deviation must be required with clear documentation of the reasons.

007.3.2.4 Mitigation of wayside noise from train operations must be compliant with the Link Noise Mitigation Policy, FTA guidelines, and any other authority having jurisdiction requirements.

007.3.2.5 The preferred order of mitigation should be source treatments followed by path treatments followed by receiver treatments.

Commentary: Examples of source treatment include rail grinding, wheel truing, and installation of rail dampers. Examples of path treatment include noise barriers, alignment modification, right-of-way acquisitions, or buffer zones. Sound insulation of buildings is an example of receiver treatment and should be considered only if all other options are deemed infeasible or impractical.

007.3.3 Ground-Borne Noise and Vibration Criteria

007.3.3.1 Ground-borne noise and vibration from train operations must meet the FTA criteria.

007.3.3.2 Ground-Borne Noise and Vibration from Train Operations

007.3.3.2.1 The FTA criteria for ground-borne noise and vibration from train operations are applicable to all Sound Transit Link operations.

007.3.3.2.2 Perform the ground-borne noise and vibration impact analysis per FTA criteria whether the source is subway or surface running trains.

007.3.3.2.3 For surface running trains, the ground-borne noise mitigation analysis must take into consideration the indoor ambient airborne noise levels at the sensitive receivers.

007.3.3.3 Ground-Borne Vibration

007.3.3.3.1 At vibration-sensitive research and laboratory facilities at the University of Washington, ground-borne vibration levels generated by train operations must not exceed the criteria established in the latest version of the Master Implementation Agreement for Sound Transit Entry to the University of Washington Campus.

007.3.3.3.2 Other vibration-sensitive receptors must be identified in the project's EIS and must be mitigated accordingly.

007.3.4 Reference Train Noise and Vibration Levels

007.3.4.1 The reference train noise and vibration levels used for modeling and impact predictions during final design must not be more than three years old.

007.3.4.2 The reference noise and vibration levels from Sound Transit fleet must be based on tests performed using FTA procedures under known conditions of rail and wheel surface.

007.3.4.3 Reference noise and vibration data that are older than three years, or from non-Sound Transit systems, may be allowed under special circumstances if there is verifiable evidence that the data is still valid and is approved by Sound Transit as a deviation request per the Engineering Procedures.

007.3.5 Wheel Squeal

Commentary: Sections of track with tight curves may create a nuisance noise condition referred to as wheel squeal. Wheel squeal typically occurs along tight curves in the track with radii of less than 600 feet but may occur on larger curves depending on other factors. Other factors that may affect the potential for wheel squeal include speed of the LRV, rail vehicle truck geometry and rigidity, the conditions of the wheels and tracks, wheel or rail damping technology, and contact-surface frictional characteristics. For more details on wheel squeal mechanisms and controlling factors, refer to the Transit Cooperative Research Program's Track Design Handbook for Light Rail Transit Second Edition (TCRP Report 155).

007.3.5.1 The potential for wheel squeal must be identified at locations where tight-radius curve trackwork is near residential or commercial buildings, or other noise-sensitive receivers.

007.3.5.2 Tight-radius curves of 600 feet or less must include wheel squeal mitigation measures in the project design as specified in Set 522 Track Construction.

007.3.5.3 Provisions for wayside lubrication must be incorporated in the project design at all curves up to a 1,250-foot radius near commercial or residential areas.

007.3.5.4 If audible wheel squeal or flanging noise are present on curve radii of 601 feet to 1,250 feet during pre-revenue service, then mitigation, such as wayside lubrication, must be applied to the rail gauge face and wheel flange as specified in Set 522 Track Construction.

007.3.5.5 If the wheel squeal remains after these measures have been implemented and results in residual noise impacts, then sound barriers, sound insulation of residential buildings, or other noise reduction measures must be implemented.

007.3.6 Trackwork Vibration Control

007.3.6.1 Trackwork vibration control must be applied to comply with environmental requirements, such as floating slab, high resilient fasteners, ultra-straight rail, and/or ballast mats as specified in Set 522 Track Construction.

007.3.7 Special Trackwork

007.3.7.1 Incorporate noise and/or vibration mitigation measures in the design to comply with environmental requirements, including moveable point frogs or other measures as appropriate (see Set 522 Track Construction).

007.3.7.2 Additional measures, such as sound barriers, sound insulation of residential buildings, or other measures, must be applied if more mitigation is needed to meet the applicable impact criterion.

007.3.8 At-Grade Crossings

007.3.8.1 All at-grade crossings, including pedestrian crossings, must have at least one AREMA-compliant crossing bell as specified in Set 120 At-Grade Crossings.

007.3.8.2 Noise impact analysis must be based upon the Forecast Year of operation, including the planned span and frequency of service.

007.3.9 Roadway Traffic Noise

Commentary: Traffic noise is a potential source of impact when a project realigns or widens a roadway, potentially moving it closer to sensitive receptors, such as residences, schools, churches, and libraries.

007.3.9.1 All link projects that have the potential to alter the traffic noise must perform a noise analysis, as appropriate, based on WSDOT or local jurisdictional policies and the FHWA Noise Standard 23 CFR 772.

007.3.9.2 A deviation to performing this analysis may be considered if the traffic noise models (TNM software or spreadsheet models) developed during earlier phases of the project are still relevant and the older models must be acceptable to WSDOT or local jurisdiction.

007.3.10 Ancillary Equipment Noise and Vibration

Commentary: Power substations, ventilation fans, vent shafts, and other mechanical equipment required for a light rail system can be sources of intrusive tonal and/or broadband noise. Intermittent noise is defined as a noise that lasts for a cumulative period of less than 10 minutes every hour.

007.3.10.1 Ancillary equipment noise must comply with the FTA noise thresholds and any applicable local noise codes unless the equipment is identified as an emergency equipment.

007.3.10.2 Refer to Table 7-1.

007.3.10.3 Refer to Sets 220 and 1005 for substation noise requirements.

007.3.10.4 Do not place ancillary equipment within 10 feet of any customer emergency station, passenger emergency telephone, or paratransit drop-off.

007.3.10.5 Where local codes do not exist, Table 7-1 presents the design criteria for community noise attributable to all ancillary equipment.

007.3.10.6 The noise limits in Table 7-1 must be reduced by 5 dBA if the noise has pure tones or contains an audible screech, whine, or hum, or contains information content such as music or public address system announcements.

007.3.10.7 In areas where the Leq is greater than the limits in Table 7-1 for continuous noise, higher noise limits based on ambient noise levels must be applied.

007.3.10.8 In no case must the noise from the ancillary equipment result in an increase in the existing day night Ldn of more than three dBA nor cause an FTA noise impact.

007.3.10.9 For fans and mechanical equipment, perform an FTA ground-borne noise and vibration impact assessment.

007.3.10.10 If there are sensitive receivers that are structurally coupled to the equipment rooms, the FTA ground-borne noise and vibration impact criteria must be applicable for structure-borne noise and vibration.

007.3.10.11 These requirements do not apply to noise from emergency equipment, operations, or daytime testing of that equipment.

Table 7-1: Noise from Transit System Ancillary Facilities – 1-hour Leq (dBA)

District of Sound Source	District of Receiving Property (daytime/nighttime)[1]		
	Residential (dBA)	Commercial (dBA)	Industrial (dBA)
Residential	55/45	57	60
Commercial	57/47	60	65
Industrial	60/50	65	70

Notes:

[1] The Residential noise level limits are presented for (daytime)/(nighttime). Nighttime is between 10 p.m. to 7 a.m. weekdays, and 10 p.m. to 9 a.m. weekends and holidays.

This table must be used where local codes do not exist.

For intermittent noise sources, allowable noise is increased by 10 dB.

007.3.11 Yard and Shop Noise and Vibration

007.3.11.1 The storage and inspection yards and maintenance shops must be designed such that the noise level at the property boundary does not exceed the limits required in the local noise standards.

007.3.11.2 If there are no local noise standards for yard and shop noise, use the levels shown in Table 7-1 and in Section 007.3.9.2.

Commentary: The applicable limit is based on the zoning of the receiving property.

007.3.11.3 In areas where the existing Ldn is greater than 60 to 65 dBA, the Ldn due to the Yards and Shops noise must be less than or equal to the existing Ldn.

007.3.11.4 This is equivalent to specifying that the introduction of this additional noise source must not increase the existing Ldn by more than 3 dBA.

007.3.11.5 Where appropriate, an FTA noise and vibration impact assessment must be performed.

007.3.11.6 Much of the equipment used in maintenance facilities has the potential of creating loud noise. To avoid excessive noise exposure of the employees, and to comply with existing and proposed standards of the Occupational Safety and Health Administration, shop equipment must not exceed 85 dBA at operator stations and 90 dBA at any point 3 feet from the equipment.

007.3.11.7 In areas where these limits cannot be met, hearing protection for the employees must be required.

007.3.12 Park-and-Ride Noise Levels

Commentary: Potential noise impacts that are associated with park-and-ride facilities are generally associated with noise from bus traffic on the park-and-ride site.

007.3.12.1 The park-and-ride must be designed in accordance with the guidance provided by the FTA Transit Noise and Vibration Impact Assessment report such that the noise level does not exceed the FTA noise limits and meets any local noise standards.

007.3.12.2 The principal noise control measure is the use of barriers when noise generated by bus traffic exceeds the applicable limit.

007.3.13 Station Noise Control

Commentary: The criteria for station acoustics include maximum noise level limits for public areas and reverberation time goals for enclosed areas. In addition to presenting the noise and reverberation criteria, this set provides general guidelines on the use of acoustically absorptive treatments in enclosed spaces.

007.3.13.1 Refer to Set 822-Station Layout-Light Rail for Station requirements.

007.3.13.2 Refer to Set 304-Audio Systems for Public Address systems at stations.

007.3.13.3 Design Requirements

Commentary: Table 7-2 summarizes the noise limits for various station noises. The limits on train noise are largely dependent on the noise emission characteristics of the LRV.

007.3.13.3.1 The design goals for station noise have been set at levels that must provide a comfortable acoustical environment for the patrons.

007.3.13.3.2 If the delivered vehicle complies with noise specifications, and the station design has acoustical absorption treatment compliant with the guidelines of Section 007.3.12, the limits on train noise in Table 7-2 must be achieved.

007.3.13.3.3 These limits do not apply to equipment rooms that must not contain noisy equipment, or not near public spaces, or do not require extensive maintenance.

007.3.13.3.4 External noise limits for LRVs, stationary and moving, are specified in Set 421 Light Rail Vehicle.

Commentary: The public spaces of unenclosed stations are sometimes exposed to noise from external sources, such as freeway traffic and railroad trains. The principal noise control measure is the use of barriers or partial enclosures to block the line-of-sight path of the sound. In some cases, careful placement of acoustical absorption treatment reduces noise exposure.

007.3.13.3.5 The traffic noise limit of a maximum hourly Leq1 of 72 dBA is compliant with the FHWA guidelines for maximum acceptable traffic noise in commercial areas and should be used as a goal.

Commentary: The EPA states that communication at close proximity (2 to 4 feet) can be understood even with ambient noise levels of 72 to 78 dBA (EPA 1974). Because it is unlikely a light rail patron would spend more than 15 minutes at a station platform, a 78 dBA 15-minute Leq platform noise level is the goal for stations that cannot meet the 72 dBA hourly Leq due to higher ambient noise levels per "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety" (EPA 1974).

Table 7-2: Design Criteria for Patron and Staff Noise Exposure in Stations and Facilities

Condition	Lmax (dBA)
On Platform, Trains Entering and Leaving	
Subway	80
At-grade/above ground, tie and ballast track	80
At-grade/above ground, concrete trackbed	83
On Platform, Trains Stationary	
Subway	68
At-grade/above ground	68
On Platform or in Enclosed Public Areas	
Ancillary Systems Operating	55[1]
Emergency Ventilation Systems operating	75[1]
Escalators	
5 feet above tread, at entrance combs	70
Elevators	
In cab, 5 feet above floor, 1 foot or more from wall, continuous noise	55
In cab, 5 feet above floor, 1 foot or more from wall, intermittent noise, peak	62
3 feet or more from elevator equipment, continuous noise	55
3 feet or more from elevator equipment, intermittent noise	62
Door operation, 3 feet or more from door	62
Noise from Other External Sources (without Train Pass by)	
Traffic noise	Hourly Leq = 72[3] 15-min Leq = 78
Other intermittent sources	Leq = 78
Station and Facilities Ancillary Rooms including Communication, Signaling, Fire Command Center, Fire Sprinkler Valve/Riser, Traction Power Substations, Mechanical and Electrical rooms	Hourly Leq = 72[3] 15-min Leq = 78
Noise in Mechanical Equipment Rooms	Lmax = 85[2]

Notes:

[1] Community noise from station ancillary systems is covered in Section 007.3.3.

[2] Maximum levels using the Slow Meter setting on a standard sound level meter.

[3] Highest traffic noise hourly Leq.

Leq is the energy average of a fluctuating sound averaged over a given time period.

007.3.13.4 Reverberation Time Limits

Commentary: Reverberation refers to the persistence of a sound in an enclosed space, as a result of multiple reflections, after the sound source has stopped. Controlling reverberation in the subway station and any other enclosed or partially enclosed public area is necessary in order to control crowd, train, and mechanical equipment noise. It is required for audibility of public address systems.

Commentary: "Reverberation time" is defined as the time that it takes a sound to decay 60 dB once the sound is suddenly interrupted. It is a measure of the persistence of an impulsive sound and the amount of acoustical absorption in the room. Table 7-3 presents the reverberation time criteria and goals for the Link stations.

007.3.13.4.1 The reverberation time criterion is a minimum requirement for the project that must be met without exception.

007.3.13.4.2 The reverberation time "goal" is a target that should be aimed by station designers unless meeting the "goal" is more expensive than just meeting the "criteria" or if there are practical challenges to achieving the "goals."

007.3.13.4.3 All enclosed public spaces must be designed to meet these limits on reverberation time.

Commentary: The reverberation time of a space is dependent on the amount of acoustical absorption in the space. As the room size increases, the design goal reverberation time increases. The increase is approximately 0.1 seconds for each doubling of the room volume. As indicated in Table 7-3, the design goal reverberation time for a large space, such as a subway station platform is 1.2 seconds. For a smaller enclosed space, such as a mezzanine or passageway, the design reverberation time is reduced to 1.0 seconds.

007.3.13.4.4 Table 7-3 gives the design reverberation times at 500 Hz. Reverberation at other frequencies is equally important; however, with the acoustical materials meeting the criteria of Section 007.3.13.6, the reverberation at other frequencies must be satisfactory.

Table 7-3: Reverberation Time Criteria (500 Hz)

Area	Maximum	Goal
Station platform areas, subway, at-grade, and above ground	1.5 seconds	1.2 seconds
Enclosed public spaces	1.2 seconds	1.0 second

007.3.13.5 Acoustical Absorption Treatments

007.3.13.5.1 Areas that must require acoustical absorption treatment are enclosed platform areas, enclosed passageways, enclosed mezzanines, mechanical and electrical equipment rooms, TPSS, HVAC, and ventilation shafts and plenums.

007.3.13.5.2 At-grade and above-ground stations that are only partially enclosed do not require acoustical treatment.

007.3.13.6 Acoustical Absorption Materials

007.3.13.6.1 Acoustical materials must be noncombustible, non-fibrous, non-asbestos, non-wicking, able to withstand heavy pressure water washing, suitable for exterior weather exposure, and must be selected in accordance with IBC.

007.3.13.6.2 If located in public areas, they must be out of reach of the public.

007.3.13.6.3 If mechanical protection must be provided with perforated panels, a minimum open area of 30 percent must be maintained.

007.3.13.7 Required Amounts of Treatment

Commentary: The required amount of treatment is dependent on the characteristics of the material used. It is recommended that a material with an NRC of at least 0.6 be used. In the station area and mechanical ventilation shafts, an additional requirement is that the treatment must have minimum sound absorption coefficients of 0.26 at 125 Hz, 0.6 at 250 Hz, and 0.8 at 500 Hz.

007.3.13.7.1 The following is a summary of recommended acoustical treatments for enclosed station spaces, but the designer must ensure that the acoustical treatments meet the reverberation time limits.

007.3.13.7.1.1 Enclosed platforms: Treatments covering a minimum of 35 percent of the total wall and ceiling area. This must include at least 50 percent of the ceiling area.

007.3.13.7.1.2 Other Enclosed Spaces: Treatment must cover a minimum of 35 percent of the wall and ceiling area. This must include at least 50 percent of the ceiling area.

007.3.14 Noise in Subway Tunnels

007.3.14.1 The noise levels inside the LRV while it is in subway tunnel must be a function of the sound transmission loss characteristics of the transit vehicle, the acoustical absorption characteristics of the tunnel walls, and the noise emission characteristics of the vehicle.

007.3.14.2 The goal for the noise level inside the car while operating at 40 miles per hour in tunnel must be 80 dBA.

007.3.14.3 Meeting the 80 dBA limit must require the Link vehicle to have effective sound isolating characteristics or the use of a sound absorption system on the tunnel walls and ceiling.

Commentary: Tunnel sound absorption treatment can reduce the car interior noise by as much as 5 dBA.

007.3.14.4 Vibration Isolation of Subway Structures

007.3.14.4.1 The subway structure must never be in direct contact with a building structure or foundation.

007.3.14.4.2 No less than 2 feet of intervening soil must be provided between the subway structure and any existing building structure or foundation.

007.3.14.4.3 Whenever there is less than 2 feet of intervening soil between a building and the subway structure, an elastomer element must be placed between the building and the subway structure.

007.3.14.4.4 The installed elastomer element must prevent direct transmission of noise and vibration to the building.

007.3.14.4.5 The elastomer element must consist of a closed-cell neoprene pad selected to give support of hydraulic and structural loads.

007.3.14.4.6 The deflection of the elastomer pad must not exceed 20 percent of the pad thickness.

007.3.14.4.7 The pad must be at least 1 inch thick.

007.3.15 Noise and Vibration Characteristics of the Light Rail Vehicle

007.3.15.1 The noise and vibration design criteria for the LRVs are provided in Set 421 Light Rail Vehicle.

007.3.16 OMF

007.3.16.1 In planning any new OMF, noise and vibration generated by equipment, such as air compressors and pumps, must be located away from office areas.

007.3.16.2 Shops and other mechanical rooms must be treated with acoustical absorption materials with an NRC of at least 0.6.

007.3.16.3 The design goal should be to limit the reverberation time to 1.0 in small mechanical rooms and 1.2 in large shop areas.

007.3.16.4 HVAC mechanical units must be located and specified such that noise and vibration transmission is minimized.

007.3.16.5 Offices and other spaces within the building where quiet is essential must be isolated from shop and other mechanical equipment areas through the use of single or composite walls, floor-ceiling, and roof-ceiling assemblies that meet a Sound Transmission Class rating of STC-60.

007.3.16.6 Refer also to Set 836-Operations and Maintenance Building-Light Rail for OMF requirements.

007.3.17 Criteria for Noise Barrier Use

Commentary: Noise barriers may be considered as a form of noise mitigation for Link projects when justified by the scope of an identified noise impact that cannot be reduced or eliminated through operational or other *source reduction measures.*

007.3.17.1 Noise barriers must be used only along elevated and at-grade trackway and only where the use of such barriers is reasonable and feasible.

007.3.17.2 Whether the use and location of such barriers is reasonable and feasible will be determined in consideration of the following: noise reduction; limits to effectiveness (e.g., the existence of a multi-story building); whether the use of a noise barrier would result in potential safety, visual, or other impacts; cost-effectiveness; or other factors as appropriate.

007.3.18 Coordination with affected property owners

007.3.18.1 Sound Transit decisions to use noise barriers, as well as barrier locations and designs, will be made in consultation with affected property owners, as appropriate.

007.3.19 Residential Sound Insultation

007.3.19.1 Criteria for Residential Sound Insulation Use:

007.3.19.1.1 Sound Transit shall implement residential sound insulation as a noise mitigation measure when justified by the scope of an identified impact that cannot be reduced or eliminated through source control or other operational measures.

007.3.19.1.2 Residential sound insulation shall be used only when the use of source or path treatments, such as noise barriers is ineffective, unreasonable, and/or infeasible.

007.3.20 Noise Reduction Levels

007.3.20.1 Unless otherwise required, sound insulation must use the Housing and Urban Development interior 45 dBA Ldn as the reference value for interior noise level reduction of light rail impacts and WSDOT’s 51 dBA peak hour Leq criteria as the reference value for traffic noise impacts.

007.3.20.2 For those locations where both light rail and traffic noise impacts are identified, the interior noise levels must meet whichever criterion achieves the greatest level of noise reduction.

007.3.21 Scope of Required Improvement

007.3.21.1 The scope of required residential sound insulation improvements shall be determined on a case-by-case basis by Sound Transit.

007.3.21.2 Improvements will be based on the need to meet the noise reduction levels in policy IV.B.

007.3.21.3 Improvements will be limited to those necessary to install the required sound insulation measures and that are consistent with the Scope Control Policy (Board Motion M2002-121).

007.3.21.4 Potential measures may include, as appropriate: the installation of replacement windows and doors and, if required, added insulation.

007.3.21.5 Required improvements shall not include major structural improvements/ modifications, property upgrades or any other improvements not required to meet applicable noise reduction levels.

007.3.22 Noise and Vibration during Construction

007.3.22.1 For noise and vibration generated during construction, authority having jurisdiction codes must be followed where applicable. The FTA 2006 Manual (VA-90-1003-06) Chapter 12 provides guidance for assessment, criteria and mitigation development where local codes do not exist or apply.

007.3.22.2 Ground-borne vibration from tunneling and excavation activities must meet the FTA damage criteria.

007.3.22.3 Ground-borne noise and vibration from tunnel muck and support trains must meet the FTA criteria for annoyance from train operations.

Commentary: Because of the short duration of construction vibration activities, annoyance from ground-borne noise and vibration is usually not an issue.

007.3.22.4 If tunneling and other underground construction activities, with the exception of tunnel muck and support trains, are anticipated to last for more than several months in close proximity to any specific sensitive receiver, a reasonable threshold for annoyance from ground-borne noise and vibration should be developed on a project-specific basis.

007.3.22.4.1 This threshold must consider the type of land use, the nature of the construction activities, and the time of day.

007.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

007.4.1 System Breakdown Structure

007.4.1.1 Noise Emitters

007.4.1.2 Vibration Emitters

007.4.1.3 Noise Control Measures

007.4.1.4 Vibration Control Measures

007.4.2 System Sites and Locations

007.4.2.1 Alignment (Track)

007.4.2.2 Stations

007.4.2.3 Operation & Maintenance Facilities

007.4.2.4 Light Rail Vehicles

007.4.2.5 Wayside Facilities

007.4.2.6 At-Grade Crossings

007.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this Requirements Set and other requirement sets. These identified interface/coordination points are not meant to be an exhaustive list.

Table 7-4: Interface between Noise and Vibration and Other Disciplines

SET SERIES	SET NAME	SET 007 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	X
400	Vehicle	X
500	Track	X
600	Fire/Life Safety	
700	Structures	X
800	Architecture	X
900	Civil	
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	
1200	Security	

007.5.1 Train Control and Signals

007.5.1.1 Coordinate with Train Control and Signals for operation and sound levels for grade crossing warning systems, where sensitive noise receptors are nearby.

007.5.2 Traction Electrification

007.5.2.1 Coordinate with Traction Electrification for placement (orientation) and sound levels for substation HVAC, where sensitive noise receptors are nearby.

007.5.3 Operational Communications

007.5.3.1 Coordinate with Operational Communications for operation, placement, and sound levels for station public address systems, where sensitive noise receptors are nearby.

007.5.3.2 Coordinate with Operational Communications for monitoring/alarm and remote data download for permanent vibration monitoring systems.

007.5.4 Vehicle

007.5.4.1 Coordinate with Vehicle for horn sound levels and wheel squeal mitigation (lubrication).

007.5.5 Track

007.5.5.1 Coordinate with Track for wheel squeal mitigation (lubrication).

007.5.5.2 Coordinate with Track for provision of vibration mitigation measures, where sensitive receptors are nearby.

007.5.6 Structures

007.5.6.1 Coordinate with Structures for provision of vibration mitigation measures and sound walls, where sensitive receptors are nearby.

007.5.7 Architecture

007.5.7.1 Coordinate with Architecture for operation, placement, and sound levels for station public address systems, where sensitive noise receptors are nearby.

007.5.7.2 Coordinate with Architecture for placement (orientation) and sound levels for station HVAC, where sensitive noise receptors are nearby.

007.5.8 Mechanical-Electrical and Building Systems

007.5.8.1 Coordinate with Mechanical-Electrical and Building Systems for placement and sound levels for HVAC and ventilation systems, where sensitive noise receptors are nearby.

007.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

007.7 ENGINEERING MANAGEMENT REQUIREMENTS

007.7.1 Interface and Integration Management (Not Used)

007.7.2 Design Management (Not Used)

007.7.3 Manufacturing and Construction Management (Not Used)

007.7.4 Installation Management

007.7.4.1 RSIP Contracting

007.7.4.1.1 Sound Transit shall provide for the installation of required residential sound insulation and related work in affected buildings using qualified contractors and subcontractors.

007.7.4.1.2 In addition to providing for the completion of the residential sound installation in accordance with stated requirements, the contractual documents shall provide for the following:

007.7.4.1.2.1 Appropriate coordination of installation of required improvements with affected property owner/tenants, in consultation and coordination with Sound Transit.

007.7.4.1.2.2 The implementation of practicable measures to minimize inconvenience to affected property owners and tenants during the installation process, such as the use of dust-proofing measures and limiting work to daytime hours only.

007.7.4.1.2.3 Reference of inquiries regarding the scope of required residential insulation measures to the RSIP manager.

007.7.4.2 Homeowner Elections to Forego Improvements

Commentary: The decision to permit Sound Transit's installation of residential insulation measures designed to mitigate noise impacts is within the discretion of affected property owners. Property owners may, accordingly, elect to forego recommended improvements. However, Sound Transit shall not provide monetary or other forms of compensation to property owners as an alternative to providing recommended noise mitigation measures.

007.7.5 Inspection and Testing Management (Not Used)

007.7.6 Training, Pre-Revenue Operations (Not Used)

007.7.7 Certification Management (Not Used)

007.8 APPENDICES (NOT USED)

END SET - 007

010 OPERATIONS

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FIGURES

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SET - 010 OPERATIONS

010.1 INTRODUCTION

010.1.1 Document Scope

010.1.1.1 This set establishes the requirements for Link light rail transit and Sounder commuter rail operations.

010.1.1.2 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Sound Transit Design Requirements Set 010 owner to determine the technical source for the design criteria.

010.1.2 Regulations, Codes, Standards, and Guidelines

010.1.2.1 International Regulations, Codes, Standards, and Guidelines (Not Used)

010.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

010.1.2.2.1 Federal Transit Administration (FTA) Regulations.

010.1.2.2.2 Code of Federal Regulations (49 CFR Part 625).

010.1.2.2.3 National Fire Protection Agency (NFPA) 704 - Standard System for the Identification of the Hazards of Materials for Emergency Response.

010.1.2.2.4 Occupational Safety and Health Association (OSHA) 1910.145 - Warning Signs and Tags.

010.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines (Not Used)

010.1.2.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

010.1.2.5 Other Jurisdictions (Not Used)

010.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

010.1.2.6.1 Link Light Rail Maintenance Management Plan

010.1.2.6.2 Revenue Service Timetable

010.1.2.6.3 Link Light Rail Rules Book

010.1.3 Abbreviations and Acronyms

010.1.3.1 AHJ–authority having jurisdiction

010.1.3.2 ATP–automatic train protection

010.1.3.3 BRT–Bus Rapid Transit

010.1.3.4 ConOps–Concept of Operations

010.1.3.5 LCC–Link control center

010.1.3.6 LRT–light rail transit

010.1.3.7 LRV–light rail vehicle

010.1.3.8 OCS–overhead contact system

010.1.3.9 O&M–operations and maintenance

010.1.3.10 OMF–operations and maintenance facility

010.1.3.11 RFMP–rail fleet management plan

010.1.3.12 ROW–right-of-way

010.1.3.13 SOC–security operations center

010.1.3.14 SOP–standard operating procedure

010.1.3.15 TOR–top of rail

010.1.4 Definitions and Classifications

010.1.4.1 Berth: The designated stopping point for a revenue service train at a station, which for Link is at the furthest end of the station for all consists and all stations, including terminal stations.

010.1.4.2 Cab signal: A device located in the control compartment (cab) of an LRV that indicates to the train operator the permissible speed of the track.

010.1.4.3 ConOps: The ConOps (Concept of Operations) sets out the vision for Link service and describes how the operation of the system will meet service delivery and quality goals.

010.1.4.4 Crossover: A pair of turnouts that connect two tracks enabling a train to operate from one track onto the other.

010.1.4.5 Dwell: The programmed (timetabled) time that a train will be at rest, with doors open, at a station.

010.1.4.6 Exclusive right-of-way: A Sound Transit Link ROW without at-grade crossings, which is grade-separated or protected by a fence or substantial barrier. Examples are underground alignments and aerial structures.

010.1.4.7 Gap train: A train stored on the main line, powered-up, and ready to be used to plug a “gap” in revenue service, such as to replace a failed train.

010.1.4.8 Guideway: Where rail vehicles travel, and may be elevated, at-grade, or in a tunnel.

010.1.4.9 Headway: The time between consecutive trains passing the same point while both trains are operating in the same direction with the same route.

010.1.4.9.1 Scheduled headway: The headway for sustained, reliable operation during a current or future year.

Commentary: Scheduled headways may vary by time of day and day of week depending upon passenger demand and other considerations. Scheduled headways may be identified in the Rail Fleet Management Plan, annual Service Plans, or updated as needed throughout the year.

010.1.4.9.1.1 Minimum scheduled headway: The minimum scheduled headway that will accommodate forecasted long-term future ridership demand.

010.1.4.9.2 Design headway: The headway to be used for design of a project and its elements.

010.1.4.9.2.1 Signal system design headway: The headway to be used for design of the signal system for train spacing in the normal direction of travel. See definition in Set 125 Link Train Control Block Design, 125.1.4.2

010.1.4.9.2.2 Single-tracking headway: The minimum achievable headway along a segment while single tracking.

010.1.4.10 Light rail vehicle: An electrically powered rail vehicle used for transporting passengers that can operate as a single unit or coupled with other units to make a train for revenue service with a total length not to exceed 386 feet with lower capacity and lower speed than heavy rail/commuter rail vehicle.

010.1.4.11 Line capacity: The maximum number of trains that can safely operate under normal signaling conditions past a fixed point in one direction per unit of time.

010.1.4.12 Link control center: The primary location for controlling, monitoring, and dispatching the entire King County Metro Link light rail system.

010.1.4.13 Link operational signage: Non-customer signage that provides direction/guidance to Link staff in the performance of their duties.

010.1.4.14 Minimum operable segment: Segment able to deliver services as a stand-alone segment and not be dependent on any future segments being constructed.

010.1.4.15 Normal speed: The maximum authorized speed for any given location.

010.1.4.16 Operation and maintenance: The functions, duties, and labor associated with the daily operations and normal repairs, replacement of parts and structural components, and other activities needed to preserve an asset so that it continues to provide acceptable services and achieves its expected life.

010.1.4.17 Operations and maintenance facility: A location for the storage, servicing, and repair of revenue vehicles, maintenance of way equipment and facilities equipment; train operating and maintenance personnel reporting and training; system supervision and control; to support administrative functions, Sound Transit oversight, and the management of all operation.

010.1.4.18 Rail fleet management plan: This plan describes Sound Transit's approach to procure and maintain sufficient fleet, along with supporting infrastructure and facilities, to meet the demand for Link light rail service and capacity over an approximately 30-year period.

010.1.4.19 Security operations center: Staffed 24 hours a day 7 days a week on the south end of the Joni B Earl Great Hall, the security operations center is a primary source for reporting issues via email, phone, text, or in person. The security operations center dispatches security officers and contacts law enforcement, when necessary, to enhance safety and security in the transit and work environments.

010.1.4.20 Semi-exclusive ROW: An ROW that is longitudinally separated and protected from parallel traffic, but which crosses non-parallel roads and railroads at-grade. Separation may be achieved by mountable or unmountable curbs, barriers, safety fences, or lane striping. Protection at grade crossings may be provided by automatic crossing gates or traffic signal.

010.1.4.21 Single tracking: Performed when a train service is required to operate in both directions (in one direction at one time) on one mainline track due to the other mainline track not being available. Train control and signaling must enable trains to run on either mainline track in either direction when circumstances require.

010.1.4.22 Sound Transit: Officially the Central Puget Sound Regional Transit Authority, it is a regional transit system serving the Greater Seattle Area since 1999.

010.1.4.23 System capacity: The total number of passengers that can be carried past a fixed point in one direction in a set amount of time.

010.1.4.24 Tail track: An extension of mainline track commonly at terminus station located beyond passenger platform, designated for train storage and possible minor interior cleaning.

010.1.4.25 Train: Any combination of one or more rail borne vehicles combined to form a single operating unit.

010.1.4.26 Vehicle load factor: The ratio of total (seated plus standing) passengers to seats in a vehicle.

010.1.5 References (Not Used)

010.2 STAKEHOLDER NEEDS

010.2.1 Passenger Experience

010.2.1.1 All aspects of the system must result in a system that is dependable, safe, clean, and available with informed passengers while striving to create an experience that is simple, seamless, and intuitive for our passengers.

010.2.1.2 Provide a safe, reliable, durable, accessible, efficient, and cost-effective rail transit service.

010.2.1.3 Link lines garages and stations must be designed to operate 24 hours a day 7 days a week.

010.2.2 Operational Needs

010.2.2.1 Refer to each requirement set for specific operational requirements applicable to that discipline.

010.2.3 Safety Needs

010.2.3.1 Refer to Set 804 Fall Protection.

010.2.3.2 Refer to Set 601 Fire/Life Safety.

010.2.4 Security Needs

010.2.4.1 Refer to Set 601 for Fire/Life Safety.

010.2.5 Reliability, Availability, and Maintainability Needs

010.2.5.1 Refer to each set for specific requirements applicable to that discipline.

010.2.5.2 For general Reliability, Availability, and Maintainability requirements, refer to Set 01 General.

010.2.6 Environmental and Sustainability Needs

010.2.6.1 Refer to each set for specific requirements applicable to that discipline.

010.2.6.2 For general Sustainability requirements, refer to Set 803 Sustainability.

010.3 SYSTEM REQUIREMENTS

010.3.1 Rail Fleet Management Plan (RFMP)

Commentary: The RFMP is updated regularly by Sound Transit for the system, including all operating lines, defining planned service levels and capacities along with planned methods of operations and maintenance over an approximately 30-year period.

10.3.1.1 The design must be in accordance with the RFMP for all facilities and infrastructure.

010.3.2 Concept of Operations (ConOps)

010.3.2.1.1 The design must be in accordance with the ConOps for all facilities and infrastructure.

010.3.3 Operating Route

010.3.3.1 All Link lines must have a minimum of two mainline tracks—one track for operation of trains in each direction.

010.3.3.2 Under normal conditions, train movements must operate on the right-hand track. All tracks must be designed to support bidirectional service.

010.3.4 Passenger Trip Time

010.3.4.1 Total one-way trip time from terminus to terminus must not exceed the equivalent trip time established at the completion of the conceptual design phase by more than 5 percent without a Deviation Request per the Engineering procedures.

Commentary: Total one-way trip time includes running time, station dwell time, operator layover at terminus and delay time (e.g., waiting at traffic signals), if applicable.

010.3.4.2 When computing run times that involve operating segments, obtain the input and time from Sound Transit Operations department calculations.

010.3.5 Design Headway

010.3.5.1 The design headway must be as specified in this set and in accordance with the RFMP.

Commentary: To allow for variability in real-world operating conditions and safe operating conditions during non-normal operation, such as schedule recovery following a disruption, design headway (e.g., tunnel ventilation, OCS) must be less than the minimum scheduled headway.

010.3.5.2 The following design headways must be used for the design of the traction electrification and other systems necessary to operate. These are based on projections beyond the RFMP and consider recovery operations:

010.3.5.2.1 Forest Street OMF to Everett = 3 minutes.

010.3.5.2.2 West Seattle to Stadium, Redmond to International District, Ballard to Tacoma = 4 minutes.

010.3.5.3 Headway design must consider tunnel ventilation zones and requirements received from the AHJ.

010.3.5.4 Signal/train control design must be in accordance with Set 125 Link Train Control Block Design.

Commentary: The projects must work with Operations if shorter headways are desired for failure resilience or if future (beyond ST3) service conditions can be envisioned. ST Engineering is to be consulted if shorter headways are decided to be incorporated.

010.3.5.5 The project must be designed to achieve the design headway.

010.3.5.6 Crossover locations. See Section 010.3.14.4.1 for crossovers requirements.

010.3.6 Operating Speed

010.3.6.1 For trains operating on exclusive or semi-exclusive ROW, the permissible operating speed must be a function of the ROW classification and the degree of train protection and grade crossing protection provided.

010.3.6.2 For vehicle, basic, and operating speed rules, refer to the current Link Light Rail Rules Book.

010.3.7 LCC

010.3.7.1 Regulation and supervision of train operations and supervisory control of the associated electrical, mechanical, and communications subsystems must be performed at the LCC and backup LCC.

010.3.7.2 These facilities must function as the nerve center of system operations.

010.3.7.3 Mainline and station operations, mainline maintenance activities, and any maintenance-of-way that affects mainline operation must be controlled, coordinated, and monitored from the LCC.

Commentary: The LCC serves as the main location from which all aspects of the system are controlled, and operational decisions are made regarding normal and non-normal operations. The facility serves as the primary, but not necessarily exclusive, point of coordination for all operational decisions affecting rail service. This coordination usually includes both internal disciplines, as well as external elements involving emergency response agencies. For additional LLC procedures and requirements, refer to the Link Light Rail SOP.

010.3.8 Maintenance Requirements

010.3.8.1 The system must include all redundancy, reliability, and maintainability design characteristics necessary to satisfy the requirements defined in Set 001 General.

010.3.8.2 The system must provide optimal maintenance that includes spare parts to support Sound Transit’s ability to maintain a ‘state of good repair’ as defined by 49 CFR Part 625.17.

010.3.8.3 The system shall incorporate diagnostic features (fault logging, fault finding and system interrogation) to permit the correction of failures and anomalies to minimize impact to service.

010.3.8.4 Lockout/Tagout and “Red Tag”

Commentary: Sound Transit has established procedures, by which equipment, tools, and other items may be removed from service when it has been determined that the equipment, tools, and other items present a potential for unintended injury when used as directed by the manufacturer.

010.3.8.4.1 Provide electrical and mechanical equipment with the means of “Lockout” in accordance with NFPA 70E to facilitate “Red Tag.” That is, the means of removal from service or otherwise prohibiting operation that may lead to danger, including during maintenance and inspection.

010.3.8.4.2 Provide means to enable a Sound Transit padlock to be applied to prevent placing back into service, as well as means to apply a “Red Tag.”

010.3.8.4.3 Apply lockout/tagout and “Red Tag” procedures during construction.

010.3.8.4.4 Designs for the de-energization of electrical equipment, including traction power equipment and distribution circuits, must follow Sound Transit procedures.

010.3.8.4.5 The contractor must follow the current Link Light Rail Maintenance Management Plan and comply with 49 CFR 674.

010.3.9 Link Track Designations

010.3.9.1 All mainline tracks must be named in the predominant geographic direction of travel (i.e., NB or SB, EB, or WB).

010.3.9.2 Protocol for milepost numbering must follow the current design as detailed in 010.6.1.3 and Set

521 Track Geometry.

010.3.9.3 Tracks within an OMF must have a separate convention.

010.3.9.3.1 Yard Tracks – Y1, Y2, etc.

010.3.9.3.2 Shop Tracks – M1, M2, etc.

010.3.10 Patronage

010.3.10.1 Projects must be designed to provide capacity supporting the peak-hour, peak-direction passenger volumes projected within the RFMP.

010.3.11 Traction Power Sectionalization

010.3.11.1 The overhead contact system must be designed to enable sections of the catenary to be de-energized, while immediately adjacent sections remain energized.

Commentary: The design providing this capability is referred to as traction power sectionalization. See Set 220 Traction Power and Set 221 Overhead Contact System.

010.3.11.2 The system must be designed to support construction and commissioning activities during system expansion as well as operating system maintenance needs in a de-energized state.

010.3.12 Operating Route

010.3.12.1 While the primary operating route is the revenue service route, allow for contingency, special event, and non-revenue routes including movements to/from the yards serving the route as well.

010.3.13 Operating Hours

Commentary: The primary operating hours are defined in the revenue service timetable.

010.3.13.1 Ensure time is also allotted for initial non-revenue movements before and after revenue hours to position trains for the start of service and to return the last trains to the yard at the end of service.

010.3.13.2 Design Sounder commuter rail lines and stations to enable train service to operate Monday through Friday service between 4 a.m. and 11 p.m.

010.3.14 Special Trackwork

010.3.14.1 Special trackwork must be provided and configured to operate the system and to provide operational resilience and schedule recovery required during different periods of the day or during emergencies, delays, failures, repairs, maintenance, and special events.

Commentary: Turnback needs will be defined in the Concept of Operations.

010.3.14.2 Special trackwork at terminus stations and at midline turn back stations must be capable of sustaining the design minimum scheduled headway.

010.3.14.3 At final design, the design must meet design headways as determined by operational model simulation (or equivalent) that is also approved by Sound Transit Operations. The operational model must also demonstrate failure modes and resulting single track headways.

010.3.14.4 Special trackwork configurations must include:

010.3.14.4.1 Crossovers.

010.3.14.4.2 Single-tracking headway must not be greater than twice the design headway or 10 minutes, whichever is greater (includes time to move through interlocking).

010.3.14.5 Pocket Track

010.3.14.5.1 Pocket or storage tracks must be capable of holding at least one train of maximum length and be energized by the overhead catenary.

010.3.14.5.2 Pocket tracks must be spaced at distances no greater than 10 miles for efficient offline storage of trains as part of the system's failure management strategy.

Commentary: Midline turnback needs will be defined in the Concept of Operations.

010.3.14.5.3 Pocket or storage tracks and other required special trackwork must be provided if midline turn back is required.

010.3.14.5.4 Midline pocket tracks must be designed to enable entry and exit at both ends of the pocket track and onto the main line.

010.3.14.6 Tail Tracks

010.3.14.6.1 Tail tracks must be provided at each permanent and temporary terminus station.

010.3.14.6.2 At terminus stations, each tail track must be capable of accommodating a train of maximum length (see Set 421 Light Rail Vehicle) while following guidelines for implementing speed codes for berthing scenarios (see Set 125 Train Control Block Design). The speed code must be coordinated with bumping post location and design.

010.3.14.6.3 Tail tracks offer flexibility and support to train schedules by providing the following:

010.3.14.6.3.1 Space for layover requirements, train staging for special events, and failure management.

010.3.14.6.3.2 Safe braking distances into platforms.

010.3.14.6.3.3 Room for construction, testing, and commissioning of new extensions to occur simultaneously with revenue service, therefore reducing or eliminating service interruptions.

010.3.15 Hi-rail Access

010.3.15.1 Hi-rail access to the main line must be provided at intervals of no greater than 3 miles.

Commentary: For Hi-rail access points in tunnels, see Set 522 Track Construction

010.3.16 Rail Activation and Acceptance

010.3.16.1 Provisions for LRV delivery and Acceptance

010.3.16.1.1 Permanent provisions must be made for LRVs to be delivered to the yard designated by Sound Transit Operations for LRV delivery.. Such facilities must be constructed prior to delivery of the first LRV.

010.3.16.1.2 OMFs and at least 1 mile of mainline track must be constructed prior to delivery of the first LRV.

010.3.16.1.3 Further details regarding LRV delivery provisions are provided in Set 836 Operations & Maintenance Building – Light Rail.

010.3.17 Handover to and Acceptance by Operations & Maintenance

Commentary: Basic design requirements for any project shall include industry best practices for Operations Readiness. Designer to define the simulations and operational tests and trials that need to be conducted to achieve readiness for pre-revenue operations.

010.3.17.1 Initial maintenance plans with maintenance procedures, asset data collection sheets, warranty log, spare parts recommended, and replacement procedures for all special equipment must be provided.

010.3.17.2 The designer must develop recommended list of trainings that needs to be delivered to operators and maintainers.

010.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

010.4.1 System Breakdown Structure

010.4.2 System Sites and Locations

010.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets. These identified interface/coordination points are not meant to be an exhaustive list.

Table 10-1: Interface between Operations and Other Disciplines

SET SERIES	SET NAME	SET 010 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	X
400	Vehicle	X
500	Track	X
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

010.5.1 Train Control and Signals

010.5.1.1 Coordinate with Train Control and Signals to ensure provision of spare parts and special test equipment.

010.5.1.2 Coordinate with Train Control and Signals to ensure provision of manuals and training.

010.5.1.3 Coordinate with Train Control and Signals to ensure provision of As-Built documentation, including software documentation and microprocessor files.

010.5.1.4 Coordinate with Train Control and Signals to ensure normal and abnormal (i.e., single-tracking and turnback) train operations needs are met.

010.5.1.5 Coordinate with Train Control and Signals to ensure that the system is safely maintainable and operable.

010.5.1.6 Coordinate with Train Control and Signals to ensure that reliability targets are met.

010.5.1.7 Coordinate with Train Control and Signals to ensure the needs consistency of operation and layout are met.

010.5.2 Traction Electrification

010.5.2.1 Coordinate with Traction Electrification to ensure provision of spare parts and special test equipment.

010.5.2.2 Coordinate with Traction Electrification to ensure provision of manuals and training.

010.5.2.3 Coordinate with Traction Electrification to ensure provision of As-Built documentation, including software documentation.

010.5.2.4 Coordinate with Traction Electrification to ensure normal and abnormal (i.e., single-tracking and turnback) train operations needs are met.

010.5.2.5 Coordinate with Traction Electrification to ensure that the system is safely maintainable and operable.

010.5.2.6 Coordinate with Traction Electrification to ensure that reliability targets are met.

010.5.2.7 Coordinate with Traction Electrification to ensure the needs consistency of operation and layout are met.

010.5.3 Operational Communications

010.5.3.1 Coordinate with Operational Communications to ensure provision of spare parts and special test equipment.

010.5.3.2 Coordinate with Operational Communications to ensure provision of manuals and training.

010.5.3.3 Coordinate with Operational Communications to ensure provision of As-Built documentation, including software documentation.

010.5.3.4 Coordinate with Operational Communications to ensure normal and abnormal train operations needs are met.

010.5.3.5 Coordinate with Operational Communications to ensure that the system is safely maintainable and operable.

010.5.3.6 Coordinate with Operational Communications to ensure that reliability targets are met.

010.5.3.7 Coordinate with Operational Communications to ensure the needs consistency of operation and layout are met.

010.5.4 Vehicle

010.5.4.1 Coordinate with Vehicle to ensure provision of spare parts and special test equipment.

010.5.4.2 Coordinate with Vehicle to ensure provision of manuals and training.

010.5.4.3 Coordinate with Vehicle to ensure provision of As-Built documentation, including software documentation.

010.5.4.4 Coordinate with Vehicle to ensure normal and abnormal (i.e., single-tracking and turnback) train operations needs are met.

010.5.4.5 Coordinate with Vehicle to ensure that the system is safely maintainable and operable.

010.5.4.6 Coordinate with Vehicle to ensure that reliability targets are met.

010.5.4.7 Coordinate with Vehicle to ensure the needs consistency of operation and layout are met.

010.5.5 Track

010.5.5.1 Coordinate with Track to ensure provision of spare parts and special test equipment.

010.5.5.2 Coordinate with Track to ensure provision of manuals and training.

010.5.5.3 Coordinate with Track to ensure provision of As-Built documentation.

010.5.5.4 Coordinate with Track to ensure normal and abnormal (i.e., single-tracking and turnback) train operations needs are met.

010.5.5.5 Coordinate with Track to ensure that the system is safely maintainable and operable.

010.5.6 Fire/Life Safety

010.5.6.1 Coordinate with Fire/Life Safety to ensure provision of, and access to, life-safety systems to provide patron and employee safety.

010.5.7 Structures

010.5.7.1 Coordinate with Structures to ensure provision of walkways and access to operational systems and equipment, as well as for safety patron evacuation.

010.5.8 Architecture

010.5.8.1 Coordinate with Architecture to ensure provision of spare parts and special test equipment.

010.5.8.2 Coordinate with Architecture to ensure provision of manuals and training.

010.5.8.3 Coordinate with Architecture to ensure provision of As-Built documentation, including software documentation.

010.5.8.4 Coordinate with Architecture to ensure normal and abnormal (i.e., delays/crowding) train operations needs are met.

010.5.8.5 Coordinate with Architecture to ensure that the system is safely maintainable and operable.

010.5.8.6 Coordinate with Architecture to ensure that reliability targets are met.

010.5.8.7 Coordinate with Architecture to ensure the needs consistency of operation and layout are met.

010.5.9 Mechanical-Electrical and Building Systems

010.5.9.1 Coordinate with Mechanical-Electrical and Building Systems to ensure provision of spare parts and special test equipment.

010.5.9.2 Coordinate with Mechanical-Electrical and Building Systems to ensure provision of manuals and training.

010.5.9.3 Coordinate with Mechanical-Electrical and Building Systems to ensure provision of As-Built documentation, including software documentation.

010.5.9.4 Coordinate with Mechanical-Electrical and Building Systems to ensure normal and abnormal (i.e., single-tracking and turnback) train operations needs are met.

010.5.9.5 Coordinate with Mechanical-Electrical and Building Systems to ensure that the system is safely maintainable and operable.

010.5.9.6 Coordinate with Mechanical-Electrical and Building Systems to ensure that reliability targets are met.

010.5.9.7 Coordinate with Mechanical-Electrical and Building Systems to ensure the needs consistency of operation and layout are met.

010.5.10 Technology

010.5.10.1 Coordinate with Technology to ensure provision of spare parts and special test equipment.

010.5.10.2 Coordinate with Technology to ensure provision of manuals and training.

010.5.10.3 Coordinate with Technology to ensure provision of As-Built documentation, including software documentation.

010.5.10.4 Coordinate with Technology to ensure normal and abnormal train operations needs are met.

010.5.10.5 Coordinate with Technology to ensure that the system is safely maintainable and operable.

010.5.10.6 Coordinate with Technology to ensure that reliability targets are met.

010.5.10.7 Coordinate with Technology to ensure the needs consistency of operation and layout are met.

010.5.11 Security

010.5.11.1 Coordinate with Security to ensure provision of spare parts and special test equipment.

010.5.11.2 Coordinate with Security to ensure provision of manuals and training.

010.5.11.3 Coordinate with Security to ensure provision of As-Built documentation, including software documentation.

010.5.11.4 Coordinate with Security to ensure normal and abnormal train operations needs are met.

010.5.11.5 Coordinate with Security to ensure that the system is safely maintainable and operable.

010.5.11.6 Coordinate with Security to ensure that reliability targets are met.

010.5.11.7 Coordinate with Security to ensure the needs consistency of operation and layout are met.

010.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

010.6.1 Operational Signage

010.6.1.1 General Requirements

Commentary: Link operational signage provides uniform operational signage on all Link light rail projects. Signage provides direction to operations staff to assist in the safe and efficient operations of the light rail system.

010.6.1.1.1 All projects must include the following Link signage design drawings by 60 percent design submittal:

010.6.1.1.1.1 Separate guideway signage sheets that show only the guideway (track) and mandatory and site-specific signs required according to this requirement set.

010.6.1.1.1.2 Guideway signage schedule sheets contain the following items as shown in Table 10-2:

010.6.1.1.1.2.1 Sign ID: This must be a letter designation that is unique for each sign type. It provides linkage between the guideway signage sheets, the guideway signage schedule sheets and the guideway signage detail sheets.

010.6.1.1.1.2.2 Location: This column contains the stationing information of where the sign is to be installed. The directional identifier (NB/SB, EB/WB) is dependent on the primary direction of travel for each Link alignment.

010.6.1.1.1.2.3 Sign Type: This identifies the type of sign.

010.6.1.1.1.2.4 Text: This column shows appropriate custom text for a sign (e.g., mileage information for milepost marker signs, and speed sign information for speed limits used during testing).

010.6.1.1.1.2.5 Mounting: This column describes mounting instructions for each sign (if applicable).

Table 10-2: Sample Guideway Signage Schedule

SIGN ID	LOCATION		SIGN TYPE	TEXT	MOUNTING
F	SB	K 1849+49.13	FIRE DEPT ACCESS SIGN		Install on wall panel. Mount sign with bottom 4 feet above finished grade.
D	SB	K 1849+52.51	STANDPIPE SIGN		See mechanical drawings for mounting details.
B	SB	K 1849+57.73	NO CLEARANCE SIGN		Install on OCS pole. Mount sign with top 6 feet above top of rail.
B	NB	1849+58.66	NO CLEARANCE SIGN		Install on OCS pole. Mount sign with top 6 feet above top of rail.
A	SB	K 1850+16.33	MILEPOST MARKER	2N 18.2	
A	NB	1850+17.73	MILEPOST MARKER	1N 18.2	

010.6.1.1.1.3 Guideway spares signage schedule that contains the following items as shown in Table 10-3:

010.6.1.1.1.3.1 Quantity: This is the number of spare signs that the Contractor procures and delivers to Sound Transit. These spare signs are additional to the signs called out in a project's guideway signage schedule. This quantity must be 2 percent of the sign quantity installed or four signs, whichever is greater.

010.6.1.1.1.3.2 Sign ID: This must be a letter designation that is unique for each sign type. It links the guideway signage sheets, the guideway signage schedule sheets, and the guideway signage detail sheets.

010.6.1.1.1.3.3 Sign Type: This identifies the type of sign.

010.6.1.1.1.3.4 Notes: This is for any additional information about each sign. For example, if the contractor does not plan to deliver any spare guideway sign to Sound Transit, add that information in this column.

Table 10-3: Sample Guideway Spares Signage Schedule

QUANTITY	SIGN ID	SIGN TYPE	NOTES
XX	B	NO CLEARANCE SIGN	
XX	C	SPEED LIMIT SIGN	
XX	D	STANDPIPE SIGN	
XX	F	FIRE DEPT ACCESS SIGN	
XX	G	LINK ACCESS SIGN	
XX	N	HIGH VOLTAGE SIGN	
XX	H	DO NOT LEAN ON OR OVER RAIL	
XX	I	YELLOW WORK ZONE SIGN	
XX	J	GREEN WORK ZONE SIGN	
XX	K	BELL SIGN	
XX	L	SLOW ZONE 300-FT SIGN	
XX	M	SLOW ZONE 800-FT SIGN	

010.6.1.1.1.4 Attach Sound Transit's Link Signage Standard Detail Drawings. If any signs not shown in these drawings are included in the design drawings, provide additional standard details on a separate sheet.

010.6.1.1.1.5 The following General Notes must be included in all guideway signage sheets:

010.6.1.1.1.5.1 For sign type, sign details, and mounting information, see Guideway Signage Schedules and Guideway Sign Details, Drawings XXX through XXX.

010.6.1.1.1.5.2 Standard Specification 10 14 56 Guideway Signage includes specifications for Link signage.

Commentary: The guideway signs in these specifications (and in the drawings/sign schedule/details) are determined on a project-by-project basis. The final determination considers if the guideway is at-grade, elevated, tunnel, and other design elements, such as at-grade crossings for pedestrians and/or vehicular traffic.

010.6.1.2 Mandatory Signs

010.6.1.2.1 The following signs are required for all current and new Link light rail segments. All signs in this section, if selected for a project, must be installed by the Contractor. The placement of signs must meet the requirements in this manual and must not impede required sight distance for pedestrians or vehicles.

010.6.1.2.2 Comply with NFPA 704 and OSHA 1910 for regulatory signs. Refer to Set 806.

010.6.1.3 Milepost Markers

010.6.1.3.1 These signs are mandatory every 0.1 miles on all Link light rail alignments. The type of mileage sign must depend on if the guideway is at-grade/elevated or within a tunnel as delineated below.

010.6.1.3.2 There must be pairs of milepost markers for each mileage so that each direction of travel has one milepost marker each.

010.6.1.3.3 The direction of travel for the milepost markers must be north/south or west/east depending on the primary alignment of the Link segment.

010.6.1.3.4 The numbering on mile markers does not start over for each extension segment and is part of the overall mileage of the link system

Figure 10-1: At-Grade/Elevated Guideway Mileage Sign

Color:	White Text on Blue Background
Size:	24” x 4.75”
Text Size	2.5”
Location	OCS poles
Spacing:	Every tenth of a mile
Height:	8’ bottom of sign to TOR

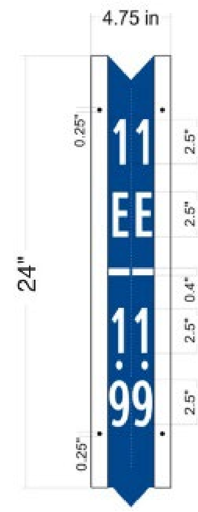
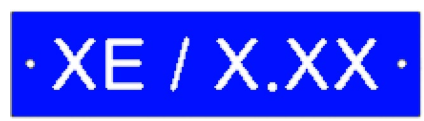


Figure 10-2: Tunnel Mileage Sign

Color:	White Text on Blue Background
Size:	16” x 5.5”
Text Size:	3.5”
Location:	Tunnel Wall
Spacing:	Every 0.02 miles
Height:	6’ bottom of sign to TOR

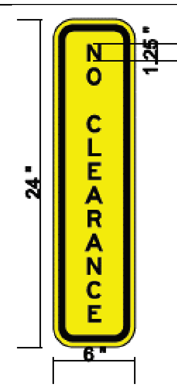


010.6.1.4 No Clearance Signs

010.6.1.4.1 These signs are required when there is no room for a person to stand between the train and the object the sign is affixed to. This is typically along a maintenance walkway where maintenance personnel would be encroaching into the dynamic envelope of an LRV.

Figure 10-3: No Clearance Sign

Color:	Black Text on Yellow Background
Size:	6’ x 24” (typical)
Text Size:	1.25”
Location:	Typically, near tunnel entrances and street crossings
Height:	Top of Sign 6’ above TOR

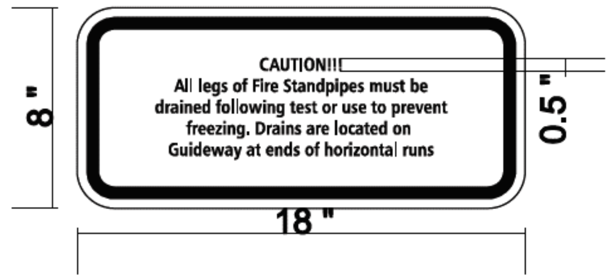


010.6.1.5 Standpipe Signs

010.6.1.5.1 This sign is required at all fire standpipes along the LRT guideway.

Figure 10-4: Standpipe Sign

Color:	Black Text on White Background
Size:	18” x 8”
Text Size:	0.5”
Location:	All fire standpipe connections and drain valves
Height:	Pedestrian Level on parapet wall or standard sign pole



010.6.1.6 Link Guideway Access Signs

010.6.1.6.1 These signs are required to control access to the guideway.

Figure 10-5: Guideway Access Sign

Color:	Black Text on White Background, black figure with 6” (dia.) red circle/stripe
Size:	12” x 18”
Text Size:	1”
Location:	On each gate/door; transit power substation, Hi-rail, signal bungalow
Height:	Bottom of sign 4’ above finished grade

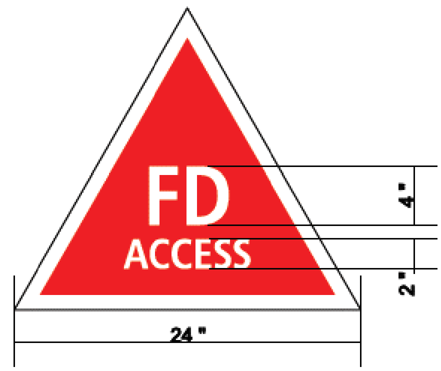
010.6.1.7 Fire Department Access Signs

010.6.1.7.1 This sign is required at points where fire department personnel can access the guideway in the event of a fire or emergency.

010.6.1.7.2 Designers to coordinate with Sound Transit Safety and local fire departments to determine access points.

Figure 10-6: Fire Department Access Sign

Color:	White Text on Red Background
Size:	Triangle, 24” per side
Text Size:	FD = 4”, other text = 2”
Location:	Gates/doors, all fire access points
Height:	Mounted for visibility for fire personnel

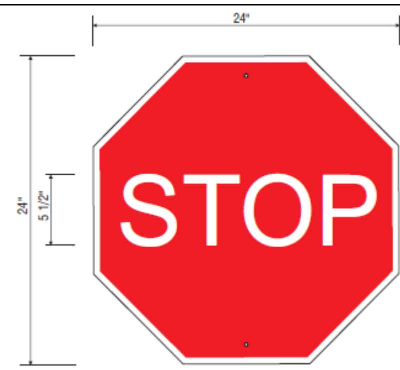


010.6.1.8 Stop Signs

010.6.1.8.1 This sign is required at the end-of-line (tail tracks and pocket tracks) for a Link segment to tell the Link LRV operator to stop.

Figure 10-7: Stop Sign

Color:	White Text on Red Background
Size:	24” x 24” (octagon)
Text Size:	5.5”
Location:	In front of bumping post (end of tail/pocket tracks)
Height:	4’ above TOR
Minimum Quantity:	3



010.6.1.9 Tunnel Directional Signs

010.6.1.9.1 This sign is required in tunnels to indicate where the exits are (e.g., tunnel portal, station) and is spaced at 80 feet on center.

Figure 10-8: Tunnel Direction Sign

Color:	White Text on Red Background
Size:	60” x 9”
Text Size:	Exit = 6”, other text = 2”
Location:	Tunnel Wall
Height:	Center of sign to be 6’-4” above TOR

010.6.1.10 Tunnel Cross Passage Signs

010.6.1.10.1 This sign is required in the cross passages in between the Link tunnels to alert maintenance personnel that a Link train may be approaching from either direction when exiting the cross passage.

Figure 10-9: Tunnel Cross Passage Sign

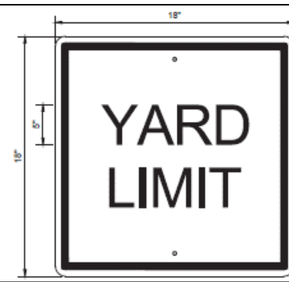
Color: Black text on yellow background	Size: 12" x 24"	

010.6.1.11 Yard Limit Signs

010.6.1.11.1 This sign is required when approaching the limits of a yard (entering/exiting).

010.6.1.11.2 When entering a yard, the operator starts to take directions from the yard vehicle supervisor. When exiting a yard, operator starts to take direction from the LCC. Coordinate with the Signaling Department for the exact height and location.

Figure 10-10: Yard Limit Sign

Color:	Black Text on White Background	
Size:	18" x 18"	
Text Size:	5"	
Location:	See sign description above	
Height:	See sign description above	

010.6.1.12 Fouling Point Markers

010.6.1.12.1 This is a marker that is located at the point past a crossover/turnout frog point where a stationary LRV can be and not interfere with an LRV using the other diverging track. One marker required for each side of the crossover for a total of two signs per crossover.

Figure 10-11: Fouling Point Marker

Color:	Yellow	
Size:	3 sets of 4" diameter	
Height/Location:	Ground level on tie after fouling point	

010.6.1.13 Site-specific Signs

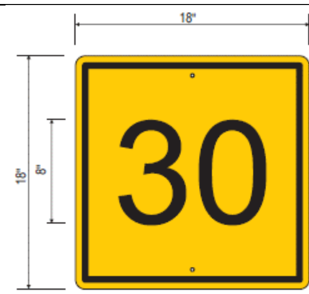
010.6.1.13.1 These site-specific signs must be reviewed to determine applicability.

010.6.1.13.2 Speed Limit Signs

010.6.1.13.2.1 These are temporary signs typically used during the testing/commissioning phase of a new light rail segment. They can be included in the operational signage package. Please consult with the Resident Engineer prior to inclusion.

Figure 10-12: Speed Limit Sign

Color:	Black Text on Orange Background
Size:	18” x 18”
Text Size:	8”
Location:	Along guideway during testing
Height:	Not applicable

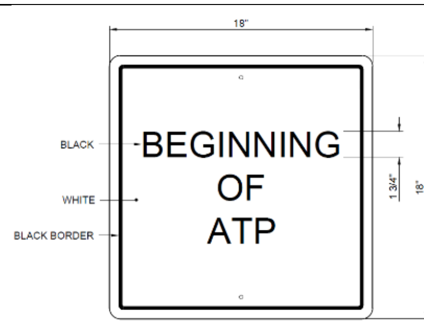


010.6.1.13.3 Beginning of ATP Signs

010.6.1.13.3.1 These are temporary signs that are used to verify leaving street running mode and entering an ATP speed-controlled section (elevated/tunnel).

Figure 10-13: Beginning of ATP Sign

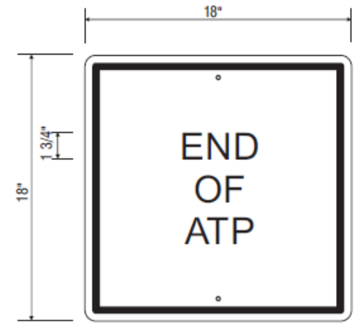
Color:	Black Text on White
Size:	18” x 18”
Text Size:	1.75”
Location:	Beginning of ATP
Height:	Mounted at operator level on parapet wall or standard sign pole



010.6.1.13.4 End of ATP Signs

010.6.1.13.4.1 These are temporary signs that are used when leaving an ATP speed-controlled zone and entering street running mode.

Figure 10-14: End of ATP Sign

Color:	Black Text on White	
Size:	18" x 18"	
Text Size:	1.75"	
Location:	End of ATP	
Height:	Mounted at operator level on parapet wall or standard sign pole	

010.6.1.13.5 Coast/Power Signs

010.6.1.13.5.1 Indicates the location of the train-to-wayside call loop in embedded track. These are typically mounted on the surface, side, or bottom of tunnels.

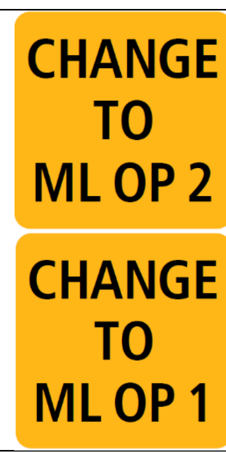
Figure 10-15: Coast/Power Sign

Color:	White reflectors	
Size:	4" x 4"	
Location:	200' upstream of a point where project requires coast through and then 400' downstream of that point	
Quantity:	12 upstream and 12 downstream	

010.6.1.13.6 Radio Channel Change Signs

010.6.1.13.6.1 These signs are used when a radio channel change is required.

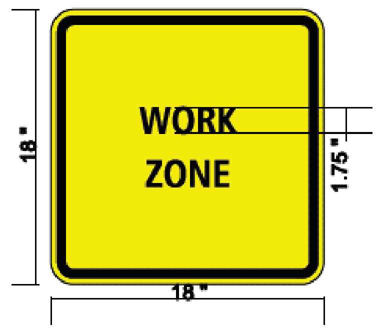
Figure 10-16: Radio Channel Change Sign

Color:	Black text on orange background	
Size:	14" x 14"	
Text Size:	2.5"	
Location:	Where LCC requires operators to switch dispatchers	
Height:	Site specific	
Quantity:	4	

010.6.1.13.7 Work Zone Signs

010.6.1.13.7.1 These signs are placed immediately on either side of a work zone. The Contractor procures these signs and delivers them to Sound Transit.

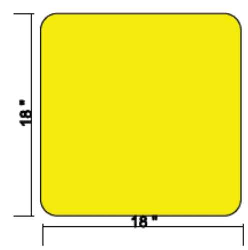
Figure 10-17: Work Zone Sign

Color:	Black Text on Yellow Background	
Size:	18” x 18”	
Text Size:	1.75”	
Location:	Work zones as needed	
Height:	Not applicable	
Quantity:	4	

010.6.1.13.8 Advance Warning Signs

010.6.1.13.8.1 The yellow sign is an advanced warning when approaching a work zone. The Contractor procures these signs and delivers them to Sound Transit.

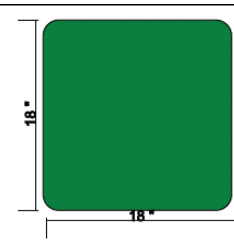
Figure 10-18: Advance Warning Sign

Color:	Yellow	
Size:	18” x 18”	
Text Size:	N/A	
Location:	Work zones as needed	
Height:	Not applicable	
Quantity:	4	

010.6.1.13.9 End of Work Zone Signs

010.6.1.13.9.1 The green sign is to indicate leaving the work zone and that it is safe to resume the track’s authorized speed. The Contractor procures these signs and delivers them to Sound Transit.

Figure 10-19: End of Work Zone Sign

Color:	Green	
Size:	18” x 18”	
Text Size:	N/A	
Location:	Work zones as needed	
Height:	Not applicable	
Quantity:	4	

010.6.1.13.10 Confined Space Signs

010.6.1.13.10.1 The sign is to provide warning at the entrance into a confined space as defined by WAC 296-809.

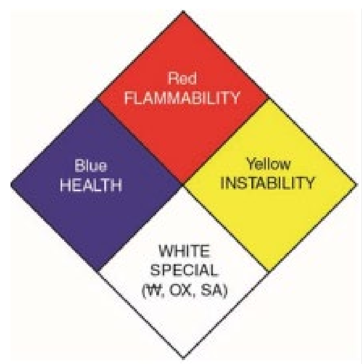
Figure 10-20: Confined Space Warning Sign

Color:	Red & Black on White	
Size:	10” x 7”	
Text Size:	5/8”	
Location:	Entrance to Confined Spaces	

010.6.1.13.11 Hazardous Materials Signs

010.6.1.13.11.1 Marking Systems to alert emergency personnel of the type and degree of hazards within an area as defined by NFPA 704.

Figure 10-21: NFPA 704 Marking System

Color:	Purple & Red & Yellow & White	
Size:	10” by 14”	
Text Size:	5/8”	
Location:	Stationary containers and above-ground tanks and at entrances to locations where hazardous materials are stored, dispensed, used or handled in quantities that require an operational permit.	

010.6.1.13.12 Storage Track Identification Sign

010.6.1.13.12.1 The sign is required for each storage track at an OMF and numbered in numerical sequence (S1, S2, S3…).

010.6.1.13.12.2 The sign must be installed on the center of the concrete tie.

010.6.1.13.12.3 The sign must be installed within 3 feet of the approach side of the yard access aisle.

010.6.1.13.12.4 Where a yard access aisle separates two storage positions, the sign must be installed within 3 feet of the yard access aisle on both sides. See Figure 10-23.

010.6.1.13.12.5 For an LRV delivery track, the sign must be placed within 3 feet of the transition from embedded track to ballasted track.

Figure 10-22: Storage Track Identification Sign

Color:	Black Text on Yellow Background
Material:	0.080” Bendable Aluminum Reflective Sheeting
Size	8” by 6” (each side)
Text Size:	4”
Mounting Hole Size:	1/4”

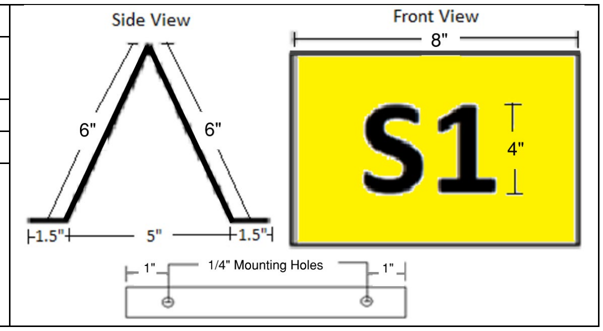
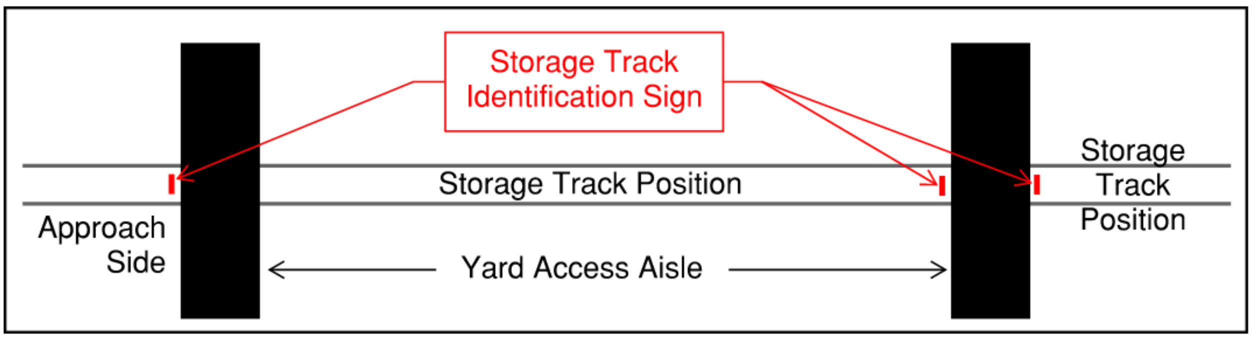


Figure 10-23: Typical Storage Track Signage Installation



010.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

010.7.1 Interface and Integration Management

010.7.2 Design Management

010.7.3 Manufacturing and Construction Management

010.7.4 Installation Management

010.7.5 Inspection and Testing Management

010.7.6 Training, Pre-Revenue Operations

010.7.7 Certification Management

010.8 APPENDICES (NOT USED)

END SET - 010

120 AT-GRADE CROSSINGS

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SET - 120 TABLE OF CONTENTS

TABLES

FIGURES

SET - 120 AT-GRADE CROSSINGS

120.1 INTRODUCTION

120.1.1 Document Scope

120.1.1.1 This set governs the selection and design of engineering treatments near Sound Transit owned Link and Sounder at-grade railroad crossings for roadways and pedestrian/bicycle pathways. This set is specific to safety and operational devices that interface with the vehicular and non-motorized users utilizing the public rights-of-way. Set 123 Train Control covers requirements associated with train detection, sequence of operation, and other railroad-side devices.

120.1.1.2 At-grade crossings consist of roadways and/or pathways crossing railroad tracks at the same elevation, as opposed to below-grade or above-grade crossings that consist of tunnels and/or bridges. From this point forward within this set, at-grade crossings and crossings are synonymous.

120.1.1.3 The designer of record (DOR) must avoid pedestrian track crossings per Sound Transit's Station Experience Design Guidelines published in June 2022.

Commentary: Under some circumstances with required hazard analysis and other studies (example: proposed Graham Street Infill Station along the Martin Luther King corridor), as well as considerations for accessibility, pedestrian track crossing may be allowed at Sound Transit's discretion.

120.1.1.4 To provide safe and efficient operations, the following modes typically include active warning treatments, including gates, bells, and flashing lights, to inform road users of the presence of rail traffic approaching the crossings:

i. All Sounder crossings.
ii. Link crossings with AHCW system.

120.1.1.5 The Link crossings where roadway traffic signals control the Link operations (street-running operations) typically include active warning treatments, such as Light Rail Transit (LRT) signals, bells, and dynamic message signs.

120.1.1.6 All crossings must include passive traffic control devices, such as signs and pavement markings, to provide warnings and traffic control near the crossings. This set includes requirements associated with mandatory and site-specific active and passive traffic control devices near Sounder and Link crossings.

120.1.1.7 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 120 owner to determine the technical source for the design criteria.

120.1.2 Regulations, Codes, Standards, and Guidelines

120.1.2.1 International Regulations, Codes, Standards, and Guidelines (Not Used)

120.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

120.1.2.2.1 Manual on Uniform Traffic Control Devices (MUTCD), Federal Highway Administration (FHWA).

120.1.2.2.2 Manual for Railway Engineering, American Railway Engineering and Maintenance-of-Way Association (AREMA).

120.1.2.2.3 A Policy on Geometric design of Highways and Streets, American Association of State Highway and Transportation Officials (AASHTO).

120.1.2.2.4 Code of Federal Regulations (CFR), Federal Railroad Administration (FRA).

120.1.2.2.5 Highway-Rail Crossing Handbook, FRA and FHWA.

120.1.2.2.6 Communications and Signals Manual, AREMA.

120.1.2.2.7 System-Wide Implementation of Rail Right-of-Way Incursion Treatments. FRA.

120.1.2.2.8 Safety and Health Regulations for Construction, Occupational Safety and Health Administration (OSHA).

120.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

120.1.2.3.1 MUTCD, Washington State Modifications.

120.1.2.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

120.1.2.5 Other Jurisdictions (Not Used)

120.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

120.1.2.6.1 Station Experience Design Guidelines, 2022, Sound Transit.

120.1.2.7 Abbreviations and Acronyms

120.1.2.7.1 AASHTO–American Association of Highway and Transportation Officials

120.1.2.7.2 AHCW–automatic highway crossing warning

120.1.2.7.3 AHJ–authority having jurisdiction

120.1.2.7.4 AREMA–American Railway Engineering and Maintenance-of-Way Association

120.1.2.7.5 DOR–designer of record

120.1.2.7.6 LRT–light rail transit

120.1.2.7.7 MUTCD–Manual on Uniform Traffic Control Devices

120.1.2.7.8 OSHA–Occupational Safety and Health Administration

120.1.2.7.9 TOD–Transit Oriented Development

120.1.3 Definitions and Classifications

120.1.3.1.1 Clear storage distance: Distance available for vehicle storage measured between 6 feet from the rail nearest to the intersection to the intersection stop line or the normal stopping point on the highway.

120.1.3.1.2 Street-running crossings: The Link crossings where roadway traffic signals control Link operations.

120.1.3.1.3 Vital AHCW System: A Vital AHCW system includes operation of warning bells, automatic gates, and flashing lights and their interconnection with wayside signaling system.

120.1.4 References (Not Used)

120.2 STAKEHOLDER NEEDS

120.2.1 Passenger Experience

120.2.1.1 The design of at-grade crossings must meet Americans with Disabilities Act standards.

120.2.1.2 At-grade crossings must be accessible to users within and near crossings.

120.2.1.3 The design must provide audible and visual warnings to non-motorized traffic.

120.2.1.4 The design must maintain uniformity of crossings' treatments throughout the Sound Transit system.

120.2.1.5 The design of at-grade crossings must meet Sound Transit's Station Experience Design Guidelines.

120.2.2 Operational Needs

120.2.2.1 The design must provide reliable train operations near vehicular and pedestrian at-grade crossings.

120.2.3 Maintenance Needs (Not Used)

120.2.4 Safety Needs

120.2.4.1 The design must provide safe operations for users within and near crossings.

120.2.4.2 The design must not impede emergency egress operation within and near crossings.

120.2.5 Security Needs (Not Used)

120.2.6 Reliability, Availability, and Maintainability Needs (Not Used)

120.2.7 Environmental and Sustainability Needs

120.2.7.1 The design of audible warning devices must meet AREMA volume requirements.

120.3 SYSTEM REQUIREMENTS

120.3.1 Active Treatments (All Sounder Crossings and Link Crossings with AHCW System)

120.3.1.1 This section includes requirements for mandatory and site-specific active crossing treatments at Sound Transit owned Sounder crossings and Link crossings with AHCW system.

120.3.1.2 At-grade crossings must include the following mandatory active treatments.

i. Warning bells.
ii. Two-quadrant vehicular automatic gates with flashing lights.
iii. Pedestrian flashing lights with additional low-mounted flashers.

120.3.1.3 A train approaching the crossing must activate the above mandatory treatments.

Commentary: Sound Transit's Engineering Procedure EP-13 includes the diagnostic review procedure for at-grade crossings and utilizes the requirements included in this set. Based on the diagnostic review of a crossing, the diagnostic team determines additional site-specific treatments for the crossing.

120.3.1.4 The design of the active treatments must meet MUTCD (including Washington State modifications), design and performance requirements of FRA Title 49, Part 234 (including Highway-Rail Crossing Handbook), and AREMA Communications and Signals Manual, Section 3.

Figure 120-1: Electronic Crossing Warning Bell

120.3.1.5 The design of a crossing must include one warning bell.

Commentary: A crossing warning bell is an audible warning device used to supplement other active traffic control devices. A bell is most effective as a warning to pedestrians and bicyclists.

Commentary: The Engineering Procedure EP-13 diagnostic review determines the number of warning bells at a crossing. Large crossings may require additional bells to meet the AREMA volume requirements.

120.3.1.5.1 The warning bell must be on top of the signal mast or cantilever.

120.3.1.5.2 The warning bell must be electronic with variable volume control and meet AREMA standards.

120.3.1.6 If Sound Transit Operations Department approves AHJ's request for wayside horn(s) near a Sounder crossing, the design must include directional wayside horn(s) and signs to provide indication to the train operator that the wayside horn is operational.

Figure 120-2: A Wayside Horn Near a Sounder At-grade Crossing

120.3.1.7 A vehicle crossing must include two-quadrant vehicular automatic gates with flashing lights.

Figure 120-3: Two-Quadrant Vehicular Automatic Gates with Flashing Lights

120.3.1.7.1 The pole-mounted flashing light signals must meet AASHTO stopping sight distance standards.

120.3.1.7.2 If the pole-mounted flashing light signals do not meet AASHTO sight distance standards, the design must include a cantilever with over–roadway flashing lights.

Commentary: Stopping sight distance is the minimum distance a vehicle driver needs to be able to see the flashing light signals, apply the brakes, and bring vehicle to a halt before crossing the stop bar. Limited visibility of the flashing light signals typically occurs due to constraints associated with horizontal and/or vertical geometry and due to buildings or infrastructure.

120.3.1.7.3 On roadways with two lanes in the same direction approaching the crossing, the design must include pole-mounted flashing signals in the median upstream of the crossing, with a crash barrier for its protection.

120.3.1.7.3.1 If a median is not feasible per diagnostic review, the design must include a cantilever with over-roadway flashing lights upstream of the crossing.

120.3.1.7.4 On roadways with more than two lanes in the same direction approaching the crossing, the design must include a cantilever with over-roadway flashing lights upstream of the crossing.

120.3.1.7.5 The cantilever signal arm must include one flasher per approach lane to the crossing not covered by pole-mounted flashers.

120.3.1.7.5.1 The design must locate the flashing lights to maximize visibility for the approaching traffic.

120.3.1.7.5.2 The DOR must design the length of the cantilever signal arm to locate flashing lights in the middle of the farthest lane of the roadway approach.

120.3.1.7.5.3 The DOR must design the crash barrier for the roadway's design speed.

120.3.1.7.6 The design of cantilever walkways must conform to AREMA, Washington State, and OSHA standards.

120.3.1.7.6.1 The DOR must design the cantilever walkways for maintainers to perform maintenance from the walkway without using a bucket truck.

Commentary: A cantilever walkway is a walkway above the cantilever that allows maintenance of the flashing light signals.

120.3.1.7.7 The design must equip a cantilever signal arm with mounting points for flashing lights and signage.

120.3.1.7.8 Signal wiring for the flashing lights must be internal to the mast and cantilever horizontal members.

120.3.1.7.9 The DOR must design the foundation for pole-mounted or cantilever flashing signals to meet AREMA standards.

120.3.1.7.10 The placement of flashing lights must not obstruct the approaching vehicles' view of the traffic signals upstream or downstream of the crossing.

120.3.1.7.11 The DOR must design the flashing lights, gates with counterbalance weights, and railroad signs to set back from the edge of curb, in accordance with MUTCD.

120.3.1.7.12 The DOR must design the gate arm lights to include LED inserts, with lights and associated wiring secured to the gate arm.

120.3.1.7.12.1 The gate arm lights must be 4 inches in diameter.

120.3.1.7.12.2 The gate arm must be shorter than 35 feet.

120.3.1.7.12.2.1 The design must include roadway median gates for roadway width more than 35 feet.

120.3.1.7.12.3 The gate arm or combination of side and median gates must extend across the entire roadway approach.

120.3.1.7.12.4 The crossing gate design must include wind guards.

Commentary: Wind guards are metal assemblies at the top of the mast that prevent the gate from being blown over by strong winds when the gate is in the vertical position.

Figure 120-4: Wind Guards

120.3.1.7.13 The DOR must design the crossing to include gate keeper assemblies.

Commentary: Gate keeper assemblies include a system of springs and a pivot point that allows for a vehicle to strike the crossing gate without removing it and allowing for the gate to return to center.

Figure 120-5: Gate Keeper Assembly

120.3.1.8 The design of a pedestrian crossing must include pedestrian flashing lights with additional low-mounted flashers and electronic warning bell(s).

Commentary: The design must not include pedestrian signal heads (upraised hand and walking person symbols) to cross an at-grade pedestrian crossing.

Figure 120-6: At-grade Pedestrian Crossing Treatments

120.3.1.8.1 When the pedestrian crossing is part of a roadway crossing, then pedestrian flashing lights must flash in unison with the roadway flashing lights.

120.3.1.8.2 Pedestrian crossings with two or more tracks must include an “ANOTHER TRAIN COMING” dynamic message warning sign in both directions of pedestrian movement.

Commentary: The “Station Access and Grade Crossing Review Analysis (2017)” report, prepared by Sound Transit Engineering, recommended a “2nd Train Approaching Warning” dynamic message sign as the analysis indicated that at crossings with more than one track, a few pedestrians seemed surprised by a second train and associate the audible and visual warnings with only the first train. When trains on both tracks activate the crossing, trigger the ANOTHER TRAIN COMING sign. The sign remains activated until both trains clear the crossing. When triggered, the text flashes but the sign will remain blank if only one train is approaching the crossing.

120.3.1.8.3 At a station platform, the design must include additional “ANOTHER TRAIN COMING” sign(s) at the end of the walkway(s) from station platform to warn passengers exiting the station.

Figure 120-7: ANOTHER TRAIN COMING Sign

120.3.1.9 At a vehicle crossing within 200 feet of an intersection controlled by a traffic signal, a pedestrian hybrid beacon, or an emergency-vehicle hybrid beacon, the design must implement advanced type of preemption that complies with MUTCD/AREMA standards.

120.3.1.9.1 Preemption must preempt the normal sequence of traffic signals.

Commentary: Preemption prevents trapping of motor vehicles on the grade crossing. The AHJ is responsible for providing a detailed written description of the roadway traffic signal operation, including the phasing and clear out times clearly indicated. The AHJ is also responsible for the continuity of interconnection wire/cable (underground), traffic signal phasing and timing, and traffic signal enclosure and field equipment. Sound Transit is responsible for the railroad equipment and its associated operation, and to provide the preemption call.

Commentary: Per EP-13 diagnostic review, the DOR coordinates with Sound Transit and AHJ representatives and executes a written agreement between Sound Transit and AHJ indicating that any changes in the traffic signal operation or changes to the operation of the railroad warning devices will be communicated and jointly evaluated prior to implementation.

120.3.1.10 At a vehicle crossing where there is a roadway intersection within 200 feet that is stop-controlled or signal-controlled with permissive turn movements toward the tracks, the design must include dynamic message warning sign(s) to prohibit permissive movements toward the grade crossing, during the signal preemption.

120.3.1.11 At a vehicle crossing where clear storage distance is 0 feet to 200 feet (or 250 feet for a roadway regularly used by multi-unit vehicles) and the vehicular traffic needs to stop upstream of the crossing per the diagnostic review, then the design must include pre-signals on the near side of the tracks.

Commentary: FRA's Highway-Rail Crossing Handbook recommends pre-signals at crossings where clear storage distance is 0 feet to 200 feet (or 250 feet for a roadway regularly used by multi-unit vehicles).

120.3.1.11.1 If the DOR locates the pre-signals downstream from the crossing, then the design must include a supplemental near-side Type 1 signal head at the stop bar.

120.3.1.11.2 The pre-signals must operate as part of the downstream signal system.

120.3.1.11.3 The design of the pre-signals must meet local AHJ standards.

120.3.1.12 At a vehicle crossing where clear storage distance is 200 feet to 450 feet (or 250 feet to 500 feet for a roadway regularly used by multi-unit vehicles) and spacing is needed downstream from the crossing to detect queue and store vehicles, the design must include queue-cutter signals on the near-side of the tracks.

Commentary: The diagnostic review of the crossing determines the need for spacing.

120.3.1.12.1 The design must include queue-cutter signals at locations where backups are likely to occur, such as entrances to secure facilities (military base), freeway entrances with traffic metering, or at special event centers (stadiums).

120.3.1.12.2 If the DOR locates the queue-cutter signals downstream from the crossing, the design must include a supplemental near-side Type 1 signal head at the stop bar.

120.3.1.12.3 The queue-cutter signals must operate independent of adjacent signals.

120.3.1.12.4 The design of the queue-cutter signals must meet local AHJ standards.

120.3.1.12.5 If the vehicular crossing is within a quiet zone, the AHJ and Sound Transit set owner must jointly decide upon supplemental safety measures that meet the requirements of FRA's 49 CFR Part 222.

Commentary: Quiet zone crossings are crossings where the train does not sound its horn. The only audible warning would be the warning bell unless the chosen supplemental safety measure is a wayside horn. The local AHJ typically requests the quiet zone designation and is responsible for capital and operating costs associated with quiet zone crossing treatments.

120.3.1.13 If a raised median/c-curb is not feasible at a crossing or a raised median would allow drivers to maneuver around the lowered gates, per diagnostic review, the design must include four-quadrant gate systems.

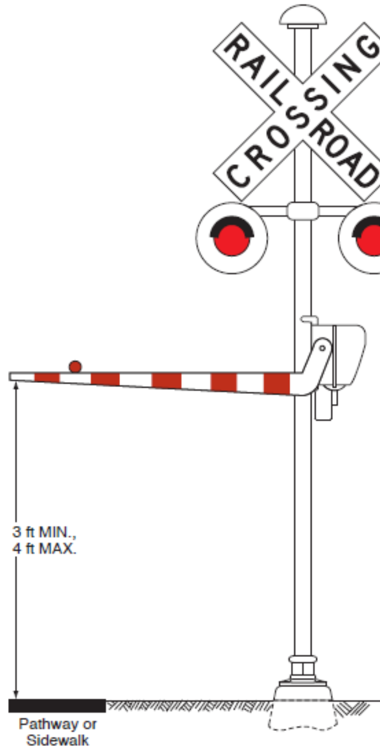
120.3.1.13.1 Four-quadrant gate system designs must comply with Set 123 Train Control– Light Rail requirements, and MUTCD and AREMA standards.

120.3.1.14 At a pedestrian crossing, if AASHTO sight distance standards are not met or if at least 60 pedestrians (or 40 school pedestrians) cross during any 2 hours of a normal day of the opening year of the crossing, the design must include automatic pedestrian gates.

Commentary: The TCRP Report 175 "Guidebook on Pedestrian Crossings of Public Transit Rail Services" recommends pedestrian automatic gates at a crossing where AASHTO sight distance standards are inadequate for pedestrians, the crossing is located in a school zone, or high pedestrian activity levels occur. The report defines a school zone as the area within 600 feet of a school boundary. High pedestrian activity levels are crossing locations where at least 60 pedestrians use the crossings during each of any 2 hours of a normal day or locations where at least 40 school pedestrians use the crossing during each of any 2 hours of a normal school day.

120.3.1.14.1 If the design includes automatic pedestrian gates at a crossing, the design must not combine pedestrian and vehicular gates (combination gates).

Figure 120-8: Automatic Pedestrian Gate



120.3.1.15 If the setback between automatic pedestrian gate and the nearest rail is less than 18 feet, the design must include a separate escape route pedestrian swing gate.

Commentary: The dynamic envelope is the region between and immediately adjacent to the tracks at a crossing where a road user could be struck by a train considering equipment sway. The distance between the rail and the dynamic envelope pavement marking is typically 6 feet.

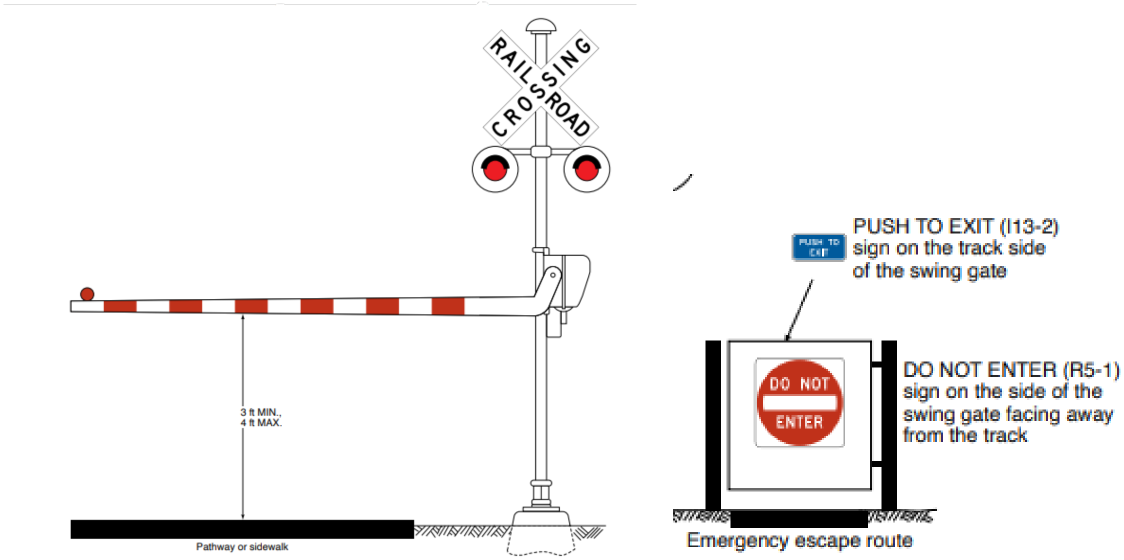
120.3.1.15.1 The design of the escape route pedestrian swing gate must include a PUSH TO EXIT sign on the track side of the swing gate and a DO NOT ENTER sign on the side of the swing gate facing away from the tracks.

120.3.1.15.2 The width of the escape route swing gate must be minimum 48 inches.

120.3.1.15.3 The design must orientate escape route pedestrian swing gates such that a person exiting the crossing pushes the gate open.

Commentary: An escape route pedestrian swing gate is a manually opened gate that swings laterally and opens only in one direction away from the track.

Figure 120-9: Automatic Pedestrian Gate and Escape Route Pedestrian Swing Gate



120.3.1.16 The design must include railroad/traffic interconnection enclosure (signal cable junction box).

120.3.1.16.1 The design must allow hand-hole access to necessary cables (between Sound Transit's grade crossing bungalow and AHJ's traffic equipment) without either party requiring access to the other authority's equipment.

120.3.1.16.2 The design drawings must depict clean demarcation points between railroad and traffic signal controller cables.

120.3.1.16.3 The design must locate junction boxes behind the sidewalk.

120.3.1.16.4 The design must require inscription on hand-hole cover to show whether hand-hole is owned by Sound Transit or the AHJ.

120.3.1.16.5 The at-grade crossing design must include two additional 4-inch PVC pipes capped or stubbed up parallel to the tracks for future use and system expansion.

Commentary: This design provision facilitates future growth and expansion of the system. It offers the added benefit of not disturbing the road pavement when conducting future improvements and upgrade of the system.

120.3.2 Active Treatments (Link Crossings in Street-Running Territory)

120.3.2.1 This section includes requirements for mandatory and site-specific active crossing treatments at Link crossings where roadway traffic signals control the Link operations.

120.3.2.2 The design of the active treatments must meet MUTCD (including Washington State modifications), FRA (including Highway-Rail Crossing Handbook), and AREMA Communications and Signals manual, Section 3.

Figure 120-10: Crossing Bell

120.3.2.3 The design of a crossing must include at least one warning bell.

Commentary: A crossing warning bell is an audible warning device used to supplement other active traffic control devices. A bell is most effective as a warning to pedestrians and bicyclists.

Commentary: The Engineering Procedure EP-13 diagnostic review determines the number of warning bells at a crossing. Large crossings may require additional bells to meet the AREMA volume requirements.

120.3.2.3.1 The warning bell must be electronic with variable volume control and meet AREMA standards.

120.3.2.4 The crossing where vehicular and/or non-motorized traffic conflicts with the LRT, the design must include signalization of the crossing.

120.3.2.4.1 The design must include a two-aspect LRT signal that controls the LRT movements at signalized intersections using steady horizontal amber (STOP) and vertical lunar (GO) bars.

Figure 120-11: LRT Signal

Commentary: The traffic signal controller for the signalized intersection operates the LRT signals. WAC 468-95-365 Light Rail Transit Signals states the following:

Amend the MUTCD Figure 8C-3 notes to read:

Notes:

All aspects (or signal indications) are either white or amber.

(1) Could be in single housing.

(2) "Go" lens may be used in flashing mode to indicate "prepare to stop."

[Statutory Authority: RCW 47.36.030. WSR 11-23-101, § 468-95-365, filed 11/18/11, effective 12/19/11.]

The WAC stated above allowed Sound Transit to design and operate LRT vehicles by utilizing white or amber signal indications. The advantages of the color differentiation for the horizontal amber (STOP) and vertical white (GO) are essential to maintain safe and efficient operations of the LRT vehicles, especially during the rainy weather.

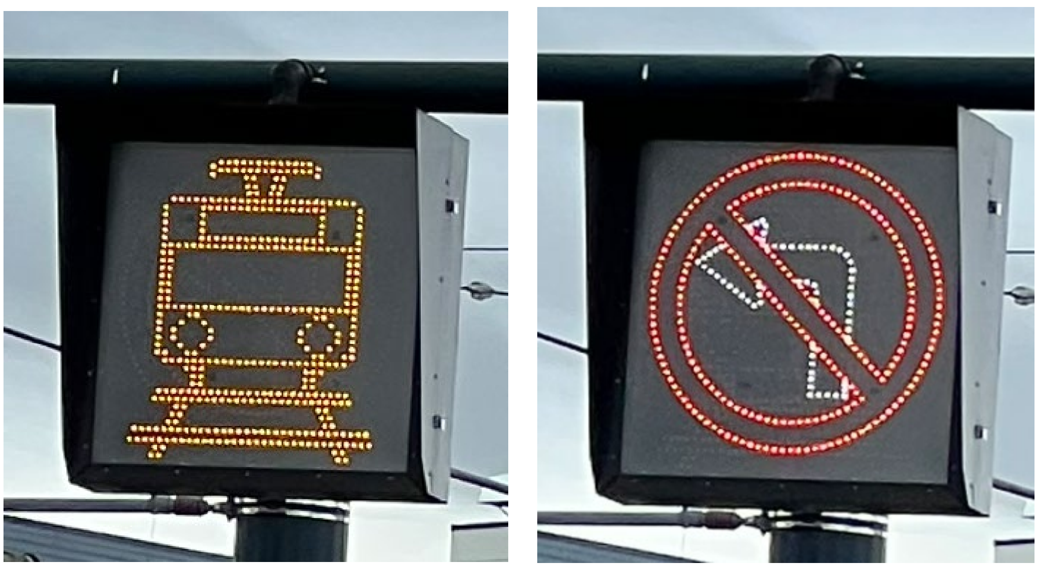
Commentary: The DOR must include a traffic signal controller that is capable of skipping conflicting phases to provide LRT priority, per agreements between Sound Transit and AHJ.

120.3.2.4.2 The traffic signal design must include only protected left-turn phasing with dedicated left-turn lane for conflicting left-turn movements.

120.3.2.4.3 The traffic signal design must prohibit right-turn movement on red signal indication for conflicting right-turn movements.

For left-turn vehicles crossing LRT track(s), the traffic signal design must include a dynamic message warning sign that alternately displays “NO LEFT TURN” and “TRAIN” symbols during the train arrival.

Figure 120-12: NO LEFT TURN/TRAIN Dynamic Message Sign



120.3.2.4.4 If left turns are restricted at a crossing along a corridor, then the traffic signal design must include a dynamic message warning sign that displays “Train” symbol during the train arrival.

120.3.2.4.5 If left turns are restricted at a crossing per AHJ restrictions, then the traffic signal design must include vertically upward green arrow signal head(s) for inside lane straight-through movement.

120.3.2.5 The pedestrian crossing must include accessible pedestrian signals (audible tones, speech messages, and vibro-tactile surface) with WALK and DON’T WALK signal heads at both ends of the crosswalk. At pedestrian crossings immediately adjacent to stations, the design must include additional pedestrian signal heads in the median.

120.3.2.6 Pedestrian crossings with two or more tracks must include an "ANOTHER TRAIN COMING with train symbol/double arrow" dynamic message warning sign, in both directions of pedestrian movement.

Figure 120-13: ANOTHER TRAIN COMING Sign

120.3.2.6.1 At a station platform, the design must include additional pedestrian warning sign(s) at the end of the walkway(s) from station platform to warn passengers exiting the station.

Commentary: The "Station Access and Grade Crossing Review Analysis (2017)" report recommended a "2nd Train Approaching Warning" dynamic message sign as the analysis indicated that at crossings with more than one track, a few pedestrians seemed surprised by a second train and associate the audible and visual warnings with only the first train. When trains on both tracks receive signal priority, trigger the ANOTHER TRAIN WARNING sign. The sign remains activated until both trains clear the crossing. When triggered, the train symbol/double arrow and the text portion flashes. The "ANOTHER TRAIN COMING" text portion of the sign will remain blank if only one train is approaching the crossing.

120.3.2.7 Pedestrian crossings with one track must include a PEDESTRIAN WARNING sign (train symbol/double arrow), in both directions of pedestrian movement.

Figure 120-14: PEDESTRIAN WARNING Sign

120.3.2.8 The design must include Railroad/Traffic Interconnection Enclosure (signal cable junction box).

120.3.2.8.1 The design must allow hand-hole access to necessary cables (between ST's grade crossing bungalow/cabinets and AHJ's traffic equipment) without either party requiring access to the other authority's equipment.

120.3.2.8.2 The design drawings must depict clean demarcation points between railroad and traffic signal controller cables.

120.3.2.8.3 The design must locate junction boxes behind the sidewalk.

120.3.2.8.4 The design must require inscription on hand-hole cover to show whether hand-hole is owned by Sound Transit or the AHJ.

120.3.2.8.5 The at-grade crossing design must include two additional 4-inch PVC pipes capped or stubbed up parallel to the tracks for future use and system expansion.

120.3.3 Passive Treatments (All Sounder Crossings and Link Crossings with AHCW System)

120.3.3.1 This section includes requirements for mandatory and site-specific passive crossing treatments at Sound Transit owned Sounder crossings and Link crossings with AHCW system.

120.3.3.2 At-grade crossings must include the mandatory signs shown below (with MUTCD sign designations).

120.3.3.2.1 ADVANCE WARNING sign (W10-1)

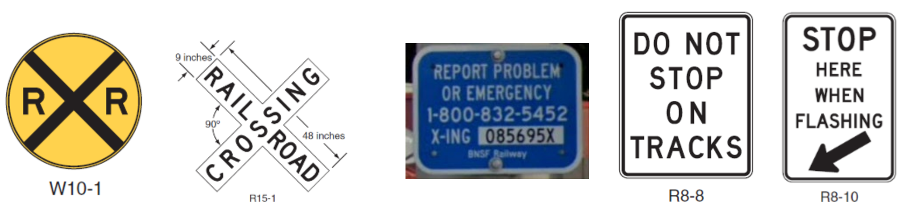
120.3.3.2.2 CROSSBUCK sign (R15-1)

120.3.3.2.3 DO NOT STOP ON TRACKS sign (R8-8)

120.3.3.2.4 STOP HERE WHEN FLASHING sign (R8-10)

120.3.3.2.5 EMERGENCY NOTIFICATION sign (I-13)

Figure 120-15: MUTCD Standard Signage



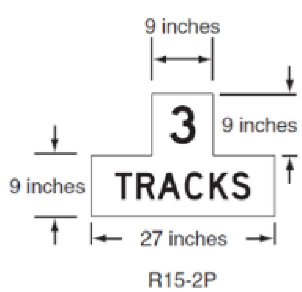
120.3.3.2.6 The dimensions and placement of grade crossing signs must meet MUTCD standards.

120.3.3.2.7 The design must include the ADVANCE WARNING sign (W10-1) on each approach to the crossing.

120.3.3.2.8 The design must include the CROSSBUCK sign (R15-1) on each approach to the crossing.

120.3.3.2.9 If two or more tracks are present, the design must include supplemental NUMBER OF TRACKS (R15-2P) plaque below the CROSSBUCK sign, on each approach to the crossing.

Figure 120-16: R15-2P Plaque



120.3.3.3 The design must include the DO NOT STOP ON TRACKS sign (R8-8) on the right-hand side of the near or far side of the crossing, depending upon the position that maximizes visibility to drivers.

120.3.3.3.1 The design must include the DO NOT STOP ON TRACKS sign on each approach to the crossing.

120.3.3.3.2 On multi-lane roadway approaches with limited sign visibility to drivers, the design must include additional DO NOT STOP ON TRACKS sign on the left-hand side.

120.3.3.4 At the crossing, the design must include STOP HERE WHEN FLASHING sign (R8-10) on the right-hand side adjacent to the stop bar location.

120.3.3.4.1 The design must include the STOP HERE WHEN FLASHING sign on each approach to the crossing.

120.3.3.4.2 If DO NOT STOP ON TRACKS sign is on the near side of the track, the design must include STOP HERE WHEN FLASHING sign below the DO NOT STOP ON TRACKS sign.

120.3.3.5 At Sounder crossings, the design must include an EMERGENCY NOTIFICATION sign (I-13) to include a unique crossing identifier and the BNSF emergency contact telephone number.

120.3.3.6 At Link crossings with AHCW system, the design must include an Emergency Notification Sign (I-13) to include a unique crossing identifier and the Link control center emergency contact telephone number.

120.3.3.7 If pre-signals or queue-cutter signals are downstream from the crossing, the design must include STOP HERE ON RED sign (R10-6) on the right-hand side adjacent to the stop bar location.

120.3.3.7.1 The design must include STOP HERE ON RED sign on each approach to the queue-cutter or pre-signal for the crossing.

120.3.3.7.2 If DO NOT STOP ON TRACKS sign is on the near side of the track, the design must include STOP HERE ON RED sign below the DO NOT STOP ON TRACKS sign.

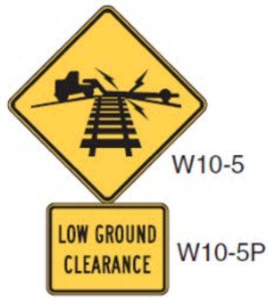
Figure 120-17: STOP HERE ON RED Sign

R10-6

120.3.3.8 At the vehicle crossing where the roadway profile is abrupt and can potentially immobilize vehicles, the design must include LOW GROUND CLEARANCE signs (W10-5/S10-5p) on each approach to the crossing.

Commentary: Per MUTCD, install these signs if the highway profile conditions are sufficiently abrupt to create a hang-up situation for long wheelbase vehicles or for trailers with low ground clearance.

Figure 120-18: LOW GROUND CLEARANCE Sign



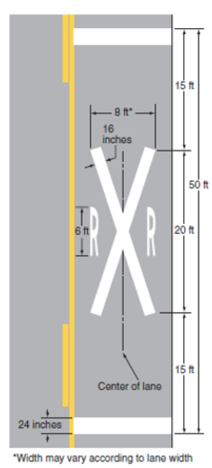
120.3.3.9 If the vehicular crossing is within a quiet zone, the design must include NO TRAIN HORN (W10-9) sign on each approach to the crossing.

Figure 120-19: NO TRAIN HORN Sign

120.3.3.10 A pedestrian crossing must include CROSSBUCK sign (R15-1) and LOOK double arrow sign (R15-8).

120.3.3.10.1 If two or more tracks are present at a pedestrian crossing, the design must include a supplemental NUMBER OF TRACKS (R15-2P) plaque below the CROSSBUCK sign, on each approach to the crossing.

Figure 120-20: Grade Crossing Pavement Marking



120.3.3.11 On each primary street traffic lane crossing track(s), the design must include pavement markings that meet MUTCD standards and consist of an X, the letters RR, double-yellow center line striping to indicate no-passing zone, stop lines, and transverse line markings.

120.3.3.11.1 On each secondary street traffic lane (with posted speed limit exceeding 35 mph) crossing track(s), the design must include pavement markings that meet MUTCD standards and consist of an X, the letters RR, double-yellow center line striping to indicate no-passing zone, stop lines, and transverse line markings.

120.3.3.11.2 Other roadway pavement markings near an at-grade crossing must be in accordance with the AHJ standards.

120.3.3.11.2.1 If AHJ standards are not available, pavement markings must meet MUTCD standards.

120.3.3.12 The vehicle crossing with two-quadrant gates must include a raised median/c-curb with flexible yellow vertical reflective delineators.

Commentary: Installing raised medians on approaches to highway-rail grade crossings is an effective way to channelize motorists and discourage RR warning device gate circumvention, U-turns movements, and motorist access to/from adjacent driveways that could impede safety at the highway-rail grade crossing. The diagnostic team determines the length of the raised median based on the vehicle queue length that forms on the approach to the grade crossing.

120.3.3.12.1 The design of the raised median/c-curb must be in accordance with the AHJ standards.

120.3.3.13 Install automatic pedestrian gate adjacent to a station (non-motorized intersection crossings on both sides of a station within 1/4 mile) per requirements included in 120.3.1.14.

Commentary: Sound Transit shall consider installation of pedestrian swing gates based on the diagnostic team's recommendation in compliance with Sound Transit Engineering Design Procedure for Light Rail Grade Crossings (EP-13). In such cases, swing gates opening must not impede pedestrian pathway and adequate pedestrian waiting area must be present.

120.3.3.13.1 If a pedestrian swing gate is installed, the design must comply with the following requirements:

120.3.3.13.1.1 The pedestrian swing gate must include a PUSH TO EXIT sign on the track side of the swing gate and a LOOK BOTH WAYS sign on the side of the swing gate facing away from the tracks.

120.3.3.13.1.2 The width of the pedestrian swing gate must be minimum 48 inches. If the pedestrian crosswalk width exceeds 8 feet, the design must include multiple gates.

120.3.3.13.1.3 The design must orientate pedestrian swing gates such that a person exiting the crossing pushes the gate open.

Commentary: The pedestrian swing gate is a manually operated gate that swings laterally and opens only in one direction away from the track. The orientation of pedestrian swing gates must be confirmed as part of the diagnostic review to maximize sight distance and passenger experience.

Commentary: See Set 601 Fire/Life Safety requirements for means of egress and accessible means of egress where applicable. Where gates and/or surface treatments are not compatible with egress requirements, the design must include area of safe dispersal.

120.3.3.13.1.4 The design must include detectable warning surface at sidewalk and pathway crossings where pedestrians cross.

120.3.3.13.1.4.1 The detectable warning surface must extend across the full width of the pathway or sidewalk.

120.3.3.13.1.5 The nearest edge of the detectable warning surface at a pedestrian crossing (with a pedestrian swing gate) must be within 6 inches of the swing gate and be at least 2 feet deep.

120.3.3.13.1.6 The design must include STOP HERE red pavement markings in front of the detectable warning surface.

120.3.3.13.1.6.1 The STOP HERE red pavement markings must extend across the full width of the pathway or sidewalk.

Figure 120-21: Pedestrian Swing Gate (Front view from station platform entrance)

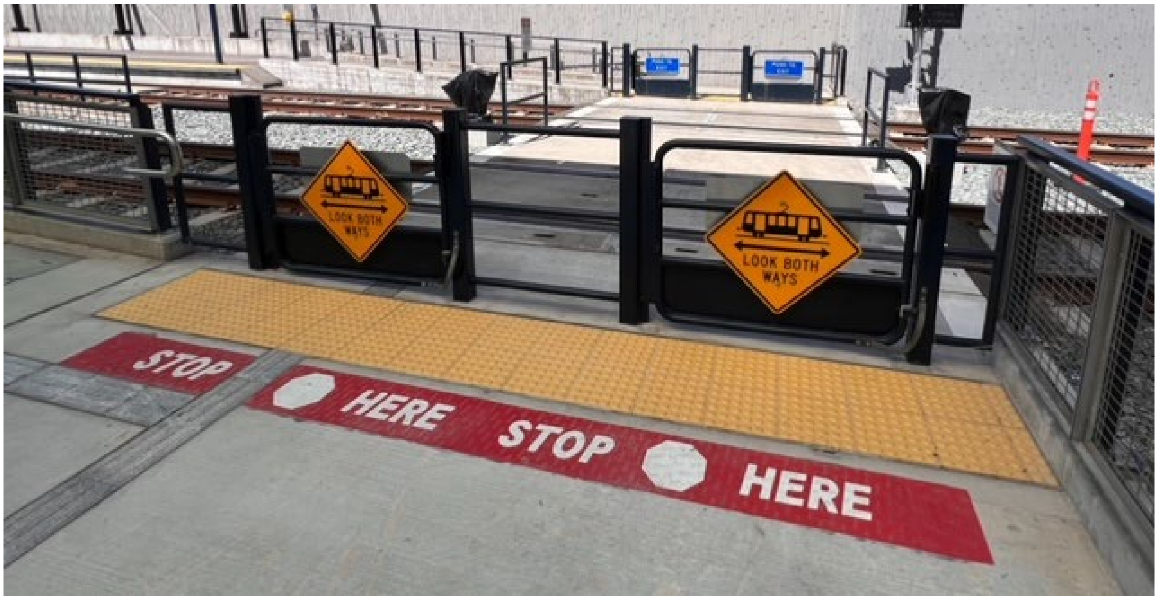
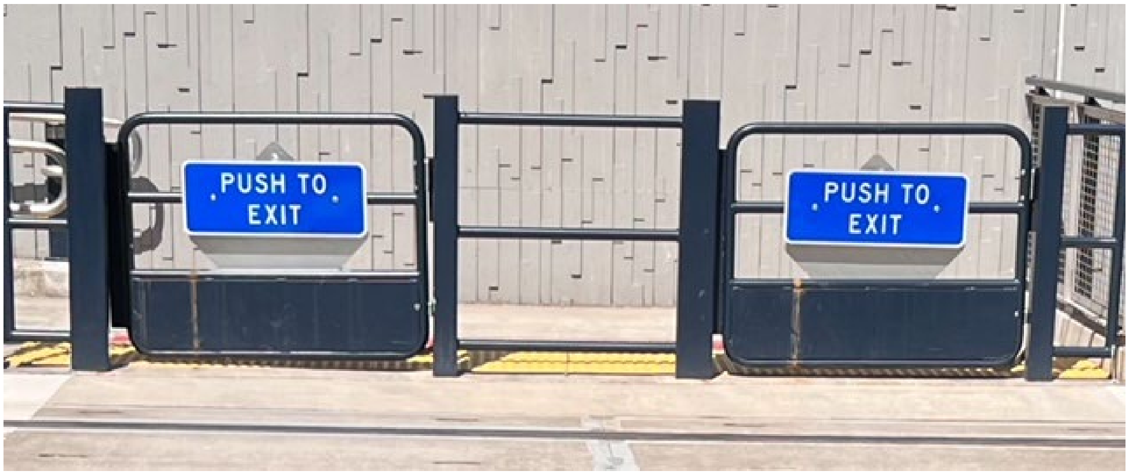


Figure 120-22: Pedestrian Swing Gate (rear view from track side)



120.3.3.14 At the vehicular crossing, the design must include 4-foot flexible white vertical reflective delineators on both sides of the tracks.

Commentary: The purpose of the delineators is to discourage any vehicular traffic to enter the tracks. FRA has recognized and recommended to consider this treatment at rail crossings, based on the experience from these installations for Long Island Railroad.

120.3.3.14.1 The design must locate the flexible white vertical reflective delineators 2 feet from a pedestrian access route and at a minimum 4 feet from the edge of travel way.

120.3.3.14.2 The design must locate the delineators a minimum of 2 feet from the outside railroad track edge.

120.3.3.14.3 The design must include two posts, 3 feet apart, on each side of the track with two white raised pavement markers in between the delineators.

Figure 120-23: Flexible White Vertical Reflective Delineators

120.3.4 Passive Treatments (Link Crossings in Street-Running Territory)

120.3.4.1 This section includes requirements for mandatory and site-specific passive crossing treatments at Link crossings in street-running territory.

120.3.4.1.1 At a vehicular crossing, the design must include NO MOTOR VEHICLES ON TRACKS (R15-6) AND DO NOT STOP ON TRACKS sign (R8-8) on each approach to the crossing per MUTCD standard.

Figure 120-24: NO MOTOR VEHICLES ON TRACKS and DO NOT STOP ON TRACKS Sign

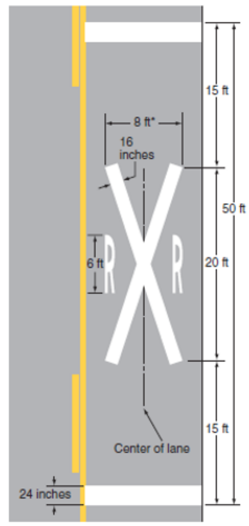
120.3.4.2 At-grade crossings must include the GRADE CROSSING ADVANCE WARNING sign (W10-1) on each approach to the crossing.

Figure 120-25: GRADE CROSSING ADVANCE WARNING Sign

120.3.4.2.1 The dimensions and placement of grade crossing signs must meet AHJ standards.

120.3.4.2.2 On each primary street traffic lane crossing track(s), the design must include pavement markings that meet MUTCD standards and consist of an X, the letters RR, double-yellow center line striping to indicate no-passing zone, stop lines, and transverse line markings. See Figure 120-26.

Figure 120-26: Grade Crossing Pavement Marking



120.3.4.2.3 On each secondary street traffic lane (with posted speed limit exceeding 35 mph) crossing track(s), the design must include pavement markings that meet MUTCD standards and consist of an X, the letters RR, double-yellow center line striping to indicate no-passing zone, stop lines, and transverse line markings.

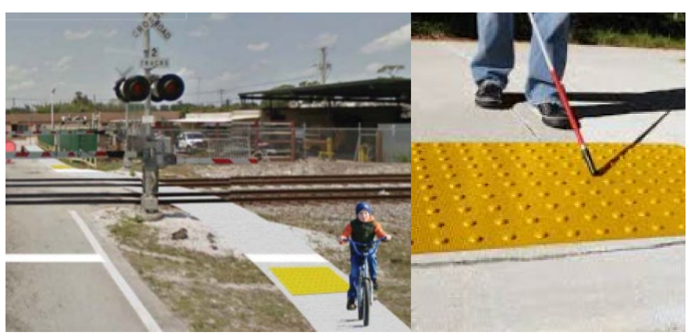
120.3.4.2.4 Other roadway pavement markings near an at-grade crossing must be in accordance with the AHJ standards.

120.3.4.2.4.1 If AHJ standards are not available, pavement markings must meet MUTCD standards.

120.3.4.3 The design must include detectable warning surface at pathway crossings where pedestrians cross and at sidewalk crossings.

120.3.4.3.1 The detectable warning surface must extend across the full width of the pathway or sidewalk.

Figure 120-27: Detectable Warning Surface



120.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

120.4.1 System Breakdown Structure

120.4.2 System Sites and Locations

120.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this Requirement Set and other requirement sets.

Table 120-1: Interfaces between At-Grade Crossings and Other Disciplines

SET SERIES	SET NAME	SET 120 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	
300	Operational Communications	
400	Vehicle	
500	Track	X
600	Fire/Life Safety	X
700	Structures	
800	Architecture	
900	Civil	X
1000	Mechanical-Electrical and Building Systems	
1100	Technology	
1200	Security	

120.5.1 Train Control and Signals

120.5.1.1 Coordinate with Train Control and Signals for active treatments' design.

120.5.2 Track

120.5.2.1 Coordinate with Track for dynamic envelopes and flangeway gaps.

120.5.3 Fire/Life Safety

120.5.3.1 Coordinate with Fire/Life Safety for means of egress near stations and other buildings.

120.5.4 Civil

120.5.4.1 Coordinate with Civil for roadway/signal/non-motorized facilities design near at-grade crossings.

120.5.4.2 Coordinate with Civil for fencing design near at-grade crossings.

120.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

120.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

120.7.1 Interface and Integration Management

120.7.2 Design Management

120.7.3 Manufacturing and Construction Management

120.7.4 Installation Management

120.7.5 Inspection and Testing Management

120.7.6 Training, Pre-Revenue Operations

120.7.7 Certification Management

120.8 APPENDICES (NOT USED)

END SET - 120

123 TRAIN CONTROL – LINK LIGHT RAIL

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SET - 123 TABLE OF CONTENTS

TABLES

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SET - 123 TRAIN CONTROL – LINK LIGHT RAIL

123.1 INTRODUCTION

123.1.1 Document Scope

123.1.1.1 This set establishes the design criteria for the train control system. The train control system must be applied to Link to enhance the safety of rail movements through interlockings, provide safe train separation for both normal and reverse traffic rail operations, interface with street traffic signal system in the street running sections to permit priority progression of the LRV trains for normal and reverse movements, and operate automatic highway crossing warning systems. Refer to Set 803 for sustainability design criteria related to the train control system.

123.1.1.2 The applicable precedence and modifications in this document must apply. See Set 001 General.

123.1.1.3 The signal system must conform to the applicable requirements of the codes and standards listed in Section 123.1.2 herein, as well as all local codes and ordinances, unless specified otherwise. Where the requirements stipulated or referenced conflict, the more stringent must apply. Unless specifically noted or approved, the latest edition of the code or standard at the time of design must apply.

123.1.1.4 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 123 owner to determine the technical source for the design criteria.

123.1.2 Regulations, Codes, Standards, and Guidelines

123.1.2.1 International Regulations, Codes, Standards, and Guidelines

123.1.2.2 International Code Council/American National Standards Institute (ICC/ANSI) A117.1-03.

123.1.2.3 Federal and National Regulations, Codes, Standards, and Guidelines

123.1.2.3.1 Federal Transit Administration (FTA) Regulation 49 CFR Part 659.

123.1.2.3.2 National Electrical Code (NEC).

123.1.2.3.3 National Electrical Safety Code (NESC).

123.1.2.3.4 Federal Railroad Administration (FRA), Title 49, Part 236.

123.1.2.3.5 Federal Railroad Administration (FRA), Title 49, Part 234.

123.1.2.4 State and Local Regulations, Codes, Standards, and Guidelines

123.1.2.4.1 Washington Administrative Code (WAC), including 296-24-75011.

123.1.2.4.2 Washington Department of Labor and Industries (L&I).

123.1.2.4.3 WSDOT Rules and Regulations of the Washington State Department of Transportation and the Washington Utilities and Transportation Commission.

123.1.2.4.4 Manual on Uniform Traffic Control Devices (MUTCD) with local amendments.

123.1.2.5 Industry Regulations, Codes, Standards, and Guidelines

123.1.2.5.1 American National Standards Institute, Inc. (ANSI).

123.1.2.5.2 American Railway Engineering and Maintenance-of-Way Association (AREMA), "Communications and Signals Manual of Recommended Practices."

123.1.2.5.3 American Society for Testing and Materials (ASTM).

123.1.2.5.4 Institute of Electrical and Electronic Engineers (IEEE).

123.1.2.5.5 Insulated Cable Engineers Association (ICEA).

123.1.2.5.6 Underwriters Laboratories, Inc. (UL).

123.1.2.5.7 American Public Transportation Association (APTA) Recommendations and Standards.

123.1.2.5.8 Electronic Industries Association (EIA).

123.1.2.6 Other Jurisdictions (Not Used)

123.1.2.7 Sound Transit Regulations, Codes, Standards, and Guidelines

123.1.2.7.1 Sound Transit Light Rail Equipment and Facilities Numbering Standard.

123.1.2.7.2 Sound Transit Light Rail Grade Crossing Diagnostic Review Worksheet (See Engineering Design Procedure EP-13).

123.1.3 Abbreviations and Acronyms

123.1.3.1 AFTC–audio frequency track circuit

123.1.3.2 AHCW–automatic highway crossing warning

123.1.3.3 ATP–automatic train protection

123.1.3.4 BMS–building management systems

123.1.3.5 EBMI–extended battery module

123.1.3.6 EMI–electromagnetic interference

123.1.3.7 HVAC–heating, ventilation, and air conditioning

123.1.3.8 IJ–insulated joint

123.1.3.9 LCC–Link control center

123.1.3.10 LCP–local control panel

123.1.3.11 LRT–light rail transit

123.1.3.12 LRV–light rail vehicle

123.1.3.13 MAS–maximum allowable speed

123.1.3.14 MCBF–mean cycles between failure

123.1.3.15 MTBF–mean time between failure

123.1.3.16 OCS–overhead contact system

123.1.3.17 OEM–original equipment manufacturer

123.1.3.18 PF–power frequency

123.1.3.19 ROW–right-of-way

123.1.3.20 SBD–safe breaking distance

123.1.3.21 SCADA–Supervisory Control and Data Acquisition

123.1.3.22 SRAC–safety related application conditions

123.1.3.23 SW–switch machine

123.1.3.24 TCS–train control system

123.1.3.25 TES–traction electrification system

123.1.3.26 TWC–train-to-wayside communications

123.1.3.27 UPS–untinterrupted power source

123.1.3.28 VETAG–vehicle tagging system

123.1.3.29 VHLC–vital harmon logic controller

123.1.4 Definitions and Classifications

123.1.4.1 Restrictive: Used in connection with the binary output for two-position components or subsystems, equivalent to stop, lower speed, deceleration, brakes applied, or actuation of alarm.

123.1.4.2 Permissive: Used in connection with the binary output for two-position components or subsystems, equivalent to proceed, higher speed, acceleration, brakes released, no actuation of an alarm.

123.1.4.3 Fail-safe: In the presence of an equipment or circuit failure, the system must continue to be in a condition of safety. An equipment failure must result in the imposition of a restrictive condition if necessary to avoid a safety issue.

123.1.4.4 Non-vital: Any design, circuit, equipment, software, or processor where flaws, operation, malfunction, or failure does not directly affect safety of train operations.

123.1.4.5 Vital: Any design, circuit, equipment, software, or processor which affects safety of train operations.

123.1.4.6 Signal bungalow: A self-contained walk-in structure that houses train control equipment.

123.1.4.7 Signal room: A room that is part of a larger structure that houses train control equipment and typically used in tunnels or other situations when using a signal bungalow is not possible.

123.1.4.8 Signal house: Either a signal bungalow or a signal room.

123.1.4.9 Locking: Restrictive state that prevents moving of switches and/or clearing of signals in situations where doing so would be unsafe.

123.1.4.10 Unsafe Condition: Any time vital train control equipment or systems do not fail-safe.

123.1.5 References (Not Used)

123.2 STAKEHOLDER NEEDS

123.2.1 Passenger Experience (Not Used)

123.2.2 Operational Needs (Not Used)

123.2.3 Maintenance Needs

123.2.3.1 Where possible, equipment utilized within the TCS must be consistent with equipment on the existing system for the sake of spare parts cataloging.

123.2.3.2 An up-to-date copy of each signal location Book of Plans must be located at each signal bungalow and room. Signal contractor must be responsible for providing as-built Book of Plans, Control Lines, Vital VHLC logic programming, other drawings, and all necessary software.

123.2.3.3 Many different types of maintenance activities must take place on and near the railroad. Design of the railroad must take this into account to minimize effort to perform maintenance. For example, the placement of interlocks should consider bridge locations to minimize number of work zones required to perform bridge inspections.

123.2.4 Safety Needs

123.2.4.1 Safety of rail movements must be the prime consideration in the design of the TCS and in the selection of its components, including relays and other devices with moving parts, insulated wire, wire terminals, binding posts, housings, conduits, resistors, capacitors, transformers, inductors, and other similar items. In the at-grade sections, safety of the train and other traffic must be the primary consideration for design of the signal system.

123.2.4.2 Application software engineer must provide certification letter that the application logic and programming meet the supplier safety case(s) for the critical train control components, including the vital processor(s) and track circuits. The certification letter must include a table with each of the OEM SRACs with a separate column indicating how the design fulfills the criteria within each SRAC.

123.2.5 Security Needs

123.2.5.1 The TCS must be protected from unauthorized users controlling the system. This is accomplished by using fail-safe logic that cannot allow remote control that is more permissive than the logic dictates and is protected by locked and alarmed entry into signal bungalows and rooms. In the case of a discrepancy between inputs into the microprocessor, the least permissive of the inputs must be selected.

123.2.6 Reliability, Availability and Maintainability Needs

123.2.6.1 Only components that have high reliability and predictable failure modes and rates and that have been proven in conditions similar to the projected service must be utilized. See Set 001 General.

123.2.6.2 Vital microprocessor-based systems (if used in lieu of vital relay logic) must be proven, fail-safe, fault-tolerant systems of high reliability, and a type proven to have a high MTBF in operation.

123.2.6.3 Vital controllers for main track applications must be provided in a redundant configuration and design to automatically switch between normal and standby systems in the event of a failure. Return to normal system must be manually performed.

123.2.6.4 All vital microprocessor-based systems must be certified as conforming to all AREMA and FRA standards governing vital processor equipment in effect at the time of purchase.

123.2.6.5 A failure of either the normal or standby microprocessor must indicate a processor health alarm through SCADA to LCC.

123.2.6.6 All signal equipment must be proven in similar North American railroad or transit service.

123.2.6.7 The signal system must have an expected service life of at least 30 years at the specified level of service. Achievement of this service life must be through off-the-shelf, proven hardware.

123.2.6.8 Each major component must incorporate provisions to allow for functional and physical interchangeability of replacement spare parts.

123.2.7 Environmental and Sustainability Needs

123.2.7.1 All systems must be designed to operate in the local environmental conditions of the area.

123.2.7.2 Signal bungalow must be equipped with HVAC units with the purpose of regulating bungalow's temperature.

123.3 SYSTEM REQUIREMENTS

123.3.1 General Requirements

123.3.1.1 Circuit design must conform to applicable portions of the "Communications and Signals Manual of Recommended Practices" of AREMA.

123.3.1.2 The following requirements must govern the design of the portions of the system or a subsystem that affect train safety:

123.3.1.2.1 Component or system failures must cause a more restrictive signal indication than that permitted with no failure.

123.3.1.2.2 Components must be combined in a manner that ensures that a more restrictive rather than a more permissive condition will result from component failure.

123.3.1.2.3 All circuits that are not confined to one housing and that affect safety must be double-wire, double-break, except signal and switch indicator light circuits.

123.3.1.2.4 Directly adjacent above ground bungalows and/or cases interconnected by vandal proof, weather tight enclosures may be considered as one housing.

123.3.1.2.5 The design of the system must be based on closed circuit principles.

123.3.1.2.6 Vital component or system failures must cause a more restrictive signal indication than that permitted with no failure.

123.3.1.2.7 Built-in fault detection and alarm generation capabilities must be used if available.

123.3.1.2.8 System safety design must be such that any single independent component or subsystem failure will result in a safe condition. Failures that are not independent (those failures that in turn always cause others) must be considered in combination as a single failure and will not cause an unsafe condition.

123.3.1.2.9 Failures of components or systems, that are not self-detecting, must not cause unsafe conditions, even in incidents of multiple failures.

123.3.1.2.10 Any latent failure of the equipment that is a failure, which by itself does not result in an unsafe condition, but which in combination with a second or subsequent failures could result in an unsafe condition, must be detected and alarmed.

123.3.1.2.11 Components or wires becoming grounded, broken wires, or damaged contacts must not cause an unsafe condition when added to one or more failures.

123.3.1.2.12 Filters used in fail-safe circuits must be designed to prevent undesired signals from passing through the filters at levels that could cause unsafe condition in the event of component failure.

123.3.1.2.13 An increase or decrease of AC or DC power supply voltages must not cause unsafe conditions.

123.3.1.2.14 Amplifier, generator, or active device breaking into spurious oscillations must not cause an unsafe condition.

123.3.1.3 Electronic circuit design must ensure that the following types of component failures have a restrictive rather than a permissive effect:

123.3.1.3.1 Two terminal devises: open, short, partial open, or partial short.

123.3.1.3.2 Multi-terminal devices: combination of opens, shorts, partial opens and/or partial shorts.

123.3.1.4 Vital, safety-critical software (where employed) must comply with standards from 123.1.2 or critical high-integrity systems.

123.3.1.5 The signal system must be a vital microprocessor-based control system. The signal system must incorporate fail-safe designs to check and control all safety critical functions concerning track switch operation, vehicle occupancy status, wayside signal indications (in ABS territory), and route security.

123.3.1.6 Non-vital circuits must utilize high-reliability solid-state technology for all non-vital logic, minimizing the use of non-vital relays. Failure of non-vital equipment must not affect the safety of the system.

123.3.1.7 All SRACS from the OEM of signal equipment must be met by the designer and application engineer.

123.3.1.8 The application engineer must submit a certification letter with evidence indicating how the design fulfills the criteria within each SRAC in the form of a table that contains each of the OEM SRACs in one column and the evidence in a separate column.

123.3.1.9 The design must use drop line bits in normal condition to show signal processor programming. Variable names must match existing Sound Transit programs.

Commentary: Redundant design by itself must not be considered an acceptable method of achieving design safety.

123.3.1.10 Provide system interface to maintenance center database to send system maintenance, indication/status, and other necessary data to the center for processing to inform predictive and maintenance scheduling.

123.3.2 ATP System

123.3.2.1 The ATP system must enforce each wayside signal.

123.3.2.2 In cab signal territory, the ATP system must enforce cab speed based on the control lines.

123.3.2.3 Signaling must enforce stops in the case of a red signal overrun.

123.3.2.4 Train detection methods must use track circuits for train detection throughout the system.

123.3.3 Interlockings

123.3.3.1 Signals placed at interlocking limits must govern train movements into and through interlocking limits.

123.3.3.2 Interlockings must be controllable from the LCC TCS and local control panel.

123.3.3.3 Routing through interlockings must utilize entrance/exit type control scheme.

123.3.3.4 Each non-conflicting route through an interlocking must be permitted simultaneously.

123.3.3.5 Interlockings must be designed for trains to make turnback moves across the interlocking with ATP protection.

123.3.3.6 Routes cleared to a destination, or across an interlocking, must assure switch locking, interlocking path track circuit vacancy, and no conflicting routes.

123.3.3.7 Routes must align all switches in the path with no manual throw required.

123.3.3.8 For Yards, turnback moves across interlockings must require additional signals.

123.3.3.9 Interlockings that have routes that diverge from a mainline track to a yard, storage track, or other mainline track must provide sectional release to allow for possible mainline routes to clear as early as possible.

123.3.3.10 Pocket tracks must have two separate interlockings at each end, using a 10-signal configuration such that sectional release is not required and the switches work in pairs.

123.3.3.11 For terminals with universal interlockings, sectional release must be provided to allow for faster route clearing for trains entering and exiting the terminal.

123.3.3.12 Interlocking switches that are not under a structure that will shield them from snowfall, must be equipped with electric switch snowmelters.

123.3.3.13 Before developing or purchasing the system software, the contractor should provide System Requirements Specifications that explain the system software functioning and interface with different systems and human-machine-interfaces to get approval from ST.

123.3.3.14 Contractor should provide Customer Requirement Specifications (CRS) based on ST operational manual and system specifications and get ST approval.

123.3.4 TWC System

123.3.4.1 The TWC system must provide the following functions:

123.3.4.1.1 Route requests

123.3.4.1.2 Cancel routes

123.3.4.1.3 Yard switch movement requests

123.3.4.1.4 AHCW system activation.

123.3.4.1.5 Train identification.

123.3.4.1.6 Vehicle car identification.

123.3.4.1.7 Vehicle location and tracking.

123.3.4.1.8 Motor vehicle traffic signal control interface.

123.3.4.1.9 Vehicle destination code.

123.3.5 Wayside Signals

123.3.5.1 Signal aspects for both the street running areas and interlockings are bar signals in accordance with Part 8 of MUTCD as amended by Washington State WAC 468-95-365 for light rail systems using both position and color differential to assist in defining proceed and stop conditions. Each signal must have an indication (meaning), which is the same wherever it is displayed throughout the Link system.

Table 123-1: LRT Signal Aspects and Indications – ATP

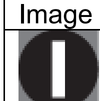
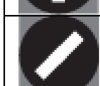
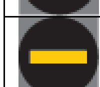
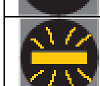
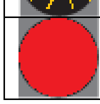
Image	Aspect	Meaning
	Lunar White vertical bar	Proceed straight ahead at the interlocking or street intersection.
	Lunar White angled bar	Proceed on the diverging route indicated at the interlocking.
	Amber horizontal bar	Stop.
	Flashing Amber Horizontal Bar	Dispatch signal is about to clear to allow train to depart.
	Bumper Signal Red	Stop before this point.

Table 123-2: LRT Repeater Signal Aspects and Indications

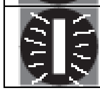
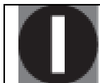
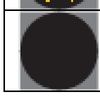
	Lunar White vertical bar	Signal ahead is cleared.
	Lunar White flashing vertical bar	Signal ahead is at stop. Be prepared to stop.

Table 123-3: LRT Signal Aspects and Indications – Street Running

	Lunar White vertical bar	Proceed but be prepared to stop short of any vehicle or obstruction.
	Lunar White flashing vertical bar	Timing out / cancelling proceed aspect. Check out cancel, time out cancel, failure of traffic cabinet cancels.
	Amber horizontal bar	Stop
	Flashing Amber Horizontal Bar	Committed in the process of clearing the white vertical bar – signal will change to white vertical bar shortly on specific timer.
	No Aspect	Stop, Contact LCC.

123.3.5.2 Wayside signals are required at the following locations:

123.3.5.2.1 Interlocking entrances.

123.3.5.2.2 Entrances to vent zones.

123.3.5.2.3 Repeater signals must be used in the instance where there is insufficient stopping distance to a signal with a train travelling MAS in street mode. The visibility of the signal will also play a role in making this determination.

123.3.5.2.4 Departure signals at terminal stations without interlockings or when interlocking is too far away.

123.3.5.2.5 Intersections in street running areas.

Commentary: Sighting distance for wayside signals is the industry standard of 600 feet. It is common that this sighting distance is not obtainable on curves and will need further review with stakeholders for mitigation.

123.3.6 Signal House

123.3.6.1 Non-wayside signal equipment must be housed within prefabricated signal bungalows except in tunnel alignments, where a signal room must be used.

123.3.6.2 Prefabricated bungalows must obtain Washington State L&I Gold Seal approval for prefabricated structures.

123.3.6.3 Bungalow location site design must provide parking for signal maintainer vehicles with easy access to the bungalow.

123.3.6.4 The bungalow location site design must also provide parking for a trailer mounted emergency generator within 50 feet and with the correct orientation for a power cable attachment to the connector plug on the exterior of the bungalow.

123.3.6.5 Signal bungalow and generator location must be located in area with adequate drainage and above flood levels. Refer to Set 901 Storm Drainage.

123.3.6.6 Signal equipment, including overhang, switch stand/handle, etc., clearances must be in accordance with Set 520 – Vehicle Clearances and Track Spacing.

123.3.6.7 Doors and lids of signal equipment cases and houses must open to full 180 degrees and be restrained from shutting by themselves.

Commentary: Doors best practice is to open to the field side, or to the wider side of clearance when installed between tracks. This also applies to pull box lids and other vertical doors.

123.3.7 Grade Crossing Active Treatment Activation

123.3.7.1 Grade crossing warning devices must be designed in conformance with Set 120 At-Grade Crossings.

123.3.7.2 See Set 125 Link Train Control Block Design for requirements regarding activation of at-grade crossing warning system.

123.3.8 Environmental Performance Requirements

123.3.8.1 All equipment, except batteries and UPS, must operate from a minimum temperature of -40 degrees Celsius (ambient) to a maximum temperature resulting from a combination of an ambient temperature, maximum sun loading, and maximum normal internal heat generation, of 55 degrees Celsius.

123.3.9 Adaptability and Expandability Requirements

123.3.9.1 The signal system design must include the following provisions to allow for future growth and expansion of the system:

123.3.9.1.1 At end-of-line equipment house locations, considerations must be incorporated into the system design and hardware configurations to minimize the effort of expanding the signal system when subsequent extensions are designed.

123.3.9.1.2 Additional space must be provided in housings for the installation of future equipment.

123.3.9.1.3 Signal system power supplies and the house utility service drop must include sufficient capacity to accommodate any proposed system expansion.

123.3.9.1.4 The Signal system designer must base the precise amount of additional space and utility capacity to be provided upon an analysis of future system requirements. Such analysis must be provided to, and agreed upon, by Sound Transit.

123.3.9.1.5 The design of individual racks and terminal boards must include sufficient space for the installation of future equipment and cable.

123.3.9.1.6 Provisions must be incorporated into the design of control and indication circuits to LCC for a logical expansion of the system.

123.3.10 Mainline to Yard Interface Requirements

123.3.10.1 Trains entering yard limits from the mainline must automatically be placed into street running mode with 25 miles per hour (MPH) max speed. Trains starting from within the yard must have the street mode manually selected.

123.3.10.2 The exact configuration of the transition between ATP / main track and street / yard track must be designed to match track geometry. These configurations are highly variable and dependent on track geometry.

123.3.10.3 Yard to mainline track interface must be submitted to Sound Transit during the preliminary project design phase.

123.3.10.4 There must be a unique TWC destination code for each yard entry/exit track. TWC calls will be made to request a route to the entry/exit track from either the mainline or from the yard.

123.3.10.5 The signal system design for exit from the yard must provide safe approach in street mode onto the final TWC loop that requests route onto the mainline taking overrun as a consideration.

123.3.10.6 Traffic circuits or directional route stick circuits must prevent head-to-head conflicting routes at the interfacing track circuits.

123.3.10.7 Although the LCC does not see or control the yard signal system, the LCC must have the ability to see interface track circuit occupancy, traffic direction, and alarm conditions from the yard bungalows via forwarding to the interfacing mainline bungalow to include in that location's SCADA data. Refer to Set 324 Train Control System – Light Rail for SCADA requirements.

123.3.11 Reliability Requirements

123.3.11.1 TCSs must meet or exceed the MTBF values listed in Table 123-4.

Table 123-4: Reliability Goals

Train Control System	MTBF (Hours)
Microprocessor-based Interlocking	36,000
Uninterruptible Power System	40,000
Audio Frequency Track Circuit	50,000
100 Hz Frequency Converter	120,000
Power Frequency Track Circuit	60,000
Maintenance Computer	50,000
Switch Control Module	24,000 MCBF
Switch Machine	24,000 MCBF

123.3.12 Other Requirements

123.3.12.1 On elevated alignments, wayside signals equipment, including junction boxes, must be within the railing and accessible from the roadway or maintenance walkways.

123.3.12.2 At terminal stations, storage tracks must have train detection and permit storage for a four-car train at a minimum.

123.3.12.3 Components subassemblies, and assemblies must be new and have a design with history of at least two years of successful revenue operation.

123.3.12.4 Vital relays, vital processors, non-vital processors, mainline switch machines, impedance bonds, frequency converters, batteries, battery chargers, power supplies, ground detectors, and UPS must have history of at least five years on at least three different railroad or rail transit properties in North America.

123.3.12.5 Track circuits must have history of at least five years on at least three different railroad or rail transit properties in North America.

123.3.12.6 All yard components that are not identified as having specific needs for yard operation must meet the same requirements as the equivalent mainline components. This includes signal processors (which do not need to be redundant for the yard bungalow), relays, power supplies, terminals, TWC interrogators (although TWC loops only need to be 6 feet, 6 inches long), wire, junction boxes, and heaters.

123.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

123.4.1 System Breakdown Structure

123.4.1.1 The Link TCS includes the following requirements:

123.4.1.1 ATP System

123.4.1.1.1.1 Cab Signal System

123.4.1.1.1.2 Cab Loops

123.4.1.1.1.3 Track Circuits

123.4.1.1.1.4 Impedance Bonds

123.4.1.1.1 Interlockings

123.4.1.1.1.1 Switch Machines

123.4.1.1.1.2 Snowmelters

123.4.1.1.1.3 Train routing

123.4.1.1.1.4 Locking

123.4.1.1.1.5 Traffic

123.4.1.1.1.6 Terminal modes

123.4.1.1.1.7 Insulated Joints

123.4.1.1.2 TWC System

123.4.1.1.2.1 Route Requests

123.4.1.1.2.2 TWC Loops

123.4.1.1.3 Wayside Signals

123.4.1.1.3.1 Signal Aspects

123.4.1.1.3.2 Signal Locations

123.4.1.1.3.2.1 Vent Zones

123.4.1.1.3.2.2 Interlockings

123.4.1.1.3.2.3 Departure Signals

123.4.1.1.3.2.4 Street Running

123.4.1.1.4 Signal Bungalow

123.4.1.1.4.1 Vital Processor

123.4.1.1.4.2 Logic

123.4.1.1.4.3 Power Distribution

123.4.1.1.4.4 Event Recorders

123.4.1.1.4.5 System Monitoring

123.4.1.1.4.6 Local Control Panel

123.4.1.1.4.7 LCC Interconnection

123.4.1.1.4.8 Relays

123.4.1.1.5 At-Grade Crossings - Active Treatment Activation

123.4.1.1.5.1 Nearside Crossing

123.4.1.1.5.2 Signal Priority/ Phase

123.4.1.1.6 Electromagnetic Interference (EMI)

123.4.1.1.7 Cabling

123.4.2 System Sites and Locations

Table 123-5: System Operation Types

Main Track	
At-Grade (separated)	This is the “standard mode” of right-of-way.
Elevated	Elevated track needs additional coordination related to maintaining signals, and potentially has tighter interlocking spacing that limits placement of equipment.
Tunnel	Tunnel alignments have different signal housing requirements as bungalows cannot be used and have vent zone requirements that the ATP system must enforce.
Street Running	This is a special operating mode where there is no ATP to enforce curve speeds or train separation. LRT signals are controlled by the AHJ’s traffic signal cabinet, and the LRVs run at the same level as the street.
Yard	
Yard	Yard requirements are similar but separate from main track requirements, as the operational needs are different between the two.

123.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identify the coordination points between this requirement set and other requirement sets.

Table 123-6: Interface between Train Control and Other Disciplines

SET SERIES	SET NAME	SET 123 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	X
400	Vehicle	X
500	Track	X
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	
1200	Security	X

123.5.1 At-Grade Crossings (Set 120)

123.5.1.1 Coordinate at-grade crossing active treatments with Set 120 At-Grade Crossings. Set 120 At-Grade Crossings includes requirements for how to determine what treatments need to be installed at each crossing, and how they are to be laid out; Set 123 and Set 125 Block Design describe how the active treatments are activated, monitored, and reported by the TCS.

123.5.2 Block Design (Set 125)

123.5.2.1 Coordinate TCS Block Design with Set 125 Block Design. Block design is all about where boundaries of track circuits are placed based on boundary conditions and operating scheme. Block design coordinates location of insulated joints, impedance bonds, B points, and other system features as required.

123.5.3 Traction Electrification (Sets 220, 221, and 222)

123.5.3.1 Coordination of negative return current, bonding, cross bonding, grounding at shared site locations.

123.5.4 Operational Communications (Sets 301, 302 and 324)

123.5.4.1 Coordination of indications to and controls from LCC, telephony, and network infrastructure requirements.

123.5.5 Vehicle (Set 421)

123.5.5.1 Coordination of automatic train protection, cab signal systems, and TWC. Minimum track circuit length is determined by the front and rear truck spacing of the LRVs. The center truck cannot be relied on to shunt a track circuit.

123.5.6 Track (Sets 520, 521, and 522)

123.5.6.1 Coordination of IJs, switch machines, impedance bonds, TWC loops, wayside signal, B point, track circuits, block design, track devices, crossing panels, guardrail, negative return, center tap cables, equipment clearances, snowmelter cases, relay cases, line of sight to signal devices, and LRV operating speed.

123.5.6.2 Verify civil elements do not conflict with insulated joint locations and train-to-wayside communication loops.

123.5.7 Fire/Life Safety (Set 601)

123.5.7.1 Coordination and enforcement of vent zones, coordination of escape routes, maintenance-of-way accessibility walkways, along alignment versus signal equipment locations.

123.5.8 Structures (Set 720)

123.5.8.1 Coordination of bungalows, foundations, and stub ups. The structures and signals design must also coordinate any structure-related operational constraints. For example, if a bridge is designed with a maximum speed of 35 miles per hour, the signal system will have to enforce a 35-mile per hour maximum speed on that bridge. Another example is that if a bridge is designed to only handle two trains at a time, the signals system must then be designed to enforce this restriction.

123.5.9 Architecture (Set 822)

123.5.9.1 Coordination of architectural elements not limiting line of sight to signal devices

123.5.10 Civil (Sets 901, 902, 903, 904, 905 and 906)

123.5.10.1 Coordination of conduit, drainage, location of civil items and other systems versus signal equipment locations.

123.5.11 Mechanical-Electrical and Building Systems (Sets 1004, 1006, 1007)

123.5.11.1 Coordination of BMS and alarms and indications from signal bungalows and rooms back to LCC. Coordination of electrical raceway and lighting requirements for signal houses.

123.5.12 Security (Sets 1202 and 1203)

123.5.12.1 Coordination of camera locations and access-control to signal bungalows and rooms.

123.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

123.6.1 ATP System

123.6.1.1 The ATP system must include a bidirectional cab signal system with overspeed protection.

123.6.1.2 The ATP system must provide information to the LRV operator regarding conditions ahead. Conditions ahead are defined as: switch position, track occupancy, civil speed restrictions, and terminal locations.

123.6.1.3 The ATP system must provide a method of manually selecting restricted maximum authorized speeds for each ATP track circuit.

123.6.1.4 The ATP system must enforce a 2-second loss of shunt timer when outside of interlockings.

123.6.1.5 In street running territory, the ATP system will only govern the MAS.

123.6.1.6 The ATP system must coordinate with requirements in Sets 421 Light Rail Vehicle and 125 Block Design.

Commentary: During an overspeed condition, the carborne ATP equipment must remove propulsion power from the motors, apply a safety brake, and provide both an audio and visual alarm to the train operator. If the overspeed condition exists and there is a delay in acknowledgement from the operator, the carborne ATP equipment must command an irrevocable penalty-brake application request.

123.6.1.7 Cab Signal System

123.6.1.7.1 The cab signal system includes transmission, reception, and enforcement of the ATP speed limit as transmitted to the vehicle by vital wayside equipment.

123.6.1.7.2 SBDs must be maintained by cab signal systems.

123.6.1.7.3 The wayside cab signal system must transmit cab signal speed commands to the train.

123.6.1.7.4 The carborne display unit must display the maximum enforced speed limit in the operating cab.

123.6.1.7.5 Signal house must be equipped rotary dial designed to adjust the maximum speed allowable in a particular track circuit.

123.6.1.7.6 As a minimum, the system must recognize and enforce at least the following eight ATP speed codes. A zero code must be used to command a stop. The cab signal system must interpret the absence of code in cab signaled territory as zero code.

Table 123-7: ATP Speed Codes

Speed Command	Frequency (Hz)	Period (ms)
0 MPH	No Code	No Code
10 MPH	6.94	144
20 MPH	7.81	128
30 MPH	8.93	112
35 MPH	10.42	96
40 MPH	12.5	80
45 MPH	15.63	64
55 MPH	20.83	48

123.6.1.7.7 In addition to the mainline ATP speed codes, the following two street running code rates must be transmitted to switch the cab signal operation to either a 35-mile per hour or 25-mile per hour street running mode. A street running mode command must be transmitted to trains approaching the end of cab-signaled territory. This command will allow the train operator to drive the train manually in the street-running mode with system speed up to 25/35 miles per hour.

Table 123-8: Street Running Speed Codes

Speed Command	Frequency (Hz)	Period (ms)
Street Running 25 MPH	4.17	240
Street Running 35 MPH	6.25	160

123.6.1.7.8 The cab signal system must coordinate with requirements in Set 421 Light Rail Vehicle.

123.6.1.7.9 Cab loops

123.6.1.7.9.1 Normal/straight routes must use either cab loops or direct injection.

123.6.1.7.9.2 Reverse direction/diverging route must utilize cab loops to transmit speed codes.

123.6.1.7.10 An overrun condition must prevent the train from receiving cab signal

123.6.1.8 Track Circuits

123.6.1.8.1 The technology of choice must be audio frequency double rail jointless track circuits as the most economical method to provide detection and cab signal.

123.6.1.8.2 Track circuits must be single rail 100 hertz or audio frequency type when track circuits extend over special track work conditions.

123.6.1.8.3 Street running alignments do not require cab signaling, allowing the possibility for double or single rail 100-hertz track circuits, phase shift overlay, or audio frequency train activated circuit to be used.

123.6.1.8.4 The design of the LRV propulsion and traction systems and selection of track circuit frequencies and modulation schemes must preclude interference between the LRV and the signal system.

123.6.1.8.5 A shunt with a resistance of 0.2 ohms at any point between the two rails of any track circuit must cause the track circuit to be deenergized. Voltage regulating transformers in the feed to the track may be used or additional track circuits may be installed, if necessary, to provide this shunting capability.

123.6.1.8.6 Track circuit boundaries and IJ position must be coordinated to detect all overrun conditions.

123.6.1.9 Cross Bonds

123.6.1.9.1 Coordinate cross bond placement with Set 220 Traction Power to minimize traction power return current imbalance.

123.6.1.9.2 Cross bonds must be installed without modifying block boundaries.

123.6.1.9.3 Cross bonds must not be placed at both ends of a single-track circuit.

123.6.1.9.4 IJ Placement

123.6.1.9.4.1 IJs must be placed where required by the signal system for proper system operation, coordinating with Set 522 Trackwork Construction.

123.6.1.9.4.2 Insulated joints must be placed to allow for maximum sectional release. This is typically located at the clearance point on the tracks, specifically at junction locations, pocket tracks, and yard ladders.

123.6.1.9.5 Yards

123.6.1.9.5.1 Yard interlockings require track circuit coverage. Trackway that acts as connecting run-around track between interlockings or yard to mainline must also have track circuit coverage. Non-interlocking tracks such as storage or shop do not require track circuit detection.

123.6.1.9.5.2 Yard track circuit selection can allow single rail power frequency, phase shift overlay, or audio frequency train activated circuit technology. Installation may utilize up to 2 receivers to provide diverging coverage or may use shunt fouling arrangement provided a 0.2 ohms shunt requirement can be assured anywhere in the track circuit. If power frequency track circuits are used, the phase must be swapped on adjacent circuits separated by an IJ.

123.6.1.9.5.3 Negative return and cross-bond must keep rail voltage as low as feasible.

123.6.1.9.5.4 The return path must not be dependent upon traversing trackway switch ladders.

123.6.1.9.5.5 Bonding and cross bonding on yard interlocking negative return rails must be redundant 500 MCM.

123.6.1.9.5.6 Bonding used exclusively for signal purposes must be redundant 250 MCM.

123.6.1.9.5.7 Negative return path design must keep in mind that yard traction power system is isolated from mainline and shop TP systems. The transition must assure a return path for any LRV transitioning from one to the other.

123.6.1.9.5.8 IJs must be located to isolate negative return between main and yard, and yard and shop TP. The positive OCS connection design must be coordinated with the location of these IJs – see Set 200 Traction Electrification. Shop locations will also have additional coordination of IJ, track circuit, OCS design, and TWC location.

123.6.1.9.5.9 For track circuit boundary requirements, see Set 125 Link Train Control Block Design.

123.6.2 Interlockings

123.6.2.1 Powered switches, movable-point frogs, over-switch track circuits and the associated governing signals must be interlocked.

123.6.2.2 Opposing or conflicting signals and routes must also be interlocked.

123.6.2.3 For a route to clear across an interlocking, the first track circuit beyond the interlocking within the route must be unoccupied.

123.6.2.4 Interlockings must have a 5-second loss of shunt prevention.

123.6.2.5 Logic must permit trains in the first track circuit outside an interlocking to turn back into unoccupied traffic zone with full signal protection.

123.6.2.6 Interlocking design must be closely coordinated with Set 522 Track Construction. The coordination of insulated joints, bonding, signal placement, crossing panel placement, TWC loop location, guardrail, and track circuits is critical. These items must be placed with signal system functionality and maintenance as the top priority.

123.6.2.7 Switch Machines

123.6.2.7.1 Switch machines must conform to all FRA and AREMA standards for power-operated rail switch machines.

123.6.2.7.2 The switch machines must provide for indication that the switch points have been moved to and are in the full normal position or full reverse position.

123.6.2.7.3 The switch machines must provide out of correspondence indication.

123.6.2.7.4 Switch machines must be powered. Manual switches must not be used.

123.6.2.7.5 Powered track switches/machines must be dual control (motor driven/manual).

123.6.2.7.6 Power for the switch machines must be from the signal bungalow.

123.6.2.7.7 Switch machines must be equipped with insulated operating rods, lock rods (mainline), and point detector rods.

123.6.2.7.8 Switch machines must be equipped with a local cutout switch that removes power from the motor circuit.

123.6.2.7.9 Switch machines must have overload protection, either by dedicated overload relay or internal to the switch machine controller.

123.6.2.7.10 Application logic must have overload timer such that if correspondence is not met within a certain time, the throw will be cancelled.

123.6.2.7.11 Switch machine plinths must be poured to match the correct foundation for the type of switch machine being used and must be at the correct height to support machine install.

123.6.2.7.12 Switch machine layout must include 24 inches to 30 inches of clearance to allow maintenance and manual operation of switch machines.

123.6.2.7.13 Mainline Switch Machines

123.6.2.7.13.1 Must provide a means for locking to prevent switch point movement when points are in full normal or full reverse positions.

123.6.2.7.13.2 Indications for each individual switch machine must be indicated to LCC.

123.6.2.7.13.3 In dual main track alignments, switch machines must be located on the outside of the two main tracks.

123.6.2.7.14 Yard Switch Machines

123.6.2.7.14.1 Yard switch machines must be trailable and designed specifically for yard operation.

123.6.2.7.14.2 The installation must include vital switch position indication either by a separate switch circuit controller or that function may be included in the switch machine body.

123.6.2.7.14.3 Yard switches must be of a non-embedded type.

123.6.2.7.15 Emergency crossing walkways must be located sufficiently far away from an interlocking such that there is no conflict with the insulated joint, TWC loop, signal, or impedance bond installations.

123.6.2.8 Special trackwork must be bonded for correct signal system operation and coordinated with Set 522 Track Construction.

123.6.2.9 LCC and LCP must have the capability to enable and disable blocking of interlocking wayside signals, and track sections between interlockings and switches.

123.6.2.10 All interlocking signals must be equipped with a positive means of detecting stop signal violation.

123.6.2.11 Stop signal violations must be recorded on the local event recorder, as well as being sent to LCC as an alarm via the SCADA system.

123.6.2.12 Yard interlocking logic must incorporate sectional release where it would allow a non-conflicting route.

123.6.2.13 The need for a derail for mainline usage must be evaluated during design.

123.6.2.14 Derail circuit design must include a circuit controller which provides normal and reverse indications to LCC.

123.6.2.15 Derails must be dual control (power/manual).

123.6.2.16 Derails must be protected by signals.

123.6.2.17 A switch blocking circuit must be provided for each switch within an interlocking. The block will be initiated from LCC or the local control panel. This block must be vitally interfaced with switch and signal circuits to prevent operation of such switch and clearance of route over the switch when the block is in effect.

123.6.2.18 Snowmelters

123.6.2.18.1 Snowmelter must automatically energize given the combination of a low temperature setting plus moisture.

123.6.2.18.2 The LCP must be able to select manual snowmelter operation for one cycle to bypass the moisture requirement.

123.6.2.18.2.1 The manual snowmelter cycle must turn the snowmelter on for a user adjustable amount of time (nominally 45 minutes).

123.6.2.18.2.2 After a manual cycle has run, another timer must delay automatic activation by temperature and moisture for a user definable amount of time.

123.6.2.18.3 Snowmelters must either utilize crib and Calrod type heating elements or be hot air blower type.

123.6.2.18.4 Snowmelter system must keep detector, throw, and lock rods clear of ice and snow.

123.6.2.18.5 Snowmelter system must have the capability to heat the running rails from the heel block to 6 inches beyond the switch point.

123.6.2.18.6 Crib and Calrod snowmelter layouts:

123.6.2.18.6.1 Must be equipped with a switch heater set including two crib heater and two rail heater elements.

123.6.2.18.6.2 Heaters must be 240 volt AC single ended construction.

123.6.2.18.6.3 Rail heaters must be flat on one side to provide best possible heat transfer.

123.6.2.18.6.4 Crib heaters must be 1000 watts each and rail heaters must be 200 watts per foot mounted to center of rail web.

123.6.2.18.6.5 Heater control must be by multiple heater control cabinets near groups of switches.

123.6.2.18.6.6 Each cabinet must have the capability to manually control those heaters.

123.6.2.18.6.7 Stock rail switch heater element effective heating section must extend from the heel block to 6 inches beyond the switch point.

123.6.2.18.7 LCC has no control of the snowmelters but must receive indications of snowmelter status.

123.6.2.19 Train Routing

123.6.2.19.1 An interlocking in auto mode must automatically route trains to the appropriate track. The interlocking must clear the auto route based on occupancy of a one-track circuit beyond the SBD approach to the interlocking.

123.6.2.19.2 All normal direction routes must be automatically cleared.

123.6.2.19.3 Automatic route rotating priority must be provided to control the flow of trains through interlockings where conflicting automatic and/or wayside push button requests will be vying for routes through interlockings. Priority must be issued on an alternate basis unless overridden by LCC.

123.6.2.19.4 Manual routes must be requested either by LCC, LCP, or via TWC call. LCC and LCP called routes must be an entry/exit operation. See Section 123.6.3 TWC System for TWC routing.

123.6.2.20 Locking

123.6.2.20.1 The following types of locking must be provided:

123.6.2.20.1.1 Approach Time Locking

123.6.2.20.1.1.1 Approach time locking must lock switches within a route governed by a cleared wayside signal when a train is occupying the approach circuit to such signal.

123.6.2.20.1.1.2 Once initiated, approach time locking must remain in effect until the locking time has transpired or until released by the occupancy of the first two track circuits in the locked route.

123.6.2.20.1.1.3 Approach time locking must prevent clearing of wayside signals for opposing or conflicting routes for a predetermined time after a cleared wayside signal has been reset to stop unless the approach to such signal was unoccupied while the signal was cleared.

123.6.2.20.1.1.4 Approach time locking must be provided for all controlled signals.

123.6.2.20.1.1.5 Approach release time must be calculated in accordance with AREMA Signal Manual Section 2.4.20.

123.6.2.20.2 Route Locking

123.6.2.20.2.1 Route locking is initiated any time a signal is cleared in an interlocking and must lock all the switches the train will traverse and must prevent clearing of opposing or conflicting signals within the interlocking.

123.6.2.20.2.2 Route locking must remain in effect until the route is canceled, the train has cleared the interlocking or satisfied sectional release, or if sectional release is incorporated into the interlocking.

123.6.2.20.2.3 Sectional release must unlock a portion of the route as the train progresses through the interlocking.

Commentary: This will allow the clearing of different, non-conflicting route before the first train has cleared the entire interlocking. Switch locking must be released only when approach locking, time locking, route locking, overlap locking, sectional release, and detector locking have released.

123.6.2.20.3 Detector Locking

123.6.2.20.3.1 Detector locking must lock all switches within the limits of a track circuit when such track circuit is occupied.

123.6.2.20.3.2 Detector locking must not be released by momentary loss of shunt up to 5 seconds.

123.6.2.20.4 Traffic Locking

123.6.2.20.4.1 Individual traffic locking logic must be provided for each section of track between interlockings.

123.6.2.20.4.2 The direction of traffic on a section of track must be locked when any track circuit within that track section is occupied, or when a route is requested into that track section, or when approach or route locking is in effect for the signal that has been cleared into that track section.

123.6.2.20.4.3 Five-second loss of shunt protection must be provided for traffic locking.

123.6.2.20.4.4 When traffic is not locked, the traffic logic must maintain the direction of traffic until reverse traffic is called.

123.6.2.20.4.5 In the event of signal processor power loss at one or both ends of a traffic circuit, the traffic direction must be remembered by a magnetic stick relay outside of the signal processor such that traffic direction will be re-established automatically.

123.6.2.20.4.6 Yard connector tracks that serve as run-around tracks between interlockings or at the yard to mainline interface must also have directional stick or traffic circuit to prevent a head to head meeting with routes from two separate interlockings.

123.6.2.20.5 Overlap Locking

123.6.2.20.5.1 Overlap locking must lock the switch(es) beyond a stop signal when there is possibility that the braking distance could extend past it, ensuring there is a path in case of a red signal overrun.

123.6.2.20.5.2 Overlap locking must expire after a predetermined time that is configurable.

123.6.2.20.6 Time Locking

123.6.2.20.6.1 Time locking must be used in situations where approach time locking is not possible. For example, signals in yards typically don't have distance or multiple track circuits available to be used as approach track circuits. Time locking is used to prevent premature switch movement or conflicting route clearing until a predetermined amount of time has passed.

Commentary: Locking is essential for preventing the unsafe operation of switches and to prevent the clearing of signals for opposing or conflicting routes.

123.6.2.21 Terminal modes

123.6.2.21.1 Train operation at terminal interlockings must be sequenced by mode selection. Mode selection logic must automatically determine the tail track and/or platform track that each train will take as it arrives at the terminal. Operation must be as follows:

123.6.2.21.1.1 Mode 1 is automatic route selection to either track for incoming trains, the diverging route being the preferred route.

123.6.2.21.1.2 Mode 2 is automatic route selection to the diverging track only into terminal station.

123.6.2.21.1.3 Mode 3 is automatic route selection to normal track into terminal station.

123.6.2.21.1.4 Manual mode is no automatic routing.

123.6.2.21.2 Pocket mode must also be accounted for based on terminal interlocking configuration.

123.6.2.21.3 Terminal mode selection must be made available to LCC via the SCADA system and locally via LCP. See SET 320 SCADA CENTRAL

123.6.3 TWC System

123.6.3.1 The TWC subsystem must be a 19-bit 100-kilohertz frequency shift keyed system compatible with the VETAG system provided on the vehicles.

123.6.3.2 A TWC subsystem must be provided to locally request and cancel normal operating routes, activate AHCW Systems (where applicable and not approach activated), and provide input to street traffic control systems, as operational requirements dictate.

123.6.3.3 Route Requests

123.6.3.3.1 The LRT operator must be able to request a route while parked over TWC loop with either a "CALL" + "Left/Right" or "CALL" + "Destination Code".

123.6.3.4 TWC Loops

123.6.3.4.1 TWC loops must be located at the following locations:

123.6.3.4.1.1 Two-car stop at station platform at terminals and at nearside stop locations on the normal direction track.

123.6.3.4.1.2 Four-car stop at station platform at terminals and at nearside stop locations on the normal and reverse direction tracks.

123.6.3.4.1.3 All four approaches to a main-track universal or diamond interlocking.

123.6.3.4.1.4 Pocket track berthing locations.

123.6.3.4.1.5 Tail track berthing locations.

123.6.3.4.1.6 Entrance and exit sides of an intersection on street-running alignments.

123.6.3.4.2 TWC loops must be clear of any obstructions (i.e., conduits, guardrails) that may cause interference with communication with loop and onboard transponder.

123.6.3.4.3 TWC loop antenna must be constructed in a figure 8 pattern as shown on standard drawings or alternate pattern that is compatible with the current system configuration. Loops are to be housed in a prefabricated fiber glass enclosure that will be located in center of trackway no higher than the top of rail.

123.6.3.5 TWC must be used to transmit train destination from the vehicle to wayside equipment to facilitate automatic routing. TWC must also permit a signal to be generated manually by the train operator to crossing starts or signal requests, as may be required at a station. Where requests are transmitted from the vehicle in a standing position, the circuits must also provide a cancel for the request.

123.6.3.6 TWC interrogators must provide the functions and information required to deliver a complete functional system.

123.6.3.7 TWC interrogators units must be H&K type HCS-V bidirectional units or Sound Transit approved equivalent.

123.6.3.8 The TWC system must have the following destinations programmed in yard locations:

123.6.3.8.1 Storage tracks.

123.6.3.8.2 Shop tracks.

123.6.3.8.3 Carwash.

123.6.3.8.4 Yard/mainline interface.

123.6.3.9 The destination codes must match the numbering schema utilized in existing yards.

123.6.4 Wayside Signals

123.6.4.1 Signals must be continuously illuminated. Signals must be LED type.

123.6.4.2 All wayside train signals must be equipped with number plates to facilitate identification and simplify record keeping in accordance with Sound Transit provided numbering scheme.

123.6.4.3 Signal Aspects

123.6.4.3.1 A wayside signal must not display a more permissive aspect from that intended because of a burnt-out lamp or broken wire. A dark signal indicates the most restrictive signal aspect.

123.6.4.4 Signal Locations

123.6.4.4.1 Location of the signals must permit non-ambiguous indication to the operator as to which track is being controlled.

123.6.4.4.2 LRT signals for intersections at street running areas must be duplicated on the near and far side of the intersection.

123.6.4.4.3 All signals must be installed in accordance with recommended practices and must be as close to the train operator's head level as practicable.

123.6.4.4.4 Signals installed within public rights-of-way must conform to applicable codes with respect to clearances.

123.6.4.4.5 Signals at station locations must be visible from both the two and four car stop locations, in both directions. The station architecture must conform to allow this visibility.

123.6.4.5 Vent Zones

123.6.4.5.1 Vent zones must be protected by signals, enforced by ATP for maximum train requirements, and coordinated with Set 601 Fire–Life Safety.

123.6.4.5.2 Entries into vent zones must have wayside signals.

123.6.4.6 Interlockings

123.6.4.6.1 Each interlocking entrance must have a wayside signal.

123.6.4.7 Departure Signals

123.6.4.7.1 Departure signals must be placed at the end of platform in the direction of travel in the following cases:

123.6.4.7.1.1 For terminal stations where it is not possible to have an interlocking within 800 feet of the direction of travel.

123.6.4.7.1.2 For terminal stations with no interlocking on the same side of the platform as the direction of travel such as Lynnwood, where the interlocking is on the back side of the platform(i.e., pull through then change tracks, then berth.

123.6.4.8 Mainline Alphanumeric Signal

123.6.4.8.1 Alphanumeric signals of two types must be utilized when interlockings are too complex for the end destination to be displayed by vertical and slant white bars alone.

123.6.4.8.1.1 LED letter aspect E, W, N, or S: This aspect indicates to the operator that the train will end up on the Eastbound, Westbound, Northbound, or Southbound track once leaving the interlocking, for more complex interlockings such as Kirkland Junction.

123.6.4.8.1.2 LED number aspect 1, 2: This aspect indicates to the operator that the train will enter the yard on track X1 or X2 at more complex interlockings such as Kirkland Junction. The yard TWC destinations will have a 1 or 2 in the second position, with the first position being variable depending on the yard (i.e., operations and maintenance facility central is code 31, 32, operations and maintenance facility east is 41, 42, and so on).

123.6.4.9 Yard Alphanumeric Signal

123.6.4.9.1 "- -" Aspect: Stop, make route request. Sign has no requests active; normal indication.

123.6.4.9.2 Flashing "- -": Requested route conflicts with another cleared route request, cleared route, or occupancy within the route request.

123.6.4.9.3 "XX" (two numbers): Displays the requested TWC destination code.

123.6.4.9.4 Flashing "XX" (two numbers): For signs that have multiple TWC request locations, where a valid destination code has been accepted by the logic and the switches and traffic circuit are in the process of aligning.

123.6.4.9.5 "NA": Used for TWC route requests that are not achievable from the requesting location.

123.6.4.9.6 If the operator requests a destination that conflicts with another route request, cleared route, or occupancy within the route then a flashing "- -" must be displayed for a user-definable time between 3 and 15 seconds before returning to a solid - - ". The exception is a TWC request from a loop sharing the yard numerical sign already displaying a numerical destination. In this case, the number or flashing number destination must continue.

123.6.4.9.7 Any TWC requested destination that cannot have a track alignment path from that loop must cause a display of "NA" for a user definable time between 3 and 15 seconds before returning to a solid " - - ".

123.6.4.9.8 Each display of a requested destination number that is not conflicted will be preceded by a flashing of the number until alignment is complete.

123.6.4.9.9 Wayside alphanumeric signs within the yard must let the operator know when his route request is decoded, if the requested route is valid, if the route is conflicted by another route or occupancy, if the route request is accepted and is being aligned; and if the route is aligned and locked. This is done using amber displays on variable message numerical signs capable of two digits or letters facing the TWC loop making the request.

123.6.4.9.10 If signal visibility allows, numerical signs may face more than one TWC loop that can request share entry into an interlocking. TWC loops with additional non-conflicting routes must have their own numerical sign.

123.6.4.9.11 If the yard alignment requires a turn-back track within an interlocking, then a second destination sign will be required for the second part of the route, but the logic must permit thru routing requests to the ultimate destination. As the train enters the interlocking the sign must turn from solid number to "- -", but route locking must protect the route. The second sign, if there is one in that pathway, must remain as a solid number until that portion of the interlocking is entered.

123.6.4.9.12 When a cancel button is used it will remove any displayed destination and must indicate "- -" to permit a new destination to be entered. If the route has already been cleared with a solid destination, then route locking must be maintained for a user selectable time.

123.6.5 Signal House

123.6.5.1 Each signal house will be equipped with a maintenance computer connection with signal processor capable of performing, maintenance, and observation of variable logging which may either be within the maintenance computer or signal processor. Logging must have the capacity to observe at least one week of events for a normal operation.

123.6.5.2 Each signal house will have an LCP.

123.6.5.3 Signal system equipment must be in wayside cases, bungalows, or signal rooms provided in the tunnels and at stations in signaled territory.

123.6.5.4 Signal cases, bungalows, and rooms must be adequately ventilated.

123.6.5.5 Signal bungalows and signal rooms must be adequately climatized for winter and summer.

123.6.5.6 Signal bungalows must meet Washington State L&I required light levels when fully populated with equipment.

123.6.5.7 Signal rooms must meet light requirements in Set 1007 Electrical Lighting when fully populated with equipment.

123.6.5.8 Signal houses containing cab signal equipment must have air-conditioning units. Climatic conditions are described in Set 720 Building Structures.

123.6.5.9 Equipment housings must be located in such a way as to not obstruct the train operators’ or motorists' (insofar as grade crossing warning equipment is concerned) view of the governing signal.

123.6.5.10 Bungalow locking hardware must meet Washington State L&I requirements and be coordinated with Set 1203 Access Control System and Set 720 Building Structures.

123.6.5.11 Controls and indications must be communicated between wayside signal equipment and the LCC via the SCADA system. The signal system must provide remote terminal unit functions to collect required information and communicate it in the necessary format and protocol.

123.6.5.12 Each signal equipment location room or bungalow must be equipped with a SCADA interface.

123.6.5.13 SCADA indications must include train positions, operating direction, interlocking status, control mode status, alarm indications, grade crossing status, signal status, switch status, status of blocks, and TWC information.

123.6.5.14 SCADA controls to the field location must include route and signal controls, control modes, terminal mode (at terminal stations), switch controls, and blocks of equipment control.

123.6.5.15 To the maximum extent possible, all signal control circuitry, including grade crossing warning control equipment and batteries, must be in walk-in central instrument locations located near to the equipment being controlled and providing easy accessibility by maintenance forces. Provide maintainers parking and parking for mobile trailer mounted emergency generator.

123.6.5.16 Grounding electrodes must be provided and installed in the signal rooms. Ground rods must also be installed at all signal cases. All connections to grounding electrodes must be by exothermic welding.

123.6.5.17 A grounding system must be provided for wayside signal system equipment in accordance with AREMA Signal Manual Section 11.4.1. DC resistance to ground must not exceed 25 ohms.

123.6.5.18 For signal bungalows and cases installed at the same site with a Traction Power Substation, an engineering study must be completed to determine if the grounds should be tied together. If the bungalow or case and the traction power substation are close enough that a person could touch both the same time, both must have their grounding tied together. Grounding at a signal system site must be coordinated with Set 1005 Electrical Power.

123.6.5.19 Wayside signals equipment connected to the running rails, such as switch machines and impedance bonds, must be electrically isolated from earth.

123.6.5.20 All electronic and solid-state devices must have effective internal and separate external surge protection. High-voltage lightning arrestors must be applied to commercial power connections.

123.6.5.21 Lightning protection including appropriate lightning arresters and equalizers must be provided at all input terminals interfacing with wayside signal appliances.

123.6.5.22 Room-to-room and room-to-wayside equipment signal wires must not be combined with signal power wires in the same cable nor must signal cable, power cable, or communication cable be run in the same conduit where duct bank is provided.

123.6.5.23 Case wiring must be #16 American wire gauge or larger as needed by the design requirements.

123.6.5.24 Wire and cable must comply with all the applicable sections of the AREMA Manuals – Signal Sections. A minimum of 10 percent, but not less than two spare conductors, must be required in each cable.

123.6.5.25 Signal bungalows must be prefabricated, prewired, and sized to accommodate all equipment required to operate that part of the system for which it will be designed, including the necessary provisions for growth and expansion.

123.6.5.26 Signal houses must provide sufficient space for the installation of communications system equipment, where applicable.

123.6.5.27 The signal system must have its own dedicated fiber network and communications equipment. For additional communication system requirements, see Set 301 Communications Infrastructure.

123.6.5.28 For signal rooms, an emergency eye-wash unit must be provided, suitably located inside.

123.6.5.29 Signal houses are normally unattended, and the design must provide reasonable protection against intruders and vandalism.

123.6.5.29.1 An intrusion detection system must be installed.

123.6.5.29.2 Any intrusion must be made immediately known to the LCC, or the security operations center, as directed by Sound Transit.

123.6.5.29.3 Each side of the house must be monitored by a CCTV camera.

123.6.5.30 Signal houses must contain portable fire extinguisher and fire detection (refer to Set 601 Fire–Life Safety).

123.6.5.31 A telephone must be installed within the signal house for use by authorized personnel (refer to Set 302 Telephony).

123.6.5.32 A work table must be included against the wall within the signal house. Shelving and cubbyholes must be included beneath the work table for the storage of binders, drawings, and small tools.

123.6.5.33 All equipment and components mounted on racks must be accessible for testing or replacement without removal of other components.

123.6.5.34 Design must provide for cooling air space around all transformers, rectifiers, reactors, and other heat generating devices.

123.6.5.35 All relays, equipment, and entrance racks will have reference test points for all voltages associated with the equipment installed on such racks.

123.6.5.36 Junction boxes for signal equipment must meet the requirements of AREMA Signal Manual, Parts 7 and 15.

123.6.5.37 Junction boxes must be provided with gaskets to prevent entrance of moisture and dust, in accordance with the AREMA Signal Manual, Part 15.2.10.

123.6.5.38 Mast-mounted equipment must be provided with split-base junction boxes.

123.6.6 Vital Processor

123.6.6.1.1 The type of equipment to be used for signal control circuits must be vital microprocessor.

123.6.6.1.2 Relay logic may be used where special purposes or functions make it advisable.

123.6.6.1.3 Each location must have a normal and warm standby signal processor with automatic switchover when a failure is detected.

123.6.6.1.4 Microprocessor units must be modular and consist of stand-alone card files or modules capable of being mounted in standard instrument racks.

123.6.6.1.5 All equipment required to provide a complete standalone system must be included in the instrument rack.

123.6.6.2 Logic

123.6.6.2.1 The application logic must be designed using normal condition drop line relay logic.

123.6.7 Power Distribution

123.6.7.1 The configuration of the signal power system must be compatible with a combination cab signal system with TWC control in street running segments.

123.6.7.2 AC power must be provided from the most convenient source, such as passenger station or utility drop.

123.6.7.3 AC power must not be provided from a traction power substation compound.

123.6.7.4 Battery systems, preferably UPS, must be used to provide backup to maintain normal operation of the signal system, except for grade crossing equipment. In the event of AC power system failure, grade crossing must be operational for at least 4 hours.

123.6.7.5 Yard signal system power does require a bungalow UPS, which may require limiting the number of switches that can throw at the same time.

123.6.7.6 Signal housings that are not a room built into a station and that have cab signal control circuits or interlocking control must have an exterior weatherproof auxiliary power outlet connector to permit a standby generator connection. Outlet must be compatible with existing Sound Transit equipment.

123.6.7.7 Event Recorders

123.6.7.7.1 Each signal equipment room must be equipped record events transpiring with the signal equipment. Events to be recorded must include:

123.6.7.7.1.1 Status of each track circuit (occupied or not).

123.6.7.7.1.2 Switch status (locked, normal, reverse, or not in correspondence).

123.6.7.7.1.3 Status of each signal.

123.6.7.7.1.4 Route requests.

123.6.7.7.1.5 Status of all alarms (including room power, grade crossing power, signal overrun, grade crossing malfunction, or equipment health).

123.6.7.7.1.6 Status of grade crossing XR (energized or de-energized), crossing preempt.

123.6.7.7.1.7 Status of grade crossing entrance, exit, and pedestrian gate arms as applicable (vertical, horizontal, or in transition).

123.6.7.7.1.8 Status of operational switch, track, and signal blocks applied by LCC or the LCP.

123.6.7.7.1.9 Communications status with adjacent signal housings.

123.6.7.7.1.10 Signal processor status.

123.6.7.7.1.11 Status of traffic circuits.

123.6.7.7.1.12 Status of interlocking mode (Auto, Local, or LCC).

123.6.7.7.1.13 Date/time.

123.6.7.8 Local Control Panel

123.6.7.8.1 A computer screen capable of performing local control panel functions must be installed at all signal equipment rooms.

123.6.7.8.2 The local status functions must include track occupancies, switch condition (normal, reverse, locked, out of correspondence), signal aspects including numerical sign, signal fleeting, traffic direction status, operational blocks (signal, track, and switch) applied by LCC or the LCP, grade crossing status, snowmelter status, ambient environment status, control mode (remote/local/ auto), alarms, and route requests.

123.6.7.8.3 The local control functions must include the capability to initiate and cancel any request for signals (utilize entrance/exit logic for signal request), add or remove operational blocks, position switches for routes, select terminal modes, and operate each power switch or crossover individually.

123.6.7.8.4 LCP must also display status of local and LCC communication links, system status, active VHLC unit (normal/ standby), LCP health, AC/ DC power status, and ground fault status.

123.6.7.8.5 The LCP must have the capability to individually request switch positions, request routes, and override the moisture sensor portion of the switch heater automatic turn-on for a user adjustable time.

123.6.7.8.6 The LCP must be designed to have precedence over the LCC.

123.6.8 At-Grade Crossing Active Treatment Activation

123.6.8.1 See Set 120 At-Grade Crossings for crossing treatment application and configuration.

123.6.8.2 The operation of AHCW system equipment must be based on a design that includes approach and island track circuits and must avoid unnecessary delays to motorists. See Set 125 Link Train Control Block Design for requirements related to the track circuit setup.

123.6.8.3 Grade crossing warning equipment must be backed up by Ni-CAD battery capacity sufficient to illuminate the warning lights for eight hours and to support normal revenue service for 90 minutes minimum.

123.6.8.4 The crossing logic must monitor gate positions (vertical and horizontal) of entry and exit gates.

123.6.8.5 The logic must cause an alarm whenever the crossing warning is activated with no trains in the crossing area or if the grade crossing gate stays down for an excessive time.

123.6.8.6 At AHCWS intersections “Another Train Coming” signs must be energized and activated by the signal crossing bungalow.

123.6.8.7 Detection of automatic gate position must be vital and must utilize vital B1 relays or equivalent within the crossing bungalow.

123.6.8.8 At street running segments, “Another Train Coming” signs must be energized and activated by the traffic controller.

123.6.8.9 For at-grade crossings that are equipped with four quadrant gates:

123.6.8.9.1 Exit gates must descend after the entrance gates on a programmable timer.

123.6.8.9.2 Exit gates must only drop if the traffic loops are unoccupied.

123.6.8.10 In the event of a traffic loop or loop controller failure, exit gate(s) must be held up and cab signals must be downgraded as if the island circuit was occupied.

123.6.8.11 Each at-grade crossing must have a bypass mode, which can be turned on by Sound Transit maintenance personnel or local police jurisdiction, with switch protected by key access on the exterior of the crossing bungalow.

123.6.8.12 The crossing bypass mode must perform the following:

123.6.8.12.1 Raise the crossing gates after a 45 second delay of being activated.

123.6.8.12.2 Silence the bells.

123.6.8.12.3 Downgrade the speed commands as if the island track circuit was occupied.

123.6.8.12.4 Have override if the island track circuit is occupied, causing the gates to drop and bells to ring.

123.6.8.12.5 In street running sections, cause a removal of street running code.

123.6.8.13 Nearside stop functionality must be provided where highway crossings are located close enough to platforms such that there would not be ample warning time for the train to travel between the platform and the crossing.

123.6.8.13.1 The warning device must not operate while the train is in the stopping profile or stopped at the platform.

123.6.8.13.2 Prior to leaving the station platform, the train operator will initiate operation of the crossing warning devices via the TWC by operation of the call button on the cab console.

123.6.8.13.3 Upon initiation of the crossing warning devices, a timer must delay the train to provide ample time for the crossing warning devices.

123.6.8.13.4 While this timer is active, speed commands must be set to zero and must not be returned until after this timer runs and gates are confirmed to be down.

123.6.8.13.5 IJs must be installed for clear delineation between island and platform track circuits.

123.6.8.13.6 Refer to Sets 125 Link Train Control Block Design and 120 At-Grade Crossings for requirements related to the operation of nearside stop crossings.

123.6.8.14 Grade crossing warning must be designed for both directions of vehicular and pedestrian traffic.

123.6.8.15 Where interlocking limits are within the approach of a crossing, the crossing control relay must be controlled by the interlocking and the gate down must be part of the home signal algorithm.

123.6.8.16 Island circuits occupancy will remain absolute in terms of activation of the crossing.

123.6.8.17 The standard interconnection scheme for interfacing crossing warning system with traffic controllers must comply with guidelines outlined in AREMA 16.30.10.

123.6.8.18 Preemption interface circuits must be either supervised communications links or normally energized circuits.

123.6.8.19 For preemption interface that uses normally energized circuits, preemption must be active when the circuit is de-energized.

123.6.8.20 For preemption interface that uses normally energized circuits, the relay contact must be rated for the interface circuit voltage.

Commentary: The engineer of record must coordinate with the AHJ to ensure that traffic signal controllers accommodate both indications of energized and de-energized condition of normally energized circuits. See Set series 100 Train Control and Signals for more information.

123.6.8.21 The design must incorporate the following conditions into the traffic signal railroad preemption interface: crossing health, traffic cabinet health, railroad preemption, and crossing activated.

123.6.8.22 The designer of record must coordinate with the local AHJ regarding preemption timing and sequences and for any additional gate delay time needed.

123.6.8.23 Four-quadrant gate exit gates must fail in the vertical position.

123.6.8.24 The exit gates must operate using a dynamic vehicle detection system.

123.6.8.25 For four-quadrant gate systems utilizing dynamic vehicle detection, detection must be only in the direction of travel of the protected portion of road.

123.6.8.26 Four-quadrant systems that use dynamic vehicle detection must utilize a normally energized vehicle detector health output.

123.6.8.27 Exit gates in four-quadrant systems must utilize gate mechanisms manufactured explicitly for exit gates.

123.6.8.28 If the vehicle detector health output fails, the crossing's exit gates must revert to timed operation.

123.6.8.29 A four-quadrant system must be equipped with a vital supervised loop (auto/motorcycle) detection system between the gates for crossing occupancy detection.

123.6.8.30 Loop occupancy must prevent the appropriate exit gate from lowering or bringing the exit gate back up until or unless the island track circuit is occupied.

123.6.8.31 Failure of the loop detection system must have a response identical to loop occupancy.

123.6.8.32 At minimum 20 percent of conductors but not less than two spare conductors must be required in each cable.

123.6.8.33 If less than 20 percent of conductors or two conductors are spares, an additional cable must be ran.

123.6.8.34 For traffic signal-controlled grade crossings, the design must include a dry TWC contact to interface with the AHJ's signal controller so that closing of this contact sends a request to signal controller for an LRT phase.

Commentary: Engineer of record, Sound Transit, and AHJ must coordinate to ensure the signal controller is capable of skipping conflicting phases to provide LRT priority, per agreements between Sound Transit and AHJ.

123.6.9 Cabling

123.6.9.1 Cable connecting to signal equipment must meet both AREMA and equipment manufacturer's standards for size, construction, and material.

123.6.9.2 Cable must be installed in conduit except for equipment termination area where air hose or flexible conduit may be used from conduit end to equipment or rail connection.

123.6.9.3 Cabling run to numerical signs must terminate on lightning protection devices suitable to protect the numerical sign equipment.

123.6.9.4 All cable connected to rails must utilize Cembre connectors. Exothermic welded bonds are not permitted.

123.6.10 EMI

123.6.10.1 The signal system, and all its subsystems, equipment, and components, must be designed and installed to be electromagnetically compatible with its environment.

123.6.10.2 The signal system must not interfere with other subsystems.

123.6.10.3 Shielded wire, twisted pair cables, and rigid steel conduit, if necessary, must be utilized for EMI noise mitigation measures.

123.6.10.4 Proper grounding and bonding of apparatus, conductor shields, and raceways, must be provided to maximize shielding and minimize circulating currents.

123.6.10.5 Surge protection against lightning and other natural sources of EMI must be provided.

123.6.10.6 Track circuit design must not permit EMI from any source, such as traction power, power supplies, communications system, LRV systems, or other wayside equipment, to interfere with its operation.

123.6.10.7 Selection of audio frequencies for track circuits, where utilized, must minimize interference and crosstalk to a level that must not cause an unsafe condition.

123.7 ENGINEERING MANAGEMENT REQUIREMENTS

123.7.1 Interface and Integration Management (Not Used)

123.7.2 Design Management

123.7.2.1 Maintenance and repair manuals for each subsystem or group of related equipment must be provided.

123.7.3 Manufacturing and Construction Management

123.7.3.1 A recommend spares list must be prepared for the signal equipment.

123.7.3.2 Required spares must be coordinated with Sound Transit and are dependent on system design and current spares stock.

123.7.4 Installation Management (Not Used)

123.7.5 Inspection and Testing Management (Not Used)

123.7.6 Training, Pre-Revenue Operations

123.7.6.1 Training must be provided for the signal system and peripheral equipment.

Commentary: such as LCP, HVAC, gate controllers, and snowmelters.

123.7.7 Certification Management (Not Used)

123.8 APPENDICES (NOT USED)

END SET - 123

125 LINK TRAIN CONTROL BLOCK DESIGN

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SET - 125 LINK TRAIN CONTROL BLOCK DESIGN

125.1 INTRODUCTION

125.1.1 Document Scope

125.1.1.1 The purpose of this Block Design requirements set is to inform the design of the transit system such that track circuits are established with boundaries and speed commands that meet headway requirements and minimize runtime, while providing SBD for trains operating in both the normal and reverse direction.

125.1.1.2 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 125 owner to determine the technical source for the design criteria.

125.1.2 Regulations, Codes, Standards, and Guidelines (Not Used)

125.1.2.1 International Regulations, Codes, Standards, and Guidelines

125.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

125.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

125.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

125.1.2.5 Other Jurisdictions

125.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

125.1.3 Abbreviations and Acronyms

125.1.3.1 ATP–automatic train protection

125.1.3.2 IJ–insulated joint

125.1.3.3 MAS–maximum authorized speed

125.1.3.4 SBD–safe braking distance

125.1.4 Definitions and Classifications

125.1.4.1 Headway: The time between trains passing the same point while both trains are operating in the same direction, with the same route. This must account for route clearing and vent zone locations.

125.1.4.2 Signal system design headway: The ideal calculated headway for train control. The signal system design headway requirements are only for the normal direction of travel of each segment.

125.1.4.3 MAS: The maximum automatic train protection (ATP) speed command given to a train in a particular track circuit. The block design must allow the best possible MAS permitted by the alignment.

125.1.4.4 Intermediate speeds: ATP speed commands less than the MAS for a particular track circuit, used in approach to occupied track circuits or interlockings at STOP.

125.1.5 References (Not Used)

125.2 STAKEHOLDER NEEDS (NOT USED)

125.2.1 Passenger Experience

125.2.2 Operational Needs

125.2.3 Maintenance Needs

125.2.4 Safety Needs

125.2.5 Security Needs

125.2.6 Reliability, Availability and Maintainability Needs

125.2.7 Environmental and Sustainability Needs

125.3 SYSTEM REQUIREMENTS

125.3.1 General Requirements

125.3.1.1 The design headway requirements and block layout must be developed based on the system operating plan and the type of signaling to be employed for each area.

125.3.1.2 The design must provide for the best feasible runtime.

125.3.2 Functional Requirements

125.3.2.1 Block design must permit following moves in the reverse direction.

125.3.2.2 There is no specific headway requirement for reverse direction operation.

125.3.2.3 The design headway for the reverse direction must be the best available using the block boundaries designed for normal direction operation.

125.3.2.4 Headway design must consider any speed restrictions, station locations and associated station dwell, interlocking operations, traction power interfaces, and energy savings.

125.3.2.5 Enforce design profile speed for the reverse direction of traffic, using only block boundaries established for the normal direction of traffic.

125.3.2.6 Intermediate speeds must be provided for each ATP controlled track circuit.

125.3.2.7 Intermediate speeds must be the highest allowable given by the SBD model.

125.3.2.8 The highest possible ATP and cab code speed limits must be used for each direction in each block, based on safety, headway, and the design profile speed requirements.

125.3.2.9 Each intermediate speed limit for each block must be provided for both directions in both normal and reverse operation.

125.3.3 Control Lines

125.3.3.1 Control lines must be made in the format shown on the standard drawings.

125.3.3.2 Control lines must use the symbols as shown on the standard drawings.

125.3.3.3 Control line drawings must be provided for each location package.

125.3.3.4 Control line drawings must show the overlap and tie-in for each location where the new extension interfaces with the existing system.

125.3.3.5 The full control line submittal must be independent of each location submittal.

125.3.3.6 Each location submittal must also have the control lines it provides ATP speed limit commands for, extending each control line out to the end of the control line where they overlap other locations.

125.3.3.7 Control line drawings must be provided for each of these configurations:

125.3.3.7.1 Normal direction.

125.3.3.7.2 Reverse direction.

125.3.3.7.3 Normal direction – divergent.

125.3.3.7.4 Reverse direction – divergent.

125.3.3.7.5 Approaches to pedestrian and vehicle crossings.

125.3.3.7.5.1 Crossing control line sheets must include all applicable times for advanced preempt, preempt, crossing relay, and all crossing related timers.

125.3.3.8 Control line drawings must include lookback speeds with use of a note on the sheet to which they apply.

125.3.3.8.1 These notes must apply to all possible speeds faster than the restricted speed in that control line.

125.3.3.8.2 These notes must specify how the release is provided.

125.3.3.8.3 In example, for a 40-mile per hour speed restriction at a curve on track circuit WB5120T, the note would state: (40): Indicates max speed until WB5120T lookback is cleared.

125.3.3.9 Control line drawings must have notes that describe each timer-controlled ATP speed command's operation, and any adjustments available.

125.3.3.10 Control line drawings must be updated during construction and after as-built completion by the contractor.

125.3.4 SBD

125.3.4.1 In creating the block design, both an ideal and worst-case train scenario must be analyzed.

125.3.4.2 Ideal and worst-case trains must be used as written in the specifications.

125.3.4.3 The ideal and worst-case train must stop prior to signals at STOP (no overrun i.e., block before signal is occupied). The only exceptions are for approach to an interlocking signal that has overlap locking for SBD beyond or approach into berthing at station that has a vent zone signal at STOP but has SBD for more than 20-mile per hour code to berth at station, and also has no signal block on the signal.

125.3.4.4 Approaches to signals displaying STOP must be permitted at the MAS given the civil, trackwork requirements, and SBD curve.

125.3.4.5 When interlockings are within SBD, the speeds for the diverging route must be shown on the control lines.

125.3.4.6 Worst-case trains and ideal trains must be allowed to move through turnouts using either route in either direction for turnback moves at interlockings.

125.3.4.7 Ensure sufficient clearance beyond the interlocking to clear the signal.

125.3.4.8 Once the system is built, the as-built track must be compared to the as-designed SBD model and certified that no conflicts have arisen based on final geometry.

125.3.5 Performance Requirements

125.3.5.1 The signal system design headway for following moves with four-car trains in the normal direction for the segments identified in 010.3.5.2 must be less than or equal to 90 seconds.

125.3.5.2 The signal system design headway for following moves with four-car trains for the segments identified in 010.3.5.3 in the normal direction must be less than or equal to 150 seconds.

125.3.5.3 Both the leading train and following train must be allowed to operate at the MAS with a 150 second maximum headway.

125.3.5.4 The performance of ideal trains operating in the normal direction must be evaluated based on response to ATP speed limit signals, stopping at all stations with station dwell of 20 seconds.

125.3.5.5 Headway and runtime must be calculated using two ideal trains running the entire alignment, including terminals, on both main tracks in the normal direction.

125.3.5.6 Merging and diverging operations must be considered during headway and runtime calculations.

125.3.5.7 The design profile speed must not be lowered to reduce the number of blocks nor to assist headway.

125.3.5.8 The design must permit ideal trains to operate in the reverse direction of traffic, on either track, with following move capabilities, in accordance with the MAS in each block.

125.3.5.9 The ideal train model must be used as described in the specifications.

125.3.5.10 Provide the lowest achievable reverse direction headway at MAS, with specified dwell time at stations, utilizing the block boundaries established for the normal direction of traffic.

125.3.5.11 Provide the best possible intermediate speeds approaching stations in the reverse direction without adding additional track circuits, except as specified at terminals.

125.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

125.4.1 System Breakdown Structure

125.4.1.1 Block Boundaries

125.4.1.1.1 Control Lines

125.4.1.1.2 Safe Braking Distance

125.4.1.1.3 Special Cases

125.4.1.1.4 Existing Alignment Interface

125.4.1.1.5 At-Grade Crossing Systems

125.4.1.1.6 Submittals

125.4.2 System Sites and Locations (Not Used)

125.5 SYSTEM INTERFACE REQUIREMENTS (NOT USED)

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 125-1: Interface Between Train Control and Other Disciplines

SET SERIES	SET NAME	SET 125 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	X
500	Track	X
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	
900	Civil	
1000	Mechanical-Electrical and Building Systems	
1100	Technology	
1200	Security	

125.5.1 At-Grade Crossings (Set 120)

125.5.1.1 Coordinate At-Grade Crossing active treatments with Set 120 At-Grade Crossings. Set 120 At-Grade Crossings includes requirements for how to determine what treatments need to be installed at each crossing, and how they are to be laid out. Set 123 Train Control and Set 125 Link Train Control Block Design describe how the active treatments are activated, monitored, and reported by the Train Control System.

125.5.2 Block Design (Set 123)

125.5.2.1 Set 123 Block Design explains where boundaries of track circuits are placed based on boundary conditions and operating scheme. Set 123 Block Design coordinates location of insulated joints, impedance bonds, B points, and other system features as required.

125.5.3 Traction Electrification (Sets 220, 221, and 222)

125.5.3.1 Coordination of negative return current, bonding, crossbonding, shared site locations.

125.5.4 Vehicle (Set 421)

125.5.4.1 Set 125 Link Train Control Set 123 Block Design is heavily reliant on vehicle model for ideal and safe braking train.

125.5.5 Track (Sets 520, 521, and 522)

125.5.5.1 Coordination of any MAS limitations due to track layout.

125.5.6 Fire/Life Safety (Set 601)

125.5.6.1 Coordination of vent zones.

125.5.7 Structures (Set 720)

125.5.7.1 Coordination of any MAS limitations due to structural design and placement of paths for crossbond cabling.

125.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

125.6.1 General

125.6.1.1 In ATP territory, track circuits outside of interlockings must be double rail audio frequency track circuits.

125.6.1.2 In street running territory (no ATP), track circuits may be double rail 100 hertz track circuits, audio frequency train activated circuit, or phase shift overlay track circuits.

125.6.2 Block Boundaries

125.6.2.1 Interlocking boundaries must be defined with an IJ and associated signal.

125.6.2.2 Vent zone boundaries must be defined with an IJ and associated signal.

125.6.2.3 Where IJs are used with track outside of an interlocking, or where main tracks connect with an interlocking impedance bond for providing a negate return current path, IJs must be placed on the main track side(s).

125.6.2.4 Impedance bonds with negative returns for the traction power system must be placed in coordination with Set 220 Traction Power.

125.6.2.5 Traction power substation negative return from center tap of impedance bond must be placed at minimum distance to TPSS unless another mandatory impedance bond location is within the immediate vicinity.

125.6.2.6 Maximum length between track circuit boundaries must not exceed manufacturer's requirements for maximum circuit length.

125.6.2.7 The number of blocks desired is the minimum possible needed to achieve the design headway in the normal direction of traffic at MAS with the block boundaries.

125.6.2.8 Track circuits outside of interlockings must be named based on their receiver's stationing.

125.6.2.9 Track circuits within interlockings must be single rail track circuits where possible.

125.6.2.10 Where geometry, spacing, and arrangement do not allow for double rail track circuits, interlocking track circuits must be single rail shunt-fouled track circuits.

125.6.2.11 Track circuits within interlockings must be named based on what track they are on.

125.6.2.12 Track circuits over switches must be denoted with "OST" or "On Switch Track" at the end of their name.

125.6.2.13 Block layout in approach to curves must slow normally operating trains to the design speed calculated in accordance with Set 521 Track Geometry. No train operating on SBD parameters can exceed 4.5 inches of unbalanced superelevation.

125.6.2.14 A track circuit boundary must be placed in approach to curves where the speed limit reduces such that a typical train meets the target speed at the spiral to curve point. If another block boundary location cannot be adjusted to the point further away to meet that goal, then control line can keep higher speed to allow up to a 4.5-inch actual superelevation using the SBD model for approach.

125.6.2.15 A block boundary must be placed within 2 seconds of the end of a speed restriction to provide "rear end release".

125.6.2.16 Being placed within 2 seconds of the end of restriction takes advantage of the loss of shunt timer expiring before code can be increased.

Commentary: A B point track circuit may be used for this purpose.

125.6.2.17 If the exit from the speed restriction area would not result in a higher speed code for an ideal train due to close approach of another speed restriction zone or station stopping profile, then a block boundary to define the exit from the speed restriction is not required.

125.6.2.18 IJs must be used to define block boundaries at both ends of station platforms.

125.6.2.19 In tunnel alignments with underground stations where a vent zone begins within pre-shunt distance from the end of platform, the vent zone IJ and signal must be used as the platform track circuit boundary.

125.6.2.20 Block boundaries must be placed to permit the highest possible speed commands within the SBD model to a signal at STOP.

125.6.2.21 Block boundaries must not exceed the SBD to the signal by more than 100 feet for 20 miles per hour normal approach to a terminal or yard entrance interlocking.

125.6.2.22 For terminal or yard entrance interlockings, provide a block boundary allowing normal direction approach to the interlocking for either 10-mile per hour or 20-mile per hour code with SBD.

Commentary: This allows for better operations at terminals and yard entrances, where a train waiting for another train to complete a conflicting route through the interlocking can wait close to the interlocking as a track circuit that provides the 10-mile per hour or 20-mile per hour code will be short.

125.6.2.23 Impedance bond center tap crossbond placement must be coordinated with the Set 220 Traction Power.

125.6.2.24 Crossbonds must not be placed at consecutive impedance bonds. There must be separation of at least two track circuits between crossbonds.

125.6.2.25 In tunnel alignments, crossbonds must be coordinated with cross passages.

125.6.2.26 In elevated alignments, crossbonds must be coordinated with civil construction to ensure the crossbond placement is possible.

Commentary: In some cases, both main tracks are in separate elevated structures, such as center platform elevated stations. At these locations, it may be impossible to run a crossbond from track to track.

125.6.2.27 For terminal or yard entrance, interlockings provide a block boundary allowing normal direction approach to the interlocking for either 10-mile per hour or 20-mile per hour code with SBD.

125.6.2.28 B points must only be used for speed restriction approach or release, or for grade crossing island track circuit definition.

125.6.2.29 If the ideal location of a block boundary is within 200 feet of another block boundary, a single block boundary can be used, providing that the desired runtime, desired headway, and the desired operational modes are not impacted.

125.6.3 Control lines

125.6.3.1 The block design must utilize the eight ATP cab signal speed code commands as described in Set 123 Train Control.

125.6.3.2 Street running (which must be ATP limited to 35 miles per hour or 25 miles per hour) – must utilize two street running code rates as described in Set 123 Train Control.

125.6.3.3 Once street running mode is entered, either by code recognition or manually, it must remain until either a non-zero speed code is decoded, or the cab is keyed down.

125.6.4 Safe Breaking Distance

125.6.4.1 A normally operating train is defined as performing in an average manner with respect to equipment and operator. Braking distance calculations for the normally operating vehicle must use the following formula:

$$BD=(Ves \times RTnom \times 1.467)+\left((Ves^2-Vf^2) \times \left(\frac{0.7333}{0.22G+BRnorm}\right)\right)$$

125.6.4.1.1 BD is the braking distance required, in approach to the spiral-to-curve point of a curve in feet.

125.6.4.1.2 Ves is the speed of the train as it enters the block and is assumed to be the cab speed.

125.6.4.1.3 RTnom is the sum of the nominal reaction times from the time the train passes a cab signal change point until the brakes are applied and is 3.5 seconds.

125.6.4.1.4 Vf is the final target speed of the calculation. For approach to curves, it is the civil design speed of the curve at the spiral to curve point that the train is approaching.

125.6.4.1.5 G is the grade in percent.

125.6.4.1.6 BRnom is the de-rated brake rate and is defined as 2.1 miles per hour per second (MPHPS).

125.6.4.2 SBD has been developed in coordination with Link design. SBD calculations must take into account maximum train speeds, response times, and track grades. The safety train model is the worst-case braking model and must be used to calculate SBD when trains are approaching an occupied block or restrictive signal. SBD must be calculated using the formula:

$$SBD=(Vos \times RTmax \times 1.467)+\left((Vos^2-Vf^2) \times \left(\frac{0.7333}{0.22G+BReff}\right) \times 1.35+(2 \times 7)\right)$$

125.6.4.2.1 SBD is safe braking distance in feet.

125.6.4.2.2 Vos is the speed of the train (in mph) as it enters the block. This is defined as the cab signal command speed plus 4 miles per hour.

125.6.4.2.3 RTmax is the sum of the worst-case reaction times from the cab signal change point until the brakes are applied and is defined as 3.8 seconds. During this time, the train is assumed to have constant velocity Vos.

125.6.4.2.4 1.467 and 0.7333 are standard conversion factors to convert from miles per hour to feet per second.

125.6.4.2.5 Vf is the final target speed of the train for this calculation. When calculating approach to an occupied block or red signal, Vf will always be zero.

125.6.4.2.6 G is the grade in percent.

125.6.4.2.7 0.22 is the correction factor used to adjust braking distance for the effects of grade.

125.6.4.2.8 BReff is the de-rated brake rate and is 1.95 miles per hour per second.

125.6.4.2.9 1.35 is the addition of a 35 percent safety factor and must be applied on to the braking portion of the SBD calculation.

125.6.4.2.10 2 x 7 accounts for the overhang of the vehicles and is assumed to be 7 feet per vehicle.

125.6.4.3 SBD must be calculated for each track circuit as if it were occupied, showing the SBD for each speed code in the approach to each track circuit.

125.6.4.4 SBD must be calculated for each ATP speed limit command (at or below MAS even if not given on the control lines) at each block boundary, considering civil design characteristics and train performance characteristics.

125.6.5 Special Cases

125.6.5.1 For locations where SBD cannot be provided to an obstruction, a 10-mile per hour ATP speed command must be given on a timer to allow trains to berth.

125.6.5.2 Such locations include trains berthing into tail tracks, trains berthing into a station platform with occupied tail track, or nearside stop crossings. Once the timer expires, the ATP speed command is changed to zero.

125.6.5.3 For terminal stations, the distance from the end of platform to the terminal interlocking must be kept as short as possible to minimize impact to operation.

125.6.6 Existing Alignment Interface

125.6.6.1 Existing alignment block design boundaries must only be modified as directed by Sound Transit.

125.6.6.2 The control lines and speed selection logic and calculations must be extended so that they tie-in with existing alignments.

125.6.7 At-Grade Crossing Systems

125.6.7.1 Except for the case of nearside stops, island track circuits within at-grade crossings must be defined by track circuit boundaries within 40 feet of the edge of street or walkway.

125.6.7.2 For nearside stop crossings, the island track circuit may extend from the platform to the other side of the crossing.

125.6.7.3 Grade crossing approach calculations must be performed for both the fastest possible and nominal model trains.

125.6.7.4 Timing for the following crossing elements must be provided as designed in coordination with the AHJ:

125.6.7.4.1 Warning time.

125.6.7.4.2 Pre-emption time (if applicable).

125.6.7.4.3 Exit gate clearance time (if applicable).

125.6.7.4.4 Interlocking delayed approaches.

125.6.7.4.5 Advanced approach time.

125.6.7.5 Crossing approach warning diagram drawings must be provided.

125.6.7.6 Control lines for the grade crossing activation must be provided.

125.6.7.7 Nearside stop grade crossings must follow requirements from Set 123 Train Control.

125.6.7.8 Crossings that have an interlocking within their approach must not activate unless there is a route cleared through the interlocking.

125.6.7.9 The crossing must have approaches calculated from all possible interlocking routes that would send a train over the crossing.

125.6.7.10 Routes through the interlocking must only clear once the crossing has provided the necessary minimum warning time minus train travel time to the crossing once the route clears and an ATP speed command is given.

125.6.7.11 Crossings must have control line diagrams explaining their activation from each approach.

125.7 ENGINEERING MANAGEMENT REQUIREMENTS

125.7.1 Interface and Integration Management (Not Used)

125.7.2 Design Management

125.7.2.1 Block design computer program: Submit written explanation and detailed flowcharts of the block design simulation programs for approval before creating a block design for submittal or civil interfaces.

125.7.2.2 Submit control line charts for normal and reverse traffic direction as a separate submittal prior to any signal package submittal. Use format and symbols for control line drawings consistent with Sound Transit existing standards.

125.7.2.3 Runtime and headway simulations: Submit computerized simulation runs used to evaluate the block design concurrently with the block design.

125.7.2.4 Submit safe braking distances from each block boundary for each MAS speed limit and all lower speed limits concurrently with the control lines.

125.7.2.5 There must be preliminary control line submittals showing speeds and stationing of block boundaries, interlocking boundaries, speed restrictions, and station platform boundaries.

125.7.2.6 The preliminary control lines must not be forced to wait on package submittals of structure or signal system so that Sound Transit may comment upon that subject specifically.

125.7.2.7 Submittal must include control line, SBD calculation, runtime calculation in table and graphic form, and headway calculation.

125.7.2.8 Subsequent control line submittals must have comments resolved and may be submitted as part of a signal system or otherwise combined package.

125.7.2.9 The contractor must update block design and control line as-built drawings to ensure they accurately reflect the most current Us.

125.7.3 Manufacturing and Construction Management (Not Used)

125.7.4 Installation Management (Not Used)

125.7.5 Inspection and Testing Management (Not Used)

125.7.6 Training, Pre-Revenue Operations (Not Used)

125.7.7 Certification Management (Not Used)

125.8 APPENDICES (NOT USED)

END SET - 125

220 TRACTION POWER

SET - 220 TABLE OF CONTENTS

TABLES

SET - 220 TRACTION POWER

220.1 INTRODUCTION

220.1.1 Document Scope

220.1.1.1 This set establishes the minimum requirements for the traction power.

220.1.1.2 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 220 owner to determine the technical source for the design criteria.

220.1.2 Regulations, Codes, Standards, and Guidelines

220.1.2.1 International Regulations, Codes, Standards, and Guidelines

220.1.2.1.1 Institute of Electrical and Electronic Engineers (IEEE), including 1653.2

220.1.2.1.2 International Code Council/American National Standards Institute (ICC/ANSI) A117.1-03.

220.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

220.1.2.2.1 American National Standards Institute, Inc. (ANSI).

220.1.2.2.2 American Railway Engineering and Maintenance-of-Way Association (AREMA).

220.1.2.2.3 American Society for Testing and Materials (ASTM), including B47 and B8.

220.1.2.2.4 Association of American Railroads (AAR).

220.1.2.2.5 National Electrical Manufacturers Association (NEMA).

220.1.2.2.6 National Electrical Safety Code (NESC).

220.1.2.2.7 NEC National Electrical Code (NEC) and to Washington Administrative Code (WAC).

220.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

220.1.2.3.1 Washington Administrative Code (WAC).

220.1.2.3.2 Washington Industrial Safety and Health Act (WISHA).

220.1.2.3.3 Washington Utilities and Transportation Commission (WUTC).

220.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

220.1.2.4.1 Underwriters Laboratories, Inc. (UL).

220.1.2.5 Other Jurisdictions (Not Used)

220.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines (Not Used)

220.1.3 Abbreviations and Acronyms

220.1.3.1 AHJ–authority having jurisdiction

220.1.3.2 BMS–building management systems

220.1.3.3 EPMS– electrical power monitoring system

220.1.3.4 ETS– emergency trip station

220.1.3.5 FCC–fire command center

220.1.3.6 HVAC–Heating, Ventilation and Air Conditioning

220.1.3.7 IED–Intelligent Electronic Device

220.1.3.8 I/O–input/output

220.1.3.9 LCC–Link control center

220.1.3.10 LCMS–local control and monitoring system

220.1.3.11 LFA–low flow analysis

220.1.3.12 LRV–light rail vehicle

220.1.3.13 OCS–overhead contact system

220.1.3.14 O&M–operations and maintenance

220.1.3.15 OMF–operations and maintenance facility

220.1.3.16 PLC–programmable logic controller

220.1.3.17 SCADA–supervisory control and data acquisition

220.1.3.18 SRI- solar reflectance index

220.1.3.19 SSS–substation shutdown station

220.1.3.20 TCN- train control network

220.1.3.21 TES–traction electrification system

220.1.3.22 TPSS–traction power substation

220.1.3.23 TRU–transformer rectifier unit

220.1.3.24 VPI–vacuum pressure impregnated

220.1.4 Definitions and Classifications

220.1.4.1 Contingency operation: The TRU out of service at a single TPSS, with the TPSS power section bypass switches closed and its DC feeder breakers open.

220.1.4.2 DC feeder system includes the ducts, cable, and/or overhead connectors from the substations to the disconnect switches and the track rails.

220.1.4.3 Normal operation: is defined as all TPSSs in service and supplying power to the system.

220.1.4.4 Overhead contact system (OCS): distributes power supplied from the TPSS to the vehicles. It includes messenger, contact wires, conductor rail, and their physical supports.

220.1.4.5 Tie stations: DC feeder circuit breakers located approximately midway between substations. They provide a means to sectionalize the OCS and provide additional protection for high-impedance faults.

220.1.4.6 Traction power substation (TPSS): Electrical substations located along the system route and connected to the local power utility company. They include all equipment necessary to transform and rectify AC 3-phase voltage to DC voltage to supply the power to the light rail vehicle (LRV).

220.1.5 References (Not Used)

220.2 STAKEHOLDER NEEDS

220.2.1 Passenger Experience (Not Used)

220.2.2 Operational Needs

220.2.2.1 The system needs to operate fully in contingency condition.

220.2.3 Maintenance Needs

220.2.3.1 Access to TPSS equipment for inspection and maintenance.

220.2.4 Safety Needs (Not Used)

220.2.5 Security Needs

220.2.5.1 Fencing and gate requirements.

220.2.5.2 Access to TPSS requirements.

220.2.5.3 Closed-circuit television at the TPSS site requirements.

220.2.6 Reliability, Availability and Maintainability Needs (Not Used)

220.2.7 Environmental and Sustainability Needs

220.2.7.1 Facility designs must promote stewardship of resources and utilities when selecting material, equipment selection, and operational strategies with the goal of conservation and efficiency.

220.2.7.2 For sustainability needs, refer to Set 803 Sustainability.

220.3 SYSTEM REQUIREMENTS

220.3.1 System Description

220.3.1.1 The LRV must collect power from the contact wire by means of a pantograph and must complete the negative return path of the power to the substation via running rails.

220.3.1.2 The mainline TES configuration must be double end fed, where electrical continuity between adjacent substations is provided by the OCS.

220.3.1.3 End of alignment must be double end fed with bypass switches closed.

220.3.1.4 The system must be designed with consideration of the effects of regeneration. During regenerative braking, power must be placed back into the DC feeder system via vehicle pantograph to the OCS.

220.3.1.5 The design of the traction power and distribution system equipment must account for the effects of the harmonic content and the dynamic of the traction load, and system faults.

220.3.2 System Capacity

220.3.2.1 The TES must be designed to support full train operations with minimum design headways and consist size under normal and contingency TPSS configuration. In contingency, TPSS must support the trains at maximum power without intentional operation reduction.

Commentary: For the design headway and consist size, refer to Set 010 Operations.

220.3.2.2 The TRU at each mainline and yard substation must be rated for extra heavy-duty in accordance with IEEE 1653.2.

220.3.2.3 The shop TPSS must be rated for heavy-duty at a minimum.

220.3.2.4 An OCS thermal analysis must be performed as modeled in the LFA. Refer to Set 221 Overhead Contact System for additional requirements.

220.3.2.5 The design of the TES must be confirmed by a TES LFA.

Commentary: Refer to 220.3.7.2 for the TES LFA software capability and typical inputs and outputs of the LFA.

220.3.2.5.1 The TES LFA must confirm conservative design capacity assuming the heaviest projected schedule (e.g., rush hours) and minimum design headway, as defined in Set 010 Operations, for both normal and contingency traction power operation at each TPSS, one at a time. Refer to Section 220.1.4 Definitions and Classifications for normal and contingency definitions.

220.3.2.5.2 The mainline TPSS capacity used must be extra heavy-duty traction per IEEE 1653.2. Typical results analysis must include the following, at a minimum. Additional items must be included as directed by ST traction power:

i. Train voltage.
ii. Rail-to-ground voltage.
iii. TRU loading (current- amps and power- kilowatts).
iv. Traction power cable loading (current- amps).

220.3.2.6 A separate load analysis must be performed to evaluate the yard and shop TES under peak storage capacity with static rolling stock auxiliary power loads, as defined in consultation with Sound Transit, and including warm-up and movement of trains for service roll-out. The analysis must confirm that the yard and shop TES designs can handle the continuous auxiliary loads for the expected peak storage capacity duration.

220.3.2.6.1 The yard and adjacent mainline TPSS load analysis must also include a contingency scenario to ensure the mainline TES can adequately back up the yard in the event of an outage at the yard substation.

Commentary: The yard TPSS can power back to mainline TES when mainline TPSS is out of service with permission of local power utility. Consult with local power utility.

220.3.2.6.2 Unless otherwise directed by Sound Transit, peak storage must be analyzed for non-revenue service, with no train loads operating on the mainline.

220.3.2.7 The addition of future line extensions must be considered in the TES design, including TPSS sizing, equipment, equipment arrangements, and duct banks that can accommodate future line extension traction power connections.

220.3.2.8 The substation design must include two spare DC feeder breaker positions, a spare TPSS power section bypass switch lineup, and raceway out to the contract limits to provide for connection to a future extension.

220.3.3 Substation Incoming Service

220.3.3.1 Incoming primary AC power to the TPSS must be supplied by the local serving utility. If the built-in TPSS powers the tunnel TES, the power may come from the tunnel electrical distribution system with approval from Sound Transit.

220.3.3.2 Adjacent TPSSs must be supplied from separate utility substations or from different buses of the same utility substation.

Commentary: It is preferred to have separate utility substations. When that is not possible, separate buses from the same utility substation can be used.

220.3.4 Substation Grounding

220.3.4.1 Each TPSS must be provided with a ground grid designed as follows:

220.3.4.1.1 The designer must perform a site survey, measure soil resistivity in accordance with IEEE 80, and design the ground grid geometry and size taking into account line-to-ground fault current values (measured from a single leg of the single-phase or three-phase service to earth ground) obtained from a short circuit study and keeping step and touch potential within IEEE 2720 recommended limits.

220.3.4.1.2 The design must comply with the following parameters:

220.3.4.1.2.1 Grounding conductor for grid and connections to grid must be bare copper sized in accordance with IEEE 80; the minimum size is 4/0.

220.3.4.1.2.2 Ground rods must be copper clad steel sized in accordance with IEEE 80; the minimum size is 3/4 inch by 8 feet.

220.3.4.1.2.3 Maximum resistance is 5 ohms.

220.3.4.1.2.4 The ground grid must extend 5 feet beyond the equipment or fence, but no less than 3 feet if the real estate for 5 feet is not available.

Commentary: IEEE 80 and AREMA MRE both recommend a minimum of 3 feet.

220.3.4.1.2.5 The ground grid must, additionally, extend a minimum of 3 feet beyond the entire path of any outward site gate swing.

220.3.4.2 In new tunnels, substation grounding may be through structural reinforcing steel, subject to engineering review and proper documentation.

220.3.4.3 Ground grid must be constructed as follows:

220.3.4.3.1 Prepare subgrade by removing and reserving native soil; the grid must be 12 inches to 18 inches below grade, per IEEE 80 and AREMA MRE.

220.3.4.3.2 Install ground rods and conductors per the ground grid design using copper conductors, ground rods, and exothermically welded connections.

220.3.4.3.3 Cover ground rods and conductors with a minimum of 6 inches of native soil.

220.3.4.3.4 If the TPSS is built on a significant area of compacted fill such that native soil is not available, the grid may be constructed in the compacted fill. If the soil resistivity is too high, alternate soil must be used.

220.3.4.3.5 Cover soil with a surface layer of high resistivity, coarse, clean gravel (at least 8,000 ohms/meters), extending minimum 5 feet beyond grid in each direction where property lines make this possible.

220.3.4.3.6 A surface layer over the gravel may be asphalt, masonry, or concrete.

Commentary: Concrete is a less desirable surface than asphalt because the resistance of wet concrete is much lower than asphalt.

220.3.4.4 The ground grid must be tested per IEEE 81.

220.3.4.5 Connections from the ground grid to the substation must adhere to the following criteria:

220.3.4.5.1 Where there are substation footings or foundation walls, the rebar must be grounded to the ground grid. Concrete slab rebar must be grounded to the ground grid.

220.3.4.5.2 Prefabricated substation building must be grounded to the ground grid at each of its four corners using ground pads welded to its steel I-beam or C-channel base.

220.3.4.5.3 The substation internal ground bus must be grounded in four places by extending ground conductors from the ground pads at each corner of the substation to the internal ground bus.

220.3.4.5.4 All connections to the ground grid and other underground connections must be exothermically welded. Above-ground connections must be irreversible compression type or exothermically welded.

220.3.4.5.5 The following AC equipment in the substations must be solidly grounded to the ground grid:

220.3.4.5.5.1 Traction power transformer enclosure.

220.3.4.5.5.2 Auxiliary power transformer neutral.

220.3.4.5.5.3 AC switchgear enclosure.

220.3.4.5.5.4 Low-voltage panels.

220.3.4.6 The following DC equipment must be grounded through a high-resistance ground relay. The ground relay must detect energized and grounded switchgear conditions and provide appropriate actions to clear faults.

220.3.4.6.1.1 DC switchgear enclosure, including the negative cubicle.

220.3.4.6.1.2 Rectifier enclosure.

220.3.4.7 The neutral of the utility source feeders must be grounded to the substation ground grid.

220.3.4.8 The following site appurtenances must be grounded to the ground grid:

220.3.4.8.1 Metallic fences:

220.3.4.8.1.1 If there is a metallic fence surrounding the substation, each fence post must be grounded to the ground grid.

220.3.4.8.1.2 If a swinging gate is used, the gate must be bonded to the supporting posts using a flexible copper bonding strap. The supporting posts must be grounded to the ground grid.

220.3.4.8.1.3 If a sliding gate is used, the gate must be bonded to the fence post using a festoon system, such as a Burndy rolling gate grounding system.

220.3.4.8.1.4 If the fence has a lower half that is concrete or masonry, with a metallic fence on the upper portion, each metallic fence post must be grounded to the ground grid.

220.3.4.8.2 Non-metallic walls:

220.3.4.8.2.1 If the wall is concrete or masonry, no grounding is required unless there is exposed metallic hardware or sections, such as gates, in which case the metallic portions must be grounded to the ground grid.

220.3.4.8.2.2 If the fence is fully non-metallic and non-conductive, no grounding is required.

220.3.4.9 The following, if metallic, must be bonded to the ground grid using bare copper equipment grounds:

220.3.4.9.1 Stairs.

220.3.4.9.2 Railings.

220.3.4.9.3 Bollards.

220.3.4.9.4 Supports for DC feeder disconnect switches.

220.3.4.9.5 Signal and communication houses or cases.

220.3.4.9.6 Distribution transformers.

220.3.4.9.7 Any other metallic equipment within the enclosed substation yard.

Commentary: For signal house grounding, refer to Set 123 Train Control Link Light Rail.

220.3.4.10 At each TPSS, a grounding test well must be provided for maintenance purposes and must not be placed in areas used by maintenance vehicles.

220.3.5 Equipment Arrangement

220.3.5.1 Equipment must be spaced and positioned to permit maintenance, removal, and replacement of any unit without the necessity of moving other units.

220.3.5.2 The equipment must be arranged to permit doors to be opened, panels to be removed, and equipment to be withdrawn without interference to other units.

220.3.6 Functional Requirements

220.3.6.1 Electrical Parameters

Table 220-1: System Voltages

Substation DC 1% Full Load Voltage	1590 Vdc
Maximum Regeneration Voltage	1900 Vdc
Substation Voltage at 100% Full Load	1500 Vdc
Voltage Regulation for Rectifier Transformer	6% +/- 0.5%
Minimum System (Vehicle) Voltage	1050 Vdc

Table 220-2: Distribution System Voltages

Normal Minimum	1200 Vdc
Contingency Minimum	1050 Vdc

Table 220-3: Maximum Rail-to-Ground Voltages

Normal Operation	60 V
Contingency Operation	90 V

220.3.6.2 Mechanical Parameters

Table 220-4: Distribution and Return System

Average contact wire wear for electrical LFA	15%
Typical running rail weight	115 lbs.
Average running rail wear for electrical LFA	5%

Table 220-5: Conductor Type and Size

Messenger wire for electrical LFA	500 KCMIL 19-strand hard drawn copper
Contact wire for electrical LFA	350 KCMIL solid grooved hard drawn copper

220.3.7 Performance Requirements

220.3.7.1 The traction power equipment must be designed for a minimum functional life expectancy of 30 years before major overhaul or complete replacement becomes necessary. The TPSS building must be designed for a minimum functional life expectancy of 50 years.

Commentary: The life expectancy is dependent on approved maintenance policies being followed. Refer to Set 010 Operations for maintenance requirements.

220.3.7.2 The software used for LFAs must have a service record of performing similar analyses for transit agencies and must be approved by Sound Transit prior to commencing the LFA. A resume of past projects must be provided.

220.3.7.2.1 The software used for LFAs must have the following capabilities, at a minimum:

220.3.7.2.1.1 Modeling of separate, but interconnected positive and negative return electrical networks with distinct TES components, which must include:

220.3.7.2.1.1.1 TPSS TRUs.

220.3.7.2.1.1.2 DC feeder breakers.

220.3.7.2.1.1.3 DC disconnect switches.

220.3.7.2.1.1.4 OCS conductors.

220.3.7.2.1.1.5 Overhead contact rail.

220.3.7.2.1.1.6 Positive DC feeder cables.

220.3.7.2.1.1.7 Positive parallel cables.

220.3.7.2.1.1.8 Negative return running rails.

220.3.7.2.1.1.9 Negative return DC cables.

220.3.7.2.1.1.10 Negative cross bonds.

220.3.7.2.1.2 Calculation of current flow in each TES component.

220.3.7.2.1.3 Calculation of train and rail-to-ground voltages along the right-of-way, with multiple trains in operation in each direction.

220.3.7.2.1.4 Modeling of forced reduced performance per vehicle specifications (e.g., current limiting).

220.3.7.2.1.5 Modeling of regenerative braking.

220.3.7.2.1.6 Simulation sampling rate of less than or equal to 1 second.

Commentary: Ability of LFA software to model wayside and vehicle energy storage systems is preferred.

220.3.7.2.2 Unless designed otherwise and directed by Sound Transit, TES load flow models must include the following parameters:

220.3.7.2.2.1 Full operation of system vehicles under normal and contingency operations, which must include the following criteria:

220.3.7.2.2.1.1 Minimum simulation run time of 3.5 hours during peak rush-hour period.

220.3.7.2.2.1.2 Vehicles consist size of four cars.

220.3.7.2.2.1.3 Vehicle passenger loading of AW2.

220.3.7.2.2.1.4 Station dwell time of 20 seconds.

220.3.7.2.2.1.5 Enabled vehicle forced reduced performance (e.g., current limiting).

220.3.7.2.2.1.6 Disable regenerative braking by default. Enabled must be requested by Sound Transit.

220.3.7.2.2.1.7 Sound Transit vehicle fleet types and characteristics. Confirm types and characteristics to be modeled in consultation with Sound Transit.

220.3.7.2.2.2 Special event operating scenarios where necessary, in consultation with Sound Transit.

220.3.7.2.2.3 Static train loads in tail tracks and pocket tracks to simulate stored trains where necessary, in consultation with Sound Transit.

220.3.7.2.2.4 TES design criteria identified in Set 220 Traction Power, and the latest available TES standard specifications and design plans. TES load flow model inputs and evaluation criteria per Set 220 must include:

220.3.7.2.2.4.1 Table 220-1: System voltages and TPSS voltage regulation, for TPSS model source voltage inputs.

220.3.7.2.2.4.2 Table 220-2: LFA evaluation criteria for minimum acceptable train voltages, for normal and contingency operation.

220.3.7.2.2.4.3 Table 220-3: LFA evaluation criteria for maximum acceptable rail-to-ground voltages, for normal and contingency operations.

220.3.7.2.2.4.4 Table: 220-4: Average contact wire and running rail wear 1 percentage and typical running rail size, for TES positive and negative network model inputs.

220.3.7.2.2.4.5 Table 220-5: Typical OCS conductor types, for OCS model conductor inputs.

220.3.7.2.2.4.6 Table 221-11: Climatic conditions, for ambient temperature model inputs.

220.3.7.2.2.4.7 Refer to 220.4.2: TPSS location/spacing considerations for TES design and modeling as well as LFA evaluation criteria for TPSS capacity.

220.3.7.2.2.4.8 Refer to 220.6.17.5: Typical positive and negative return traction power cable requirements for TES model cable inputs.

220.3.7.2.2.4.9 Refer to Set 221 Overhead Contact System: OCS requirements for additional OCS model inputs, as needed.

220.3.7.2.2.4.10 Table 221-14: Contact and messenger wire properties, for OCS model inputs

220.3.7.2.2.5 Vehicle design criteria outlined in Set 421 Light Rail Vehicle, and the latest available vehicle standard specifications and available manufactures' data for each vehicle type. The worst case vehicle must be used for the load flow analysis. Coordinate with ST Vehicles to determine this.

220.3.7.2.2.6 Track design criteria identified in Set 520 Vehicle Clearances and Track Spacing, Set 521 Track Geometry, and Set 522 Track Construction, and the latest available track standard specifications and design plans to identify civil details, such as track-to-earth resistance to ground values by track type, track design speed limits, grades, and curves

220.3.7.2.2.7 Signals design criteria identified in Set 123 Train Control – Link Light Rail and Set 125 Link Train Control Block Design, and the latest available signals standard specifications and design plans to identify modeling details, such as operational requirements, signals speed limits, and negative return cross bonding

220.3.7.2.3 If only a segment of the TES is being analyzed and the boundary station on either end of the LFA is not normally an end-of-line station, the load flow model must be extended by at least two substations past the LFA limits (at the existing end), when possible, to generate proper train movements and the associated electrical demand on the system.

220.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

220.4.1 System Sites and Locations

220.4.1.1 Mainline

220.4.1.1.1 The mainline tracks, inbound and outbound, must provide means to break the power via dedicated DC feeder breakers and no-load, feeder disconnect switches for electrical OCS section.

220.4.1.2 OMF Yard and Shop

220.4.1.2.1 Mainline and yard tracks must be isolated from ground. Refer to Set 522 Track Construction.

220.4.1.2.2 Yard traction power must have a dedicated DC power supply electrically segregated from the shop traction power system and the mainline system in both the positive and negative DC power circuits.

220.4.1.2.3 Yard TPSS must receive backup power from a nearby mainline TPSS via a dedicated feeder system. The mainline TPSS and Yard TPSS must be interlocked using a Kirk key system

220.4.1.2.4 The contractor must get approval from Sound Transit on whether the mainline TPSS can be fed from OMF yard TPSS.

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

220.4.1.2.6 The shop TPSS must be located outside of OMF building but in the vicinity of the OMF building. The shop TPSS must not be located in the same building as the yard TPSS.

220.4.1.2.7 Shop tracks must be solidly grounded to shop ground grid, which is connected to the building ground and shop TPSS negative DC bus.

220.4.1.2.7.1 There must be insulated joints in the apron tracks at the entrance to and exit from the shop with corresponding non-bridging section insulators in the OCS.

220.4.1.2.7.1.1 Insulated joints must not be located where a train will routinely stop, bridging the insulated joints.

220.4.1.2.7.2 The shop tracks make direct contact with the concrete floor and the tracks must be grounded in multiple places to the building steel. Each track must be bonded to each other and to the shop TPSS negative bus.

220.4.1.2.8 ETSs at the shop building must use a parallel circuit with indication lamp or light to identify the location of the activated ETS. The ETS indication lamp or light must be provided.

220.4.2 Traction Power Substation (TPSS) Sites and Locations

220.4.2.1 The preferred location for TPSS is at passenger stations, but final locations and capacities must be based on the system load flow study. The selection of suitable locations for substation must include an evaluation of the following as a minimum:

220.4.2.1.1 LFA finds for normal and contingency operation conditions.

220.4.2.1.2 Minimizing the distance between the substation and right-of-way to minimize the lengths of positive feeder and negative return circuits.

220.4.2.1.3 Availability and cost of medium voltage service from the applicable electric utility.

220.4.2.1.4 Visual impact on surroundings/neighborhood.

220.4.2.1.5 Construction and maintenance access.

220.4.2.1.6 TPSSs must not be located where there are potential water intrusion issues, even if water intrusion prevention design is in place—for example, under passenger station plazas.

220.4.2.2 Above ground substations are preferred. Underground substations are only allowed at underground passenger stations with Sound Transit traction power and operations approval. When substations underground are used, the substation must have equipment hatches or doors for removal and replacement of equipment from the substation to either track level in the tunnel or surface level. A circulation drawing for removing the TPSS equipment must be provided, and must detail what vehicles are required to lift the TPSS equipment up or down for removal.

Commentary: The final grade requirements for TPSS sites are in Set 904 Grading.

Commentary: The flood risk requirements for TPSS sites are in Set 901 Storm Drainage.

220.4.2.3 TPSS must be designed to accommodate the community environment. The use of decorative facades and landscaping may be considered to allow the TPSS to inconspicuously blend with its surroundings.

220.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 220-6: Interfaces between Traction Power and Other Disciplines

SET SERIES	SET NAME	SET 220 INTERFACE
000	General	X
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	X
400	Vehicle	X
500	Track	X
600	Fire/Life Safely	X
700	Structures	
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	
1200	Security	X

220.5.1 General

220.5.1.1 Coordinate LFA inputs with Set 010 Operations (e.g., projected schedule).

220.5.2 Train Control and Signals

220.5.2.1 Coordinate location of cross bonds.

220.5.2.2 Coordinate grounding for cohabitated yards for signal house and TPSS.

220.5.3 Traction Electrification

220.5.3.1 Stray current.

220.5.4 Operational Communications

220.5.4.1 Coordinate TPSS radio frequency signal implementation.

220.5.4.2 Coordinate location of communication cabinet and which I/O will be located inside and outside of the TPSS.

220.5.4.3 Coordinate control I/O spare capacity for growth.

220.5.4.4 Access card reader to TPSS requirement.

220.5.4.5 Coordinate private branch exchange and emergency telephone system wiring.

220.5.5 Vehicles

220.5.5.1 Coordinate for vehicle input data for LFA.

220.5.5.2 Regenerated maximum overvoltage criteria.

220.5.6 Track

220.5.6.1 Coordinate the grounding of equipment that may contact the rails.

220.5.6.2 Coordinate clearances for track, poles, walkways, and egress.

220.5.7 Fire/Life Safety

220.5.7.1 Requirement of TES cables installed in tunnels.

220.5.7.2 Coordinate fire detection and indication systems in TPSS.

220.5.8 Architecture

220.5.8.1 Coordinate TPSS screening and security fencing materials for aesthetics.

220.5.9 Civil

220.5.9.1 Coordinate power utilities.

220.5.9.2 Coordinate parking and access road for TPSS.

220.5.9.3 Coordinate fencing and gates at TPSS.

220.5.9.4 Coordinate the access of trailer-mounted generator.

220.5.9.5 Coordinate finished grade in TPSS site and flood risk.

220.5.10 Mechanical/Electrical Building Systems

220.5.10.1 Coordinate station power redundancy in tunnels.

220.5.10.2 Coordinate grounding between OCS, tunnels, facilities, and substation grounding.

220.5.10.3 Requirement of BMS.

220.5.10.4 Coordinate the connection of Sound Transit dedicated EPMS to TPSS dedicated power meter.

220.5.11 Security

220.5.11.1 TPSS fencing and gates requirements.

220.5.12 Operations

220.5.12.1 Coordinate design headways as load flow analysis inputs.

220.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

220.6.1 General

220.6.1.1 The TPSS must include the following elements: substation enclosure, AC switchgear, TRUs, DC switchgear, negative return system, protective systems, control and monitoring system, train control network (TCN) interface, BMS when integrated into a facility, intrusion detection systems (Set 1202 CCTV - TDIS) and Fire Detection Systems (Set 601 Fire/Life Safety), auxiliary power supply systems, busbars, grounding systems, HVAC systems, batteries and chargers, surge arresters, power meter, rail voltage monitoring system, and lighting (Set 1007 Electrical Lighting).

220.6.1.2 The TPSS must power the TES, including the TPSS enclosure interior and exterior lighting.

220.6.1.3 The TPSS must not power an adjoining facility or equipment, including wayside lighting systems, train control systems, stations, wayside communication equipment, at a minimum.

220.6.1.4 The TPSS must have a fire detection system, such as smoke and heat detectors at TPSS. Refer to Set 601 Fire/Life Safety for detailed requirements.

220.6.2 Substation Site

220.6.2.1 Where TPSSs are located at-grade and not within an O&M yard, provide fence as follows. See Set series 200 for further grounding requirements. Coordinate with Set 903 Fencing.

220.6.2.1.1 All metallic fences, including posts and gates, must be grounded 5 feet out from the perimeter. Refer to 220.3.4 for additional grounding requirements.

220.6.2.1.2 The design of the TPSS fence must coordinate with the station architecture and/or surrounding environs as well as local authority having jurisdiction (AHJ)/zoning requirements and not create inaccessible or security risk spaces or alleys. The design must accommodate full functionality of the gate and be coordinated for required grounding and other clearances. Where TPSS and associated fence are near OCS, coordinate with Sound Transit TE Group. See Set 221.

220.6.2.1.3 In areas of high visibility, the exterior of the TPSS fence may be an opportunity for public art as coordinated with the overall public art approach for the project. All art must be grounded if it is metallic and must be installed in a manner that is easily accessible and safe to maintain. Coordinate all art associated with the TE group. Refer to Set 808.

220.6.2.2 The TPSS enclosure placement in the site must allow access to rear doors, TPSS man door, and TPSS double door.

220.6.2.3 Power meters that must be accessed by the local utility companies must be readable from the exterior of the enclosure. When required by the utility, the meters must be located outside of the TPSS fence.

Commentary: PSE local power utility is required to obtain dedicated pad-mounted metering cabinet exterior of TPSS.

220.6.2.4 Gates must accommodate vehicles to replace equipment including transformers, switchgear, circuit breakers, and to provide temporary generators. A circulation diagram indicating accessible path of the equipment and vehicles from the TPSS front doors or rear access door of TPSS enclosure to the gate must be provided, showing appropriate clearances. Gates must be manual, not motorized, to minimize maintenance. Structure of gates, hinges, and all associated hardware must be industrial grade to provide long life cycle and minimal maintenance.

220.6.2.4.1 Substation yards must have a vehicle gate that is wide enough to allow the transformer unit to be removed and replaced. Refer to Set 903 for additional gate requirements.

Commentary: Refer to 220.3.1.4 for grounding details of metallic fences and gates.

220.6.2.5 TPSS site design must provide parking for TPSS maintainer vehicles with access to the TPSS. Refer to Set 904 Grading for additional requirements. The TPSS location site design must also provide the space for a trailer-mounted emergency generator within 40 feet and orientation for the power cable attachment to the generator plug on the exterior of the TPSS.

220.6.3 Substation Enclosure

220.6.3.1 The substation equipment must be housed in weatherproof prefabricated substation buildings for mainline and yard TPSSs. Built-inplace TPSSs in passenger station facility buildings may be acceptable with Sound Transit approval.

220.6.3.2 Prefabricated substations must have all subsystems factory pre-wired and pre-tested and be ready for mounting on foundations.

220.6.3.3 Prefabricated substations, except for the shop TPSS, must have an identical footprint to existing prefabricated substations.

Commentary: The footprint of the shop TPSS may vary and may require consultation with Sound Transit TE group.

220.6.3.4 The layout of subsystems within prefabricated substations must match the layout of subsystems within existing prefabricated substations.

Commentary: The built-in place TPSS may have a different layout due to the building design. If keeping a similar layout is not possible, consult with Sound Transit TE group.

220.6.3.5 The prefabricated TPSS must sit on top of a concrete foundation.

220.6.3.6 The TPSS must have a basement or vault under the TPSS floor.

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

220.6.3.8 Ceiling heights, enclosure openings, and door openings must permit entry and removal of the largest components installed in the enclosure.

Commentary: Prefabricated TPSS enclosures have rear doors to maintain and remove equipment. Each equipment cubicle has its own rear access panels.

220.6.3.9 Walls, ceilings, floors, and doors must have an insulation rating sufficient to prevent condensation and dust.

220.6.3.10 For interior, exterior, and emergency lighting requirements, refer to Set 1007 Electrical Lighting.

220.6.3.11 Substations must have an AC panelboard for the substation auxiliary equipment.

Commentary: Substation auxiliary equipment consists of lighting, convenience receptacles, HVAC, battery charger, heater, isolation transformer, and communications case.

220.6.3.12 Substations must have a DC panelboard for control power.

220.6.3.13 TPSS must be air conditioned. Refer to Set 1003 for HVAC requirements.

220.6.3.14 TPSS must have reliable operations radio coverage inside with the door closed. The telecommunications designer must ensure the correct RF signal enhancement is provided. Refer to SET 303.

220.6.3.15 TPSS buildings must comply with the latest edition of the International Building Code as modified by the State of Washington and the local AHJ. Refer to Set 720 Building Structures.

220.6.3.16 The TPSS must follow WAC and ANSI standards related to hatches, ladder, confined spaces, and fall protection to facilitate maintainability and safety.

220.6.3.17 TPSS vault ladders must comply with ANSI 14.3.

220.6.3.17.1 The hatch design in prefabricated TPSSs must prevent accidental closure or strain on the hinge.

220.6.3.17.2 The hatch lid must allow one person to open the lid from below or above. The force required to open the lid must not exceed 45 pounds.

220.6.3.18 Hatch lid design must not cause tripping hazards and must be flush with the floor.

220.6.3.18.1 Hatch ladders must follow WAC 296-880 fall protection regulations for ladder design and placement. Refer to Set 804 Fall Protection for additional requirements.

220.6.3.19 The TPSS building must have a solar reflectance index (SRI) of at least 82 on all exposed surfaces.

220.6.4 AC Switchgear

220.6.4.1 The AC switchgear assembly must be metal-clad and rated for the utility supplied voltage.

220.6.4.2 The assembly must be housed in dead-front enclosures containing AC draw-out circuit breaker, relaying, metering equipment, and auxiliary power supply.

220.6.4.3 The AC switchgear assembly must provide the means to deliver and control substation power.

220.6.4.4 The TPSS must provide a connection to and be integrated with a networked Sound Transit EPMS to measure the required substation power consumption for Sound Transit use.

220.6.4.5 Designer must provide calculations required to complete their electrical design and properly size equipment based on these criteria and pertinent codes. Designer must produce calculations required by the AHJ and serving utility to document compliance with electrical codes and service requirements. The studies must be based on design–basis equipment and prove that selective coordination is possible.

220.6.4.6 During construction, the contractor must perform and provide final electrical short-circuit, AC and DC coordination, and arc-flash hazard studies to prove compliance with electrical codes. Systems studies must be provided to Sound Transit and the AHJ after each update and approved by the DOR. Electrical equipment must have proper arc-flash hazard labels prior to substantial completion or as required by the AHJ.

Commentary: System studies are performed and completed during construction phase by contractors to validate the design is sufficient with the selected equipment.

220.6.5 Rectifier Transformer

220.6.5.1 The rectifier transformer must be copper wound vacuum pressure impregnated dry-type (VPI), self-cooled, and equipped with appropriate taps.

220.6.5.1.1 Provisions must be included for future addition of fans for increasing the output to the limit of the specified base.

Commentary: The specified base refers to the transformer rating.

220.6.6 Rectifier

220.6.6.1 The rectifier must be of uncontrolled diode design. The rectifier must be naturally convection cooled.

220.6.6.2 Provisions must be included for future addition of fans for increasing the output to the limit of specified base.

220.6.6.3 Rectifier must consist of full wave bridges providing 6-phase 12-pulse rectification, as specified by IEEE 1653.2 circuit 31.

220.6.6.4 Rectifier for the shop substation must have a minimum 3-phase 6-pulse rectification, as specified by IEEE 1653.2 circuit 23.

220.6.7 DC Switchgear Assembly

220.6.7.1 The DC switchgear assembly must form a lineup of dead-front metal enclosures with provision to trip breakers to prevent accidental contact with live parts.

220.6.7.2 Medium voltage terminations must be protected to prevent accidental intrusion from an external source.

220.6.7.3 The DC circuit breakers must be stored energy, draw-out, single-pole units with arc chutes.

220.6.7.4 A main DC circuit breaker must be provided in each line up.

220.6.8 Disconnect switches

220.6.8.1 Positive and negative disconnect switches must be non-load-break type and must be housed in insulated enclosures.

Commentary: Consult with Sound Transit Traction Electrification Group if a load break type switch is considered to use.

220.6.8.2 Disconnect switches must be rated to withstand the system worst-case overload and short circuit conditions without overheating.

220.6.8.3 Positive Disconnect Switches

220.6.8.3.1 In each assembly, DC feeder disconnect switches must open the connection between DC feeder breakers and the OCS power section.

220.6.8.3.2 For each mainline traction power substation, pad-mounted, fully enclosed, DC feeder disconnect switch and tie switch equipment lineup must be provided in the substation yard.

220.6.8.3.3 The tie switch in each assembly must bridge the section insulator or insulated overlap that electrically separates the power sections for that track.

220.6.8.3.4 Sectionalized disconnect switches must be installed near track without any interference.

Commentary: This switch may be installed in line up with disconnect switches at TPSS yard if there is a space constraint. Consult with Sound Transit Traction Electrification Group.

220.6.8.4 Negative Disconnect Switches

220.6.8.4.1 Negative feeder conductors must terminate in a dedicated cubicle

220.6.8.4.2 Negative feeder conductors must be provided with a negative disconnect switch

220.6.8.4.3 A cubicle with a non-load- break negative dc disconnect switch (Device 89N) and provisions for terminating the negative return conductors must be provided. The switch must be mechanically interlocked with the positive main DC circuit breaker.

Commentary: The Kirk Key interlock between main DC breaker and negative disconnect switch is provided to preclude the operation of a rectifier when its negative is disconnected

220.6.9 Rail Voltage Monitoring and Grounding Equipment

220.6.9.1 TPSS must include a rail-to-ground device to automatically ground the rails and/or trip DC breakers when rail voltages exceed the defined settings in Specification 34 21 16.27.

220.6.9.2 A rail-to-ground device, which detects the voltage and current between the negative return and ground, must be installed in each traction power substation.

220.6.9.3 The device must contain a thyristor and contactor which must react to pre-specified rail-to-ground voltage/current and time increments, which must be programmable and variable.

220.6.9.4 The rail-to-ground device must clamp the voltage between the return rail and ground if the timing or magnitude of voltage is reached.

220.6.9.5 The rail-to-ground system must be self-acting and resetting.

220.6.9.6 The LCMS and SCADA must monitor the rail to ground devices.

220.6.10 Protective Devices

220.6.10.1 Based on the magnitude of load, overload, and short circuit currents, a comprehensive protective scheme must be designed to protect the substation equipment, the feeders, and the OCS.

220.6.10.2 Protective relays must be multifunction intelligent electronic device utility-type draw-out devices. Protective relays must be enclosed in rustproof, dust-proof, high-impact cases with test switches.

220.6.10.3 Relays must be visible, accessible for maintenance, and grouped with devices of related functions.

220.6.11 Local Centralized Monitoring System

220.6.11.1 Substations must be equipped with a local control and annunciation system, including an HMI. These must be fully integrated with the Sound Transit SCADA system headend. Substations involved in transfer trip scheme must be integrated with associated substations new and existing.

220.6.11.2 PLCs must be provided for TPSS control and interface to SCADA headend.

220.6.11.3 The PLC must provide time synchronization between the SCADA mother clock and all networked substation equipment's clocks, while still isolating remote I/O and TPSS internal equipment networks per SET 301.

220.6.11.4 The TPSS must have a solid-state dynamic color display. The display must have annunciation with acknowledge and reset functions and a display of the TPSS one-line diagram. The display must provide complete status indication and control of AC and DC breakers.

220.6.12 Transfer Trip

220.6.12.1 Transfer tripping of substations adjacent to the section where a fault is detected must be provided. Refer to Specification 34 21 16.23 for transfer trip specifications.

220.6.12.2 The transfer trip signal between TPSSs must be provided by a dedicated fiber connection.

220.6.12.3 The communication protocol used for transfer trip must be routable to support Set 301 transfer trip network requirements. Emergency Trip Station and Substation Shutdown Station

220.6.12.4 Each substation must be equipped with traction electrification ETS and SSS functions.

220.6.12.5 The ETS button must be mounted in an enclosure outside the entrance door. One SSS button must be mounted near each exit inside.

220.6.12.6 Activation of the ETS must trip and lock out the incoming AC breaker and DC feeder breakers at the substation, and transfer trip and lock out the DC breakers at the adjacent substations for the associated line sections, thus completely isolating the sections.

220.6.12.7 Passenger stations must be equipped with FCC ETS buttons for both directions of OCS from the station.

220.6.12.8 FCC ETS buttons must be located in a panel in the fire control room at passenger stations.

220.6.12.9 Activation of the FCC ETS must trip the dedicated DC feeder breakers that feed the section that is tripped.

220.6.12.10 Activation of the SSS must trip and lock out the incoming AC breaker and all DC feeder breakers but not initiate transfer trip.

220.6.13 Train Control SCADA Provisions

220.6.13.1 Substation equipment must be designed for remote supervision from LCC via the existing Sound Transit SCADA system.

220.6.13.2 Each substation must be equipped with a dedicated TCN network access switch interface, which will connect to the LCMS PLC. Refer to Set 301, Network for detailed requirements.

220.6.13.3 A SCADA points list for digital and analog signals must be provided to the TES equipment supplier by specification. The points list must include definitions of how information from each point will be used at the TPSS and by LCC.

220.6.13.4 To prevent remote operation of local equipment at TPSS, supervisory control local mode must be provided as a function of the TPSS automation system.

220.6.13.5 Equipment must be specified to accommodate desired SCADA functions.

220.6.13.6 The TPSS must utilize breaker controllers (or intelligent electronic devices) that are enabled to support IEC61850 communication for operations and maintenance support.

220.6.13.7 Electrically operated circuit breakers must be specified to accommodate TPSS and SCADA monitoring and control.

220.6.13.8 Motor operated disconnect switches must be specified to accommodate TPSS and SCADA monitoring and SCADA control.

220.6.13.9 Manually operated disconnect switches must be monitored by TPSS LCMS and SCADA.

220.6.13.10 The breaker indication must be programmed to display the circuit breaker state, not its command state, in the SCADA system.

220.6.14 Auxiliary Power

220.6.14.1 Each transformer within the TPSS must be VPI.

220.6.14.2 Each TPSS must be furnished with a battery charger/eliminator and DC distribution panel board, which must be sized to supply substation control power loads sufficiently.

220.6.14.3 The auxiliary power voltages for substations must be 120/240 volts, 1-phase and 208Y/120 volts, 3-phase.

220.6.14.4 AC panel board must provide for substation auxiliary equipment, lighting, convenience receptacle and HVAC.

220.6.14.5 The AC panel must provide 25 percent spare breakers.

220.6.14.6 Each prefabricated TPSS must be equipped with a low-voltage generator connection, which consists of a manual transfer switch and generator plug.

220.6.15 Busbars and Bus Connectors

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

220.6.15.2 Busbars must be rigid, highly electrically conductive copper.

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

Commentary: The purpose of the insulation is to mechanically protect the surrounding equipment. Insulations levels are covered in AC switchgear, DC switchgear, and control power specifications.

220.6.15.4 Bus connections must be bolted and furnished with silver-plated or zinc-plated surfaces with secured torqued mark.

220.6.15.5 Each joint's conductivity must be equal to or greater than the busbar's conductivity.

220.6.15.6 Each bus connection must be provided with the number of bolts sufficient to maintain the designed electrical connection. This requires a minimum of two bolts. Larger busbar joints must be provided with a minimum of four bolts.

220.6.16 DC Feeder Subsystem

220.6.16.1 The DC feeder subsystem consists of all running rails, feeder conductors, jumpers, cable ducts and raceways, and associated hardware that feed the DC power from the substation to the OCS, and the return current to the negative bus in the substation.

220.6.16.2 The distribution feeder cables must have at least 2.4 kilovolts insulation and must be sized according to the system load flow study.

220.6.16.3 The negative return path consists of the distribution equipment between the connections to the running rails and the TPSS DC negative bus.

220.6.16.3.1 Except at yard and shop track interfaces, the running rails must be constructed as an electrically continuous power distribution circuit through use of rail joint bonds, impedance bonds, cross bonds, continuously welded rail, or a combination of all four.

Commentary: Refer to Set 123 Train Control- Link Light Rail for additional negative return and cross-bonding requirements.

220.6.16.3.2 The return path for the tractive load current must only be through running rails.

220.6.16.4 DC positive and negative feeder cables must be sized for the designed loads per LFA.

220.6.16.4.1 Each circuit on mainline must consist of the number of 500 kcmil copper cables that will support the designed load.

220.6.16.4.2 The cable insulation must have a minimum rating of 2.4 kV to meet NEMA WC 71 and UL1072.

220.6.16.4.3 In tunnels and enclosed stations, low smoke ethylene propylene rubber insulated in compliance with NFPA130, non-shielded cables must be used unless approved by Sound Transit.

220.6.16.5 Cable Ducts and Raceways

220.6.16.5.1 The TE (DC positive and negative feeders) raceway type must be provided as shown in Table 220-7. Otherwise, refer to Set 1006 Electrical Raceway.

Table 220-7: TE Raceway Types

Location	Application	Raceway Type
Underground	Feeders from substation to OCS poles or track	PVC sched. 40 conduit or RTRC Type AG SW per UL 2515 or Type BG designated EB or DB per UL 2420, encased in a concrete duct bank per Sound Transit Standard drawings
Stub-up and stub-outs from underground to above ground in protected locations.	Feeders stubbing into substation or into tubular OCS poles	RTRC epoxy fiberglass, Type AG SW per UL 2515
Stub-up and stub-outs from underground to above ground subject to damage		RTRC epoxy fiberglass, Type XW
Above ground, exterior, exposed, subject to damage, including on OCS WF poles		RTRC epoxy fiberglass, Type XW
Above ground, encased in concrete		PVC Sched. 40 conduit or RTRC Type AG SW per UL 2515 or Type BG designated EB or DB per UL 2420, encased in a concrete duct bank per ST standard drawings
Tunnel or enclosed station, exposed		RTRC phenolic fiberglass, Type XW
Tunnel or enclosed station, concrete encased with minimum 3 inches of concrete cover		PVC Sched. 40 conduit or RTRC Type AG SW per UL 2515 or Type BG designated EB or DB per UL 2420

220.6.16.5.2 DC positive and DC negative traction power cables must be installed in separate raceways and pull boxes to minimize the possibility of potential damaging DC short circuits.

220.6.16.5.3 The TE spare raceway must be provided as shown in Table 220-8.

Table 220-8: TE Spare Raceway Types

Application	Quantity of Spare Raceway	Notes
From substation to first TE vault (positive)	2	
From first TE vault to last TE vault before OCS pole	2	
From last TE vault to each OCS pole	1	Stub up location varies
From substation to first vault (negative)	2	
From first TE vault to last TE vault before tracks	2	
From last TE vault to each rail	1	Run to closest rail. Cross bonding can be added where needed.

220.6.16.6 Ancillary Systems

220.6.16.6.1 Switch machines, signaling devices, train communication systems, and other devices or systems that may contact the rails, must be electrically isolated from earth.

220.6.16.6.2 Electrical equipment in direct contact with track must not be interconnected with power neutral grounds.

220.6.16.6.3 Isolation transformers that isolate the AC neutral from earth ground must be installed. Provisions for isolated grounds must be made if the electrical equipment must be grounded.

220.6.16.6.4 Dielectric materials must be used to electrically separate the devices/systems from earth, or solid-state isolation devices designed specifically for the purpose.

220.6.17 Surge Arrestors

220.6.17.1 Surge arresters must be installed in all substations on each outgoing feeder external to switchgear in the vault and between the negative bus and the ground.

220.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

220.7.1 Interface and Integration Management

220.7.2 Design Management

220.7.3 Manufacturing and Construction Management

220.7.4 Installation Management

220.7.5 Inspection and Testing Management

220.7.6 Training, Pre-Revenue Operations

220.7.7 Certification Management

220.8 APPENDICES (NOT USED)

END SET - 220

221 OVERHEAD CONTACT SYSTEM

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TABLES

FIGURES

SET - 221OVERHEAD CONTACT SYSTEM

221.1 INTRODUCTION

221.1.1 Document Scope

221.1.1.1 This set establishes the minimum requirements for the Overhead Contact System.

221.1.1.2 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Sound Transit Design Requirements Set 221 owner to determine the technical source for the design criteria.

221.1.2 Regulations, Codes, Standards, and Guidelines

221.1.2.1 International Regulations, Codes, Standards, and Guidelines

221.1.2.1.1 European Standard (EN) 50119 – Railway applications – Fixed Installations – Electric traction overhead lines.

221.1.2.1.2 Institute of Electrical and Electronic Engineers (IEEE).

221.1.2.1.3 International Code Council/American National Standards Institute (ICC/ANSI) A117.1-03.

221.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

221.1.2.2.1 American National Standards Institute, Inc. (ANSI).

221.1.2.2.2 American Railway Engineering and Maintenance-of-Way Association (AREMA).

221.1.2.2.3 American Society for Testing and Materials (ASTM), including B47 and B8.

221.1.2.2.4 Association of American Railroads (AAR).

221.1.2.2.5 National Electrical Manufacturers Association (NEMA).

221.1.2.2.6 National Electrical Safety Code (NESC).

221.1.2.2.7 NEC National Electrical Code (NEC) and to Washington Administrative Code (WAC).

221.1.2.2.8 Occupational Safety and Health Administration (OSHA).

221.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

221.1.2.3.1 Washington Administrative Code (WAC).

221.1.2.3.2 Washington Industrial Safety and Health Act (WISHA).

221.1.2.3.3 Washington Utilities and Transportation Commission (WUTC).

221.1.2.4 Industry Regulations, Codes, Standards, and Guidelines.

221.1.2.4.1 Underwriters Laboratories, Inc. (UL).

221.1.2.5 Other Jurisdictions (Not Used)

221.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines (Not Used)

221.1.3 Abbreviations and Acronyms

221.1.3.1 APS- auxiliary power system

221.1.3.2 CCTV–closed-caption television

221.1.3.3 CWW–contact wire wear

221.1.3.4 CSW–carbon strip wear

221.1.3.5 LCC–Link control center

221.1.3.6 LRV–light rail vehicle

221.1.3.7 MWCT–messenger wire construction tolerance

221.1.3.8 OCS–overhead contact system

221.1.3.9 O&M–operations and maintenance

221.1.3.10 OMF–operations and maintenance facility

221.1.3.11 OWF–other wayside factors

221.1.3.12 PHC–pantograph horizontal clearance

221.1.3.13 PHCF–pantograph horizontal clearance factor

221.1.3.14 PVC–pantograph vertical clearance

221.1.3.15 TES–traction electrification system

221.1.3.16 VDE–vehicle dynamic envelope

221.1.4 Definitions and Classifications

221.1.4.1 Contact wire construction tolerance: The installation tolerance for the contact wire height, which can typically be taken as +/- 1 inch relative to the designed contact wire height. This value will change at critical clearance locations, such as above crossings (+1/-0 inches), below overpasses or bridges (+0/-1 inches) or at overlaps (+/- 1/2 inch).

221.1.4.2 Contact wire wear allowance: The maximum allowable wear on the contact wire for continued operation, measured as a change in vertical thickness.

221.1.4.3 Electrical static clearance: The electrical clearance requirement between the OCS conductors and any adjacent or overhead structure under static conditions with no train or pantograph present.

221.1.4.4 Electrical passing clearance: The electrical clearance requirement between the OCS conductors and any adjacent or overhead structure under dynamic conditions with a train and pantograph passing.

221.1.4.5 Lockdown height: The height at which the pantograph will lock into a down position.

221.1.4.6 Pantograph carbon strip wear allowance: The maximum allowable wear on the contact wire for continued operation, measured as a change in vertical thickness.

221.1.4.7 Pantograph sway. The lateral movement of the pantograph head induced by the lateral movement of the vehicle.

221.1.4.8 Passing structure construction tolerance: The vertical tolerance on the installation elevation of an overhead structure (i.e., pedestrian or highway bridge).

221.1.4.9 Pantograph uplift: The vertical displacement of the contact wire created by the contact force from the pantograph.

221.1.4.10 Rake: A lean preset of an OCS pole from vertical, before loading, such that when loaded, the pole does not lean forward from vertical.

221.1.4.11 Sag: The vertical deviation of a conductor between two supports; the process of wire tensioning when employing the magnitude of a sag measurement to obtain a preset tension in a conductor.

221.1.4.12 Stagger: Offset of the contact wire from a projected track centerline at a support due to registration and created to distribute wear on pantograph carbon collectors.

221.1.4.13 System Height: Distance between center of messenger wire to the bottom of the contact wire of a catenary system at the support structure.

221.1.5 References (Not Used)

221.2 STAKEHOLDER NEEDS

221.2.1 Passenger Experience

221.2.2 Operational Needs

221.2.2.1 The system needs to be able to use single tracking.

221.2.3 Maintenance Needs

221.2.4 Safety Needs

221.2.5 Security Needs

221.2.6 Reliability, Availability and Maintainability Needs

221.2.7 Environmental and Sustainability Needs

221.2.7.1 Facility designs must promote stewardship of resources and utilities when selecting material, equipment selection, and operational strategies with the goal of conservation and efficiency.

221.2.7.2 For sustainability needs, refer to Set 803 Sustainability.

221.3 SYSTEM REQUIREMENTS

221.3.1 System Description

221.3.1.1 The OCS distributes the power supplied from the TPSS to the vehicles. It includes messenger and contact wires, or conductor rail, and their physical supports.

221.3.1.2 The OCS must be designed to allow the trains to operate with all pantographs in contact with the conductors up to the maximum allowable speed without excessive oscillations of the system and without pantograph bouncing or arcing.

221.3.1.3 The OCS consists of all equipment from the feeder cable terminations to the vehicle pantograph. The equipment must include foundations, poles, cantilevers, bridge arms, system conductors, parallel feeders, hangers, jumpers, guys, terminations, tensioning devices, sectioning equipment, and all other necessary equipment.

221.3.1.4 The OCS must be designed to be environmentally acceptable. Within the mechanical and structural design constraints, the system structures and associated equipment must be as lightweight and must use components as visually non-intrusive as possible.

221.3.1.5 The messenger wire and the contact wire system must be double insulated with each level of insulation compatible with the system insulation class.

221.3.2 Pantograph Clearance Envelope

221.3.2.1 PVC is a build-up of various tolerances and allowances affecting the final installed static position of the contact wire and the maximum dynamic movement anticipated.

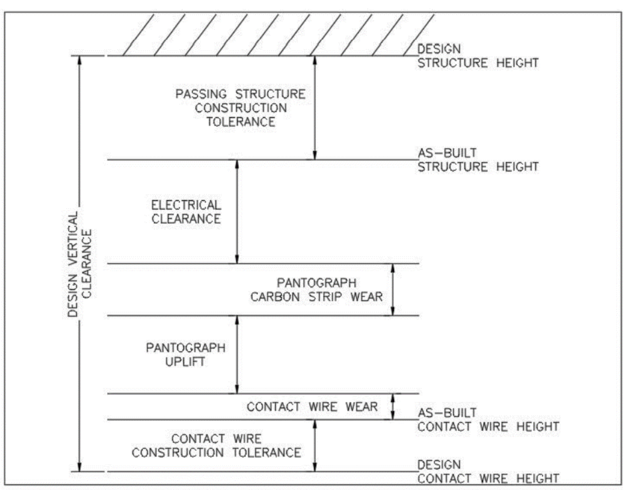
PVC = **VDE** + **PVCF**

221.3.2.1.1 Within the tunnel, the designer must coordinate the OCS design with track, structures, Civil, Fire/Life/Safety, Lighting, Ventilation, and any other discipline that will be utilizing the overhead space.

Commentary: Refer to Set 520 Track Constructions for Vehicle Dynamic Envelope.

221.3.2.2 Single Wire Vertical Design Clearance

Figure 221-1: PVC for Single Wire Design



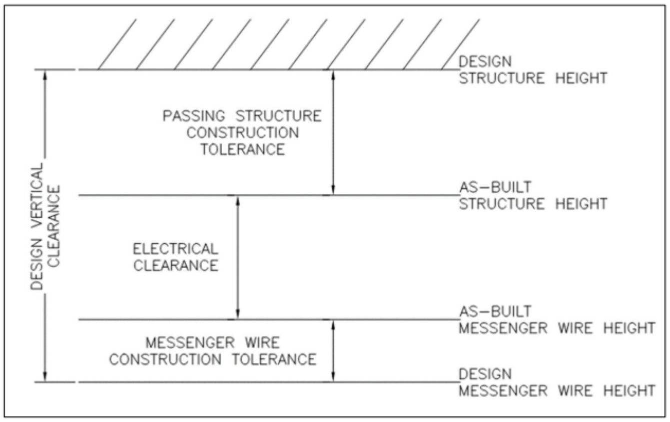
CWCT= contact wire construction tolerance (Refer to 221.1.4.1)
CWW= contact wire wear (0.25”)
Du= pantograph uplift (Open 3”, Tunnel 1.5”)
CSW= carbon strip wear (0.5”)
EC= electrical passing clearance (3.5”)

Passing Structure Construction Tolerance = The vertical tolerance on the installation elevation of an overhead structure
(i.e., pedestrian or highway bridge)

221.3.2.3 Messenger Wire Vertical Design Clearance

221.3.2.3.1 Use the worst-case conditions for the messenger wire height for these clearances. This includes wire movements due to temperature changes.

Figure 221-2: PVC for Messenger Wire Design



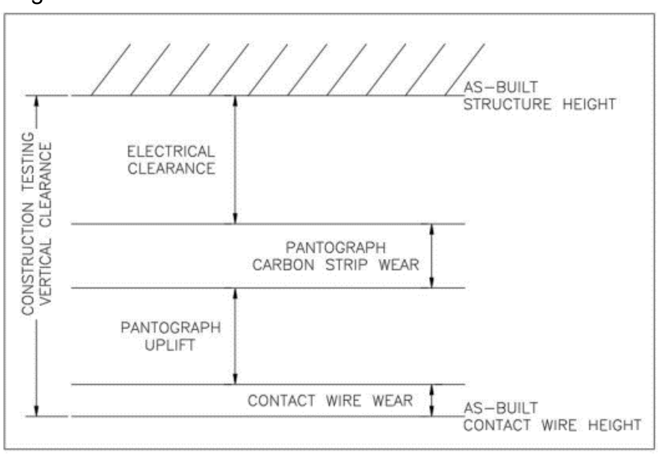
MWCT= messenger wire construction tolerance
(system height CT=1 inch)
EC= electrical static clearance (5”) or 3” + ½ of worst sag of wire, which is greater value taken per NESC table 234-2(2) with reference to Table 235-6

Passing Structure Construction Tolerance = The vertical tolerance on the installation elevation of an overhead structure. Refer to Structure Set 700
(i.e., pedestrian or highway bridge)

PVCF= MWCT + **EC** (+ Passing structure construction tolerance, if applicable)

221.3.2.4 Construction Clearance

Figure 221-3: PVC for Construction



CWW= contact wire wear (0.25”)
Du= pantograph uplift (open 2”, tunnel 3”)
CSW= carbon strip wear (0.5”)
EC= electrical passing clearance (3.5”)

PVCF = CWW +**DU** +**CSW** + **EC**

221.3.2.4.1 The following locations may require the deviation to be anticipated and readily incorporated:

i. Tighter construction tolerances on structures (or removal of the structural construction tolerance for existing structures).

ii. Tighter construction tolerances in embedded track areas.

iii. Tighter installation tolerances on contact wire.

iv. Revised uplift allowance due to site-specific calculations.

v. Additional site-specific insulation barriers to allow reduction in electrical clearances.

221.3.2.5 Pantograph Horizontal Clearance (PHC) is heavily dependent upon the vehicle characteristics. The relationships are shown below:

PHC = **VDE** + **OWF** + **PHCF**

VDE = vehicle dynamic envelope

OWF = other wayside factors (construction tolerance + maintenance tolerance).

PHCF = pantograph horizontal clearance factor= electrical passing clearance (3.5 inches).

Commentary: Refer to Set 520 for VDE and OWF.

Commentary: See Table 520-2 for TCT (Tunnel Construction Tolerance = 4 inches).

221.3.3 Sectionalization

221.3.3.1 The OCS must be electrically separated into discrete sections (sectionalized). The OCS must be designed for the following:

i. To enable the electrical protective relays to disconnect faulted sections of the distribution system and minimize disturbance to the remaining system.

ii. To perform planned maintenance.

iii. To achieve flexible operation during system emergencies.

iv. To meet AHJ requirements for fire zones in tunnels.

221.3.3.2 Single tracking mode must be achievable through each interlocking while the adjacent track OCS is de-energized.

221.3.3.3 Mainline sectionalization must be achieved by means of insulated overlaps.

221.3.3.4 Where physical constraints preclude the use of insulated overlaps, section insulators must be used.

221.3.4 Tie-ins

221.3.4.1 The OCS design must include a design drawing in plan for the potential future installation of an un-insulated overlap at the tie-in of the future extension of light rail tracks. The plan must include any potential future removal.

221.3.4.2 The OCS work must be designed and constructed to accommodate potential future expansion by Sound Transit at the end of the line, or as otherwise directed by Sound Transit.

221.3.4.3 The OCS design must allow for future operating changes with minimal reconstruction.

221.3.5 Disconnect Switches

221.3.5.1 No-load disconnect switches must be used to electrically connect and disconnect OCS sections.

221.3.5.2 Manually operated, no-load disconnect switches must be provided at each TPSS yard, to isolate the OCS from the TPSS,

221.3.5.3 A tie (or bypass) switch must be installed on all OCS sections that are fed from a single TPSS, to allow dual fed OCS sections to remain dual fed when any one substation is completely disconnected from the OCS.

221.3.5.4 OCS sectionalizing switches for the mainline must be located trackside. OCS sectionalizing switches for the mainline must be manually operated.

221.3.5.5 Enclosures containing switches must not contain both positive and negative cables or equipment.

221.3.5.6 Switches and components must be housed in insulated enclosures.

221.3.5.7 Spare conduits to accommodate an upgrade to motor-operated switches must be included for all manually operated disconnect switches.

221.3.6 OCS Styles

221.3.6.1 Simple catenary auto tensioned: The simple catenary auto tensioned system utilizes a messenger wire supporting a contact wire using suspension hangers. The system maintains a constant tension throughout a specified temperature range and environmental conditions by means of a counterweight or constant-tension spring termination. The simple catenary auto tensioned system must be used throughout open route sections of the mainline.

221.3.6.2 Low profile, simple catenary fixed terminated: The low profile, simple catenary fixed terminated system must only be used on the mainline track in tunnel sections and must employ a messenger wire supporting a contact wire using hangers. The system is tensioned by fixing the ends of the wire to a support on the tunnel wall or ceiling. The tension in the wire may vary due to temperature and environmental conditions. The low-profile condition must maintain a minimum system height of 1.3 feet.

221.3.6.3 Low profile, simple catenary auto tensioned: The low profile, simple catenary auto tensioned system must be used in locations where structure and wire height are limited. Typical locations are under bridge sections.

221.3.6.4 Single wire fixed terminated: The single contact wire system must be used in storage yards and the OMF. The contact wire must be tensioned by fixing the ends of the contact wire to a pole or other support. The tension in the wire may vary due to temperature and environmental conditions.

221.3.6.5 An auto-tensioned system must be used along the open route sections at mainline.

221.3.6.6 The contact system must be supported and registered by means of hinged cantilevers attached to steel poles located between the tracks. Where necessary, poles located on the outer sides of the track or cross-span wire arrangements may be used.

221.3.7 Structure Spacing

221.3.7.1 Structure spacing (the distance between poles typically) for the overhead system must be as long as practicable and must be based on the pantograph security analysis.

221.3.7.2 To minimize the possibility of harmonic oscillation in the OCS, no more than five spans must be located successively. A span which is at least 10% shorter must be inserted to minimize the possibility of any sympathetic oscillation.

221.3.7.3 The structure spacing must be selected so that the contact wire will remain on the pantograph head within the specified pantograph security.

221.3.8 Stagger

221.3.8.1 The contact wire must have a stagger, an offset from the projected pantograph centerline, to avoid uneven wear of the pantograph carbon running strip. To achieve even wear of the pantograph, the stagger must alternate from center.

Commentary: The typical alternation pattern is at each structure or point of support.

221.3.8.2 Staggers must be designed to provide a minimum of ten-pound radial load on the contact wire to prevent contact wire swivel clamp chatter, which can exacerbate wear.

221.3.8.3 Staggers of in-running contact wires must utilize maximum stagger values on tangent tracks (alternating) and on curves (consistent one side of track centerline).

221.3.9 System Height

221.3.9.1 The system height on the tangent mainline section must be four feet.

221.3.9.2 The system height on tunnel sections must be 1.3 feet.

221.3.10 Stagger Sweep

221.3.10.1 The sweep rate of the contact wire must be designed to minimize carbon strip wear.

221.3.10.2 The minimum sweep rate must be 2 inches per 100 feet. The minimum stagger sweep must be qualified as being necessary for at least 80% of a given span.

Commentary: Instances of special trackwork such as overlap, crossover, reverse curves, yard turnout etc. may not allow for the minimum required sweep. These locations can be allowed with designer justification and Sound Transit Traction Electrification approval.

221.3.10.3 The maximum sweep rate may achieve to restrict the sweep on tangent track sections to 1 full sweep every two sections. The stagger sweep must not cause the loss of contact, resulting in arcing.

Commentary: For yard application, no maximum sweep rate is necessary since the vehicle speeds would prevent the risk of lost contact due to a wire traversing too quickly across the pantograph carbon strip.

221.3.11 Tension Length Design

221.3.11.1 The OCS for each track must include a sequence of overlapping tension lengths.

221.3.11.2 Each tension length must be designed as long as possible considering system alignment, manufacturing limits of conductor length, and the dimensional constraints of the system parameters, such as displacement of contact wire due to swinging cantilevers, tension loss along the system, and counterweight travel or constant-tension spring termination compensation length.

221.3.11.3 The conductors of each full tension length (wire run with a midpoint termination) must be terminated at each end by constant-tension spring terminations or counterweights.

221.3.11.4 Half tension lengths (wire run without a midpoint termination), where one end of the length uses a fixed termination and the other end a counterweight or constant-tension spring termination, may also be used.

221.3.11.5 On steeply graded sections of track (over four percent gradient), half tension lengths must only be used with counterweights or constant-tension spring termination located at the downhill end.

221.3.12 Overlaps, Crossovers, and Turnouts

221.3.12.1 Overlaps must be used between adjacent tension lengths to provide mechanical and electrical continuity of the overhead system.

Commentary: Insulated overlaps do not provide electrical continuity.

221.3.12.2 Each mainline crossover and turnout must be of the same OCS style as the mainline.

221.3.12.3 The overlap, crossover, and turnout arrangements must be designed considering the electrical sectionalization and mechanical properties of the overhead system.

221.3.12.4 At transitions, a smooth pantograph passage and good current collection without arcing must be achieved as required under all operating conditions, unless ice is present.

221.3.12.5 At overlaps, a minimum 3-inch clearance must be maintained between cantilevers and between the cantilever frames and adjacent conductors of different wire runs.

221.3.12.6 The overlap, crossover, and turnout arrangements must be designed using poles with single or twin cantilevers.

221.3.12.7 In areas where center poles are used, the overlaps must be staggered along the track to avoid having more than one system terminated per anchor pole.

Commentary: One balance weight or two constant-tension spring terminations.

221.3.13 Grounding and Bonding

221.3.13.1 All OCS poles must be grounded by grounding rods. Methods and materials must be in accordance with NEC 250 requirements, unless otherwise specified.

221.3.13.2 Ground wire must be terminated to the OCS pole with a lug. Jumper wire to connect the foundation horizontal/vertical rebar must be exothermically welded to the ground rod. All other connections must be exothermically welded.

221.3.13.3 At elevated structures, OCS poles may be allowed to use an irreversible compression type crimp instead of exothermically welded to prevent corrosion. This must be approved by the Set 221 owner.

221.3.13.4 Ground wire must be 4/0 American wire gauge minimum.

221.3.13.5 Ground rods must be at least 8 feet in length and embedded a depth of at least 10 feet.

221.3.13.6 The insulated 4/0 cable of the surge arrester must be connected to a dedicated surge arrester grounding system, such as grounding rods, to meet 5 ohms or less.

Commentary: Separate grounding for the surge arrester complies with IEEE 1627

221.3.13.7 The surge arrester grounding system must be separate from other grounding systems. The surge arrester grounding cable cannot be used as a ground reference for the stray current test boxes/stations.

221.3.13.8 On OCS support structures including poles, a maximum resistance to ground of 25 ohms is required. If required resistances are not achieved, additional ground rods must be installed and connected to the jumper until the required resistance is attained.

221.3.13.9 Additional ground rods must be spaced a minimum of 10 feet from the original ground rod and each other.

221.3.13.10 OCS poles located within the limits of a passenger station grounding system must have its pole ground interconnected to the station ground. Do not locate OCS poles within 6 feet of the platform edge where passengers may make contact.

221.3.13.11 OCS poles located on aerial structures must meet the following criteria, depending on the type of aerial structure.

221.3.13.11.1 Where the aerial structure does not include welded deck reinforcing steel, provide a ground electrode system to electrically interconnect to the OCS support poles.

i. Provide a copper cable from each OCS support pole to the grounding electrode system.
ii. The copper cable must be sized based upon anticipated fault current and fault clearing time.
iii. The ground cabling must be routed off the structure in conduit and terminated in junction boxes or test cabinets that house wires from the deck reinforcing steel and the ground electrode system.
iv. Cabling must be designed to allow for connection of interconnected OCS poles along the aerial structure to all ground electrode systems installed with a particular aerial structure.

221.3.13.11.2 Where the aerial structure has welded deck reinforcing steel, electrically connect the OCS support poles to the welded deck reinforcing steel.

i. Provide a copper cable from each OCS support pole to the deck reinforcing steel.
ii. The copper cable must be sized based upon anticipated fault current and fault clearing time and be a minimum of 4/0 American wire gauge.
iii. Thermite weld or braze the cable to the OCS support pole and to the nearest electrically continuous reinforcing bar in the aerial structure deck.

221.3.14 Headspans/Cross-spans

221.3.14.1 Headspans and cross-spans must be used at locations where cantilever construction cannot be achieved.

221.3.14.2 A headspan consists of two or three spans of wire that cross the track and support the OCS. A cross-span consists of a single wire. Registration utilized for both span types must allow for along track movement.

221.3.15 EMI Mitigation

221.3.15.1 When required by project agreements, the designer must coordinate TES design for EMI mitigation.

Commentary: The EMI requirements are unique to each project and will be required on a project-by-project basis.

221.3.15.2 In the EMI section, when it is required, the messenger wire must be sectionalized with inline insulators and must not be energized. It is used only to support the contact wire to continue the mechanical attributes of the OCS relative to the pantograph as it passes from the normal section to the EMI section and vice versa.

221.3.16 OCS Thermal Analysis

221.3.16.1 Perform an OCS thermal analysis to verify that the OCS design can support peak normal and contingency operations, as modeled in the LFA, without exceeding the OCS conductor temperature ratings. This must include the assessment of maximum peak and average temperatures during steady state operations. The TES load flow model must be used as a tool to gather OCS conductor current loading results to support thermal analysis.

221.3.16.1.1 The OCS thermal analysis must include assumptions and justifications for the input parameters chosen, the method of calculation used, and any adjustments made to the parameters for environmental criteria such as tunnels or sheltered locations.

i. Maximum allowable wire temperature limits are in accordance with EN 50119, Table 1.
ii. Minimum base ambient temperature is 40 degrees Celsius (104 degrees Fahrenheit).
iii. Wind speed and angle is 2 feet per second (0.61 meters per second) and perpendicular wind speed must be per IEEE 738.
iv. Calculation methods must be in accordance with IEEE 738.

221.3.16.1.2 The OCS thermal analysis as modeled in the LFA must be performed during preliminary design and used to validate the final design if needed.

221.3.17 Electrical Parameters

Table 221-1: Section Insulation Requirements

Wet flashover	45 kV
Dry flashover	25 kV

Table 221-2: Minimum Electrical Clearances

Static clearance	5 in
Passing clearance	3.5 in
Notes: Refer to Section 221.3.1.2 Pantograph Clearance Envelope	

221.3.18 Mechanical Parameters

Table 221-3: Distribution and Return System

Average contact wire wear for electrical load flow analysis	15%
Average running rail wear for electrical load flow analysis	5%
Typical running rail weight	115 lbs.

Table 221-4: Conductor Material

Messenger wire	HD Copper
Contact wire	HD Copper

Table 221-5: Factors of Safety – Conductors and Wires

Operating	2.0
Non-operating	1.6
Contact wire wear for mechanical design	30%

Table 221-6: Factors of Safety – Hardware

Operating	2.5
Non-operating	2.0

Table 221-7: Minimum Contact Wire Height Above Top-of-Rail

Exclusive right-of-way, at grade or elevated trackway	15 ft 0 in
In-street system	20 ft 6 in
Road and street grade crossing	20 ft 6 in
Railroad crossings	22 ft 6 in
New tunnels	13 ft 10 in
Existing tunnels	13 ft 0 in

Table 221-8: Minimum Clearance between OCS and Overhead Utility Power Lines at Worst Case Sag

Type of Overhead Line	Min Clearance to OCS conductors	Min Clearance to OCS supporting infrastructure other than pole	Min Clearance to OCS poles
Utility Power Up to 50kV including neutral	15 ft	15 ft	10 ft
Utility Power exceeding 50kV including neutral	See 221.3.18.1	See 221.3.18.1	See 221.3.18.1
Communication	10 ft	5 ft	5 ft

221.3.18.1 The overhead distribution and transmission lines are based on phase to ground voltage of 750 volts to 50 kilovolts. For overhead lines above 50 kilovolts, an additional 0.4 inches per kilovolt exceeding 50 kilovolts must be added to the clearance.

221.3.18.2 A 5-foot envelope is necessary Sound Transit workspace above and around the OCS must be clear of all obstructions. It is included in the clearances in Table 221-8. Refer to JOD115 for a visual of the clearances.

221.3.18.3 Any third-party utility owner's clearance criteria must take precedence if they are more conservative.

Table 221-9: Maximum Contact Wire Gradients for Design

Description	Maximum Percent
Yard/ Shop Design	2.3%
30 mph (48 km/hr)	1.3%
45 mph (73 km/hr)	0.8%
60 mph (96 km/hr)	0.6%
Gradient change	Half of above values

Table 221-10: Pantograph Security

Minimum Pantograph Security	6 in
Pantograph uplift allowance open route	3 in
Pantograph uplift allowance tunnels	1.5 in
Notes: Refer to Section 221.3. 2 Pantograph Clearance Envelope	

221.3.18.4 Track Maintenance Tolerance. Refer to Requirement Set 520.

221.3.18.5 Vehicle Clearances. Refer to Requirement Set 520.

221.3.18.6 Pantograph and vehicle characteristics. Refer to Requirement Set 421.

221.3.19 Climatic Parameters

Table 221-11: Climatic Conditions

	Temperature (degrees F)	Wind Speed (MPH)	Radial Ice (inches)		Notes
			MW	CW	
Operating Conditions					
OP1	60	0	0	0	Nominal Conditions
OP2	0	55	0	0	Lowest Temp, Max Operating Wind
OP3	0	40	0.5	0.25	Lowest Temp, Max Ice plus wind
OP4	120	0	0	0	Highest Temp (used for sag and blow-off calcs on fixed termination applicable only)
OP5	40	0	0	0	Tunnel Lowest Temp
OP6	40	55	0	0	Tunnel Lowest Temp, Max Operating Wind, near portals
OP7	100	0	0	0	Tunnel Highest Temp (used for sag calcs)
Non-Operating Conditions					
NOP1	60	110	0	0	Structural Wind (from ASCE 7-16)
NOP2	0	110	0	0	Low Temp, Structural Wind (from ASCE 7-16)

Table 221-12: Contact Wire Temperature Range for Catenary Auto-Tensioning

Upper Limit of Auto-Tensioning	130°F
Lower Limit of Auto-Tensioning	5°F

221.3.20 OCS Life Cycle

221.3.20.1 The OCS must be designed for a minimum functional life expectancy of 30 years before major overhaul or complete replacement becomes necessary.

221.3.21 Aesthetics Criteria

221.3.21.1 Visual appearance of the OCS must be addressed in the design of the system. This must include

a. Symmetry of system.
b. Pole clusters having the same height and diameter.

c. Tensioning device/overlaps at least one adjacent pole away from a station.
d. Down guy and feeder poles must not be located at intersections or stations.
e. OCS pole location for at-grade and grade-separated stations must be coordinated with station design and structural grid. The OCS poles must be aligned with primary station structural grids where OCS calculations allow this without compromising the functionality and longevity of the OCS.

   Commentary – An aesthetic consideration is desired for aligning inter-track fencing with the platform and structural grid of the station. OCS pole locations are desired to facilitate this by aligning with structural grid.

221.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

221.4.1 System Breakdown Structure (Not used)

221.4.2 System Sites and Locations

221.4.2.1 Mainline

221.4.2.1.1 OCS poles must not be used for lighting, signals, or CCTV.

221.4.2.2 Yard

221.4.2.2.1 Provide traction power feeders to storage yards such that they afford operational flexibility permitting isolation of discrete sections by switching and circuit breakers. Incorporate switching from the wayside that must allow any exterior track to be powered from more than one circuit.

221.4.2.2.2 The OCS system design must adopt the single wire fixed terminated at storage yard and OMF.

221.4.2.2.3 Storage tracks must have individual isolation when feasible via disconnect switches. These disconnect switches must be interlocked with dedicated feeder breakers.

221.4.2.2.4 Storage tracks must be divided into groups of three tracks or less. Each group must have a dedicated circuit breaker/no-load disconnect switch and may be sectionalized from the run around track by a no load disconnect switch and/or bridging type section insulator.

221.4.2.2.5 Non-bridging section insulators must be used between yard and mainline to reduce the risk of arcing due to different power supplies. The track and OCS design must be coordinated to ensure that non-bridging section insulators and track insulated joints are as close to each other as possible.

Commentary: Generally, the track IJ should be no further from the corresponding SI than the lateral distance between vehicle pantograph and its leading wheel set.

221.4.2.2.6 The lead track at the yard must match the mainline OCS configuration at the point of tie-in. Unless otherwise required by specific project requirements, the lead track must be designed as auto tensioned wire runs.

Commentary: The yard wire run terminations being served by self-supporting poles rather than the use of down guys is preferred.

221.4.2.2.7 The OCS must be designed to ensure the OCS pole handholes are oriented to maximize worker safety.

221.4.2.2.8 Yard OCS wire must be staggered to provide uniform of pantograph wear.

221.4.2.2.9 Tapered tabular steel poles, which are used for freedom of application of the direction of cross-spans and terminations, must be used.

221.4.2.2.10 The yard OCS gradient must meet Table 221-20 Maximum Contact Wire Gradients.

221.4.2.2.11 OCS poles must not be used for lighting, signals, or CCTV.

221.4.2.3 Shop

221.4.2.3.1 The OCS system design must adopt the single wire fixed terminated at storage yard and OMF.

221.4.2.3.2 The tracks inside the OMF building must be individually isolated from each other through non-bridging type section insulator and disconnect switches.

221.4.2.3.3 Non-bridging section insulators must be used at the entry of the shop from the yard to prevent the risk of arcing due to different power supplies.

221.4.2.3.4 Means to de-energize and/or sectionalize the shop OCS must be provided to Link maintenance personnel. The disconnect switches used in the shop must be grounded and interlocked with APS, fall gate, crane, wheel lathe, and paint booth if applicable.

221.4.2.3.5 The shop OCS gradient must meet Table 221-20 Maximum Contact Wire Gradients.

221.4.2.3.6 To achieve a flat contact wire elevation, the shop entry height must be coordinated with worker clearance requirements for all work platforms within the shop and the heights necessary to serve any vehicle hoist areas.

221.4.2.3.7 The shop designer must coordinate with the OCS designer to ensure there is no interference between shop equipment (e.g., vehicle hoist, crane) and the OCS.

221.4.2.3.8 The contact wire transition through the shop entry doors must be handled with either an articulated door bridge that moves the contact wire out of the way of a closing door, or an opening in the door itself that allows the contact wire to remain continuous through the doorway.

Commentary: Continuous wire through doorway is preferred if feasible. It has multiple benefits, such as fewer mechanical parts for inspection and maintenance, less risk of arcing while passing through the doorway, and less structure loading on the building since the contact wire through the opening remains tensioned.

221.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 221-12: Interface Between OCS and Other Disciplines

SET SERIES	SET NAME	SET 221 INTERFACE
010	General	X
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	X
500	Track	X
600	Fire-Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	
1200	Security	

221.5.1 Train Control & Signals

221.5.1.1 Coordination to ensure OCS poles do not obstruct view of the LRV signals from the LRVs cab.

221.5.2 Traction Power
Coordination of Traction Power and OCS design

221.5.3 Stray Current

221.5.4 Operational Communications

221.5.5 Track Engineering

221.5.5.1 Coordinating lining up section insulators with existing insulated joints.

221.5.5.2 Resistivity of the rail, track to earth resistances.

221.5.5.3 Pantograph security.

221.5.5.4 Overlaps, crossovers, and turnout requirements coordination.

221.5.5.5 Coordinate OCS height in tunnels.

221.5.6 Fire/Life Safety

221.5.6.1 Coordination of center poles vs side poles for maintenance clearance for walkways.
Coordinating tunnel vent zones with TES isolation zones.

221.5.7 Structures

221.5.7.1 OCS poles and foundations, down guys.

221.5.7.2 Seismic requirements

221.5.7.3 Pole design, including live load deflection

221.5.7.4 Coordinate OCS height in tunnels

221.5.7.5 Grounding of structures near OCS

221.5.7.6 Location of OCS poles in stations to align with the station structural grid.

221.5.8 Architecture

221.5.8.1 Coordination of throw-protection fencing/shield.

221.5.8.2 Aesthetics requirements of OCS poles and attachments at stations.

221.5.8.3 Coordinate shop design with OCS designer to prevent equipment interference with OCS.

221.5.8.4 OCS clearance envelope

221.5.9 Civil

221.5.9.1 Coordinate with Civil for protective fencing for OCS.

221.5.9.2 Coordinate OCS height in tunnels.

221.5.10 Mechanical/Electrical Building Systems

221.5.10.1 OCS grounding and bonding.

221.5.10.2 Coordinate OCS height in tunnels.

221.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

221.6.1 Foundations

221.6.1.1 The design of foundations for supporting structures and guy anchors must be based on structure loading calculations and soil data. Refer to Set 720 Building Structures for additional requirements.

221.6.1.2 The design of OCS foundations must use the working stress method.

221.6.1.3 Supporting structure foundations must be designed to accept bolted base poles and must have provisions for feeder conduits including spare conduit and structure grounding as required.

221.6.1.4 Pole foundation size and anchor bolt design must be standardized to minimize the number of varying sizes.

221.6.2 Poles and Supporting Hardware

221.6.2.1 Poles must be designed to be free standing, except for termination poles which may include down guys. Refer to Structures Set 720 for additional requirements.

221.6.2.2 Wide flange beam poles must be used, unless otherwise stated in Set 221.

221.6.2.3 For operations in paved track or street-running sections where Sound Transit designates additional aesthetic criteria, side-mounted tapered tubular steel poles must be used.

221.6.2.4 Structures must be designed so that normal operating across-track live load deflection must not exceed 2 inches (1 inch in either direction laterally) at contact wire level.

221.6.2.5 For tubular poles, taper rate must be consistent: 0.14 inches per feet.

221.6.2.6 Refer to Set 701 Geotechnical for seismic criteria of OCS structures.

221.6.2.7 Poles and supporting hardware must comply with Sound Transit Standard Drawings to ensure consistency across projects and spares interchangeability.

221.6.3 Down Guys

221.6.3.1 Down guys are used to reduce the bending moment applied to the pole and foundation.

221.6.3.2 A down guy must be attached in line with the conductor termination and anchored into an engineered attachment point, such as a drilled foundation or structure attachment.

221.6.3.3 A separate down guy wire must be provided for each wire terminating wire at a structure. Two down guy wires may terminate to a single guy anchor.

221.6.4 Cantilevers

221.6.4.1 Cantilevers must be hinged at their pole clamps to accommodate conductor along-track movement.

221.6.4.2 Cantilevers must be designed to either hold the conductors away from the pole (push-off) or to hold the conductors towards the pole (pull-off).

221.6.4.3 No parts of a cantilever, except the contact swivel clamp, must intrude into the pantograph clearance envelope, Table 221-10, with the contact wire uplifted.

221.6.4.4 Maximum contact wire deviation at a single contact wire swivel clamp must be 7 degrees.

221.6.5 Bridge Supports and Tunnels

221.6.5.1 Elastic arm-type OCS supports must be used at bridges and in tunnels where there is insufficient clearance to accommodate cantilever-type assemblies.

221.6.5.2 Supports must restrict uplift of the contact wire when subjected to pantograph pressure and must be capable of providing vertical and across-track adjustment.

221.6.5.3 OCS bridge supports must permit the longitudinal movement of contact wire.

221.6.5.4 Wedge, sleeve, or undercut anchors must be used for horizontal or vertical applications.

221.6.5.5 Anchors for bridge and tunnel supports must not use epoxy due to the degradation of the mechanical strength.

221.6.6 Hangers

221.6.6.1 Hangers consist of a messenger wire clamp, contact wire clamp, and stainless-steel wire.

221.6.6.2 Hangers must be installed vertically, evenly spaced with a maximum spacing of 30 feet. V-hangers may be used in low profile applications.

221.6.6.3 The hanger must be non-current carrying and must use insulated thimbles or sleeves at messenger wire clamp and contact wire clamp. The hanger length must be determined by the normal sag of the messenger.

221.6.6.4 In EMI sections insulated hangers with synthetic rope must be used.

221.6.7 Insulators

221.6.7.1 Insulators must provide electrical insulation in accordance with the system insulation class and must have the mechanical safety factors specified in Table 221-7.

221.6.7.2 The insulators must have resistance against deterioration from exposure to sunlight and airborne chemical pollutants.

221.6.7.3 The insulators' life expectancy must be greater than or equal to the life expectancy of the rest of the system.

221.6.7.4 The energized parts must have a minimum of two levels of insulation from grounded structures. One level of insulation must be at the contact wire attachment.

221.6.7.5 Section insulators must not be used in the mainline, except in crossover sections or spur tracks or as otherwise permitted.

221.6.7.6 DC hipot insulation testing must use a test voltage of 4.5 kilovolts and the leakage current to ground must be less than or equal to 5 milliamperes per mile of single-track OCS.

221.6.8 Conductors and Associated Items

221.6.8.1 Contact wire and messenger wire must have the following conductor properties

Table 221-14: Contact and messenger wire conductor properties

CHARACTERISTICS	CONTACT WIRE	MESSENGER WIRE
Material	Hard-drawn copper	Hard-drawn copper
Description	Solid-grooved	Stranded
Insulation	None	None
Specification	ASTM B47	ASTM B8, Class AA
Size	350 kcmil	500 kcmil
Conductor Properties		
Diameter	.62 in.	.811 in.
Area	.27 sq. in.	.3928 sq. in.
Weight	1.063 lbs/ft	1.544 lbs/ft
Breaking Strength	11,810 lbs.	21,590 lbs.
Coeff Thermal	9.4×10^{-6}	9.4×10^{-6}
Modulus of Elasticity	17×10^{6}	17×10^{6}
Max Allowable Wear	30%	None

221.6.8.2 Feeder jumpers must be insulated, stranded copper conductors with sufficient flexibility to prevent fatigue failure of the cable due to movement and/or vibration of the overhead conductors.

221.6.8.3 When attached to contact wires and to messenger wires, feeder jumpers must have two clamps per conductor per clamped location.

221.6.8.4 Conductor connections, attachments, hangers, and clamps must be copper or bronze fittings and must be designed for ease of replacement and maintenance.

Commentary: Hangers and clamps used as conductor supports are allowed to be stainless steel.

221.6.8.5 Continuity and equalizing jumpers must be flexible bare copper conductors.

221.6.8.6 The jumpers must face in the normal direction of travel.

221.6.8.7 Spacing of equalizing jumpers must be based on required conductivity, with a minimum of one jumper per 200 feet.

221.6.8.8 When attached to contact wires and to messenger wires, continuity jumpers at overlaps and at crossovers must have two clamps per conductor per clamped location.

221.6.8.9 Where jumper cables are used to provide full-feeding electrical continuity, they must be equal to or greater than the electrical capacity of the OCS circuit ampacity.

221.6.8.10 No contact wire and messenger wire splices are permitted.

221.6.9 Terminations and Midpoint Anchors

221.6.9.1 Strain-type termination assemblies must be lightweight and aesthetically pleasing. Wire wrap, straight line, cone, or wedge type designs are acceptable.

221.6.9.2 Turnbuckles must be included as appropriate and must have adequate adjustability.

221.6.9.3 A mid-point anchor arrangement must be used within 500 feet or 10 percent of the midpoint of each tension length of auto-tensioned equipment, whichever is greater, to restrict movement of the conductors at that point.

Commentary: For smaller tension lengths, the 10 percent may not be attainable. In this case, the increased percentage, using 500 feet, would not have negative impacts.

221.6.9.4 Where constant-tension spring termination assemblies are used, the mid-point anchor must restrict movement of the messenger wire and the contact wire.

221.6.10 Tensioning Devices

221.6.10.1 Auto-tensioned system conductors must be tensioned using cast iron or steel counterweights, or constant-tension spring termination assemblies.

221.6.10.2 At wide flange beam poles, counterweights must be constrained from horizontal motion. Counterweights must be positioned between the flanges.

221.6.10.3 When in areas frequented by passengers or pedestrians, counterweights must be provided with protective shields.

Commentary: The protective shields are used to prevent pinch hazards to passengers or pedestrians.

221.6.10.4 At tubular poles, counterweights must be outside of the poles.

221.6.10.5 The tensioning devices must accommodate conductor expansion and contraction as well to limit the damage to the system under "broken wire" conditions.

221.6.10.6 The operating cables must be flexible stainless-steel wire.

221.6.10.7 Where constant-tension spring termination assemblies are used, separate spring units are required for each contact wire and each messenger wire.

221.6.10.8 An analysis of conductor termination height must be provided at each location. At a minimum, the analysis must consider clearance to adjacent equipment, clearance at wire crossings, horizontal and vertical loading of the out-of-running assembly, and clearance for operation of termination equipment, over the range of environmental conditions.

221.6.11 Surge Arresters

221.6.11.1 Over-voltage protection for the overhead system must be provided by surge arresters.

221.6.11.2 Surge arresters must be rated to withstand the maximum system voltage regeneration and anticipated voltages induced from paralleling high-voltage transmission lines.

221.6.11.3 Surge arresters must be capable of discharging the energy resulting from lightning strikes or other excessive surges.

221.6.11.4 At a minimum, surge arresters must be installed at feeder terminations located adjacent to each substation, each tie station, substation feeder switches, and 1,000 feet either side of the substation, midway between substations, and in areas of reduced clearances, such as overhead bridges and tunnel portals.

221.6.11.5 The ground electrode resistance of surge arrester must be 5 ohms or less. Each surge arrester must have a dedicated grounding system.

Commentary: The OCS pole grounding is separated from the surge arrester’s grounding.

221.6.11.6 The surge arrester must not be installed at passenger stations platform.

Commentary: This prevents passengers from being exposed to the safety hazard in case the surge arresters blow up.

221.6.12 Protective Fencing

221.6.12.1 When OCS is constructed near buildings and structures, screening and fencing must be erected on the structures and stairs if the OCS wires are within 10 feet of the space a person can occupy. Refer to Set 903 Fencing for additional requirements.

221.6.12.2 Screening and fencing must be bonded.

221.6.12.3 When OCS is constructed below bridges, garages, or other aerial structures, throw-protection fencing must be used above the OCS.

221.6.12.4 All protective screening and fencing must match the surrounding architecture.

221.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

221.7.1 Interface and Integration Management

221.7.2 Design Management

221.7.3 Manufacturing and Construction Management

221.7.4 Installation Management

221.7.5 Inspection and Testing Management

221.7.6 Training, Pre-Revenue Operations

221.7.7 Certification Management

221.8 APPENDIX (NOT USED)

END SET - 221

222 STRAY CURRENT CORROSION CONTROL

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SET - 222 STRAY CURRENT CORROSION CONTROL

222.1 INTRODUCTION

222.1.1 Document Scope

222.1.1.1 This set provides requirements for stray current control to prevent premature corrosion failures on transit systems facilities and underground structures.

222.1.1.2 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 222 owner to determine the technical source for the design criteria.

222.1.2 Regulations, Codes, Standards, and Guidelines

222.1.2.1 International Regulations, Codes, Standards, and Guidelines (Not Used)

222.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines (Not Used)

222.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

222.1.2.3.1 City of Bellevue Light Rail Utility Standards (2022).

222.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

222.1.2.4.1 ACE 10b189 “Direct Current Operated Rail Transit Stray Current Mitigation.

222.1.2.5 Other Jurisdictions (Not Used)

222.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines (Not Used)

222.1.3 Abbreviations and Acronyms

222.1.3.1 CP–cathodic protection

222.1.3.2 TPSS–traction power substation

222.1.4 Definitions and Classifications

222.1.4.1 Traction power substations: Electrical system facilities located along the system route and connected to the local power utility company. They include all equipment necessary to transform and rectify AC three-phase voltage to DC electrification voltage.

222.1.4.2 Cathodic protection: Technique used to control the corrosion of a metal surface by making it the cathodic side of an electrochemical cell.

222.1.4.3 Stray current: Current that flows elsewhere rather than along the intended current path.

222.1.5 References (Not Used)

222.2 STAKEHOLDER NEEDS

222.2.1 Passenger Experience (Not Used)

222.2.2 Operational Needs (Not Used)

222.2.3 Maintenance Needs

222.2.3.1 Sound Transit will perform track-to-earth resistance and voltage gradient testing to ensure rail isolation levels are maintained in service and stray current is mitigated. Please see Appendix #1.

222.2.4 Safety Needs

222.2.4.1 Excessive stray current levels can lead to corrosion, short life expectancy, and/or failure of structures or utilities under or near the rail.

222.2.4.2 Any access points for stray current related work must require safe access.

222.2.5 Security Needs (Not Used)

222.2.6 Reliability, Availability and Maintainability Needs (Not Used)

222.2.7 Environmental and Sustainability Needs (Not Used)

222.3 SYSTEM REQUIREMENTS

222.3.1 General Requirements

222.3.1.1 Stray current control is required to prevent premature corrosion failures on transit systems facilities and underground structures.

222.3.1.2 Stray current control must reduce or limit the level of stray currents at the source (track isolation or resistance to ground), under normal operating conditions.

222.3.1.3 Structural requirements must reduce or limit the effects of stray current on the elevated and tunnel structures as specified in Set 721 Bridge and Elevated Structures and 722 Tunnel and Underground Structure Design.

222.3.1.4 Utilities requirements must reduce or limit the effects of stray current on utilities in the vicinity of the light rail as specified in Set 902 Utilities.

222.3.1.5 Track requirements must reduce or limit the effects of stray current on the transit system as specified in requirements Set 522 Track Construction.

222.3.2 Functional Requirements

222.3.2.1 See traction electrification requirements Section 220.6.9 for rail-to-ground voltages in mitigating stray current.

222.3.2.2 See Set 522 Track Construction requirements regarding rail isolation and continuous rail in mitigating stray current.

222.3.2.3 See structure requirements in Set 721 Bridge and Elevated Structures and Set 722 Tunnel and Underground Structure Design regarding stray current collection within elevated and tunnel structures in mitigating stray current.

222.3.2.4 See Section 226.6.1 for test box requirements in monitoring stray current measurements.

222.3.2.5 See the C700 City of Seattle and Sound Transit Operations & Maintenance agreement for typical requirements on utility agreements and stray current.

222.3.2.6 The number, location, and earth resistance of the ground electrode system must be determined on an individual structure basis.

222.3.2.7 The number, location, and earth resistance of the ground electrode system must be determined on an individual structure basis.

222.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

222.4.1 System Breakdown Structure

222.4.2 System Sites and Locations

222.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 222-1: Interface Between Stray Current and Other Disciplines

SET SERIES	SET NAME	SET 222 INTERFACE
000	General	
100	Train Control and Signals	
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	
500	Track	X
600	Fire-Life Safety	
700	Structures	X
800	Architecture	
900	Civil	X
1000	Mechanical-Electrical and Building Systems	
1100	Technology	
1200	Security	

222.5.1 Traction Electrification

222.5.1.1 See requirements Set 220 Traction Power for traction power-related stray current requirements.

222.5.2 Track

222.5.2.1 See requirements Set 522 Track Construction for track-related stray current requirements.

222.5.3 Structures

222.5.3.1 See requirements Set 721 Bridge and Elevated Structures and 722 Tunnel and Underground Structure Design for structural-related stray current requirements.

222.5.4 Civil

222.5.4.1 See requirements Set 902 Utilities for utilities-related stray current requirements.

222.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

222.6.1 Test Boxes

222.6.1.1 Install test boxes for stray current monitoring.

222.6.1.2 Install test boxes for measurement of stray current flow on the track slab reinforcing steel at end of each station structures, intermediate collector bar locations, traction power substations, and at intervals not greater than 500 feet.

222.6.1.3 The test boxes must house test wires from the collector bars, rails, and ground electrode system, if present.

222.6.1.4 The test boxes must be easily accessible on the structure for maintenance and testing.

222.7 ENGINEERING MANAGEMENT REQUIREMENTS

222.7.1 Requirements Management (Not Used)

222.7.2 Interface and Integration Management

222.7.2.1 Coordinate design with adjacent utility owners and develop maintenance and monitoring agreement.

222.7.3 Design Management

222.7.3.1 Each Link light rail project must have an experienced corrosion control engineer to develop a stray current mitigation design in accordance with the requirements found here.

222.7.4 Manufacturing and Construction Management (Not Used)

222.7.5 Installation Management (Not Used)

222.7.6 Inspection and Testing Management (Not Used)

222.7.7 Training, Pre-Revenue Operations (Not Used)

222.7.8 Certification Management (Not Used)

222.8 APPENDICES

222.8.1 Appendix 1: Stray Current Activity Remedies

Table 222-2: Stray Current Activity Remedies

Total Time-Weighted Variation, in Structure-to-Earth Potential, millivolts DC	Stray Current Activity Designation	Suggested Remedy
Less than 25	Negligible	No further action required
25 to 75	Mild	No further actions required, flag for future testing
75 to 150	Moderate	Increased testing frequency, analyze impact to CP systems
Greater than 150	Severe	Troubleshoot and repair

END SET - 222

301 NETWORK COMMUNICATIONS INFRASTRUCTURE

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SET - 301 NETWORK COMMUNICATIONS INFRASTRUCTURE REQUIREMENTS

301.1 INTRODUCTION

301.1.1 Document Scope

301.1.1.1 This set provides communications network infrastructure standards and requirements for the design of a safe, secure, and reliable communications network. Where there is conflict between requirements, standards or codes, the most safe, reliable, and maintainable approach must prevail.

301.1.1.2 This document provides the Sound Transit communications network infrastructure standards and requirements for the design of a safe, secure, and reliable communications network. Proper implementation of these standards and requirements will result in a maintainable, scalable, and uniform network. These standards and requirements provide the requisite redundancy, resiliency, and fault tolerance minimizing down time and providing alternative communications routing throughout.

301.1.1.3 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Sound Transit Design Requirements Set 301 owner to determine the technical source for the design criteria.

301.1.2 Regulations, Codes, Standards, and Guidelines

301.1.2.1 International Regulations, Codes, Standards, and Guidelines

301.1.2.1.1 ITU-T Rec. G.691 Optical interfaces for single channel STM-64 and other SDH systems with optical amplifiers

301.1.2.1.2 ITU-T Rec. G.911 Parameters and calculation methodologies for reliability and availability of fiber optic systems

301.1.2.1.3 ITU-T Rec. G.957 Optical interfaces for equipment and systems relating to the synchronous digital hierarchy

301.1.2.1.4 ITU-T Rec. G.959.1 Optical transport network physical layer interfaces

301.1.2.1.5 ITU-T Rec. G.1050 Network model for evaluating multimedia transmission performance over Internet Protocol IEEE 802.1 Higher Layer LAN Protocols

301.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

301.1.2.2.1 NFPA 70 National Electrical Code

301.1.2.2.2 NFPA 72 National Fire Alarm and Signaling Code

301.1.2.2.3 NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems

301.1.2.2.4 IEEE 802.1 Higher Layer LAN Protocols

301.1.2.2.5 IEEE 802.3 Ethernet

301.1.2.2.6 IEEE 802.11 Wireless LAN (WLAN) & Mesh (Wi-Fi certification)

301.1.2.2.7 ANSI/TIA-568 Commercial Building Telecommunications Standard

301.1.2.2.8 ANSI TIA-569 Commercial Building Standard for Telecommunications Pathways and Spaces

301.1.2.2.9 ANSI TIA-606 Cable Labeling Standards

301.1.2.2.10 ANSI/TIA-607 Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises

301.1.2.2.11 ANSI TIA-758 Customer Owned Outside Plant Telecommunications Infrastructure Standard

301.1.2.2.12 Building Industry Consulting Services International (BICSI) “Telecommunications Distribution Methods Manual (TDMM)” most current version

301.1.2.2.13 Building Industry Consulting Services International (BICSI) “Information Transport Systems Installation Methods Manual (ITSIMM)” most current version

301.1.2.2.14 TIA-568 Commercial Building Telecommunications Standard

301.1.2.2.15 TIA-569 Telecommunications Pathways and Spaces

301.1.2.2.16 TIA-606 Cable Labeling Standards

301.1.2.2.17 TIA-758 Customer Owned Outside Plant Telecommunications Infrastructure Standard

301.1.2.2.18 APTA-SS-CCS-RP-002-13 Securing Control and Communications Systems in Rail Transit Environments Part II: Defining a Security Zone Architecture for Rail Transit and Protecting Critical Zones.

301.1.2.3 Other Jurisdictions (Not Used)

301.1.2.4 Sound Transit Regulations, Codes, Standards, and Guidelines

301.1.2.4.1 Sound Transit Engineering Procedures

301.1.2.4.2 Sound Transit Design Criteria Manual (this document)

301.1.2.4.3 Sound Transit Standard Specifications

301.1.2.4.3.1 27 11 16 Communications Houses, Cabinets and Racks

301.1.2.4.3.2 27 13 23 Systems Optical Fiber Cabling

301.1.2.4.3.3 27 15 02 Communications Conductors and Cables

301.1.2.4.3.4 27 15 13 Communications Copper Horizontal Cabling

301.1.2.4.3.5 27 17 00 Testing of Communications Copper Horizontal Cabling

301.1.2.4.3.6 27 21 29 Network Systems

301.1.2.4.3.7 27 80 00 Communications Reliability Program

301.1.2.4.3.8 Sound Transit Systems Standard Drawings

301.1.3 Abbreviations and Acronyms

301.1.3.1 ACS– access control system

301.1.3.2 APN– access point name (cellular gateway)

301.1.3.3 APTA– American Public Transportation Association

301.1.3.4 BICSI– Building Industry Consulting Services International

301.1.3.5 BMS– building management system

301.1.3.6 BRT– bus rapid transit (Stride)

301.1.3.7 CCTV– closed circuit television

301.1.3.8 EFN– emergency fan/fire life network

301.1.3.9 EMI– electromagnetic interference

301.1.3.10 ETEL– emergency telephone

301.1.3.11 EVS– emergency ventilation system

301.1.3.12 FBMS – facility building management system

301.1.3.13 FDP– fiber distribution panel

301.1.3.14 FDB– fiber distribution box

301.1.3.15 Gbps– gigabits per second

301.1.3.16 GPS– global positioning system

301.1.3.17 I/O– input/output

301.1.3.18 ITARCH– Sound Transit IT Network Architecture

301.1.3.19 LAN– local area network

301.1.3.20 LCC– Link control center

301.1.3.21 LTE– long-term evolution (cellular network)

301.1.3.22 Mbps– megabits per second

301.1.3.23 MTBF– mean time between failure

301.1.3.24 MTTF– mean time to failure

301.1.3.25 MTTR– mean time to recovery

301.1.3.26 NFPA– National Fire Protection Association

301.1.3.27 NTP– network time protocol

301.1.3.28 PBX– private branch exchange (office phone system)

301.1.3.29 PDU– power distribution unit

301.1.3.30 PET– passenger emergency telephone

301.1.3.31 PIMS– passenger information management system

301.1.3.32 PLC– programmable logic controller

301.1.3.33 SCADA–supervisory control and data acquisition

301.1.3.34 SMFO– single mode fiber optic

301.1.3.35 SNTP– simple network time protocol

301.1.3.36 TCN– train control network

301.1.3.37 TCP/IP– transmission control protocol/internet protocol

301.1.3.38 TCS– train control system

301.1.3.39 TDMM– telecommunications distribution methods manual

301.1.3.40 TIA– telecommunication industry association

301.1.3.41 TPSS– traction power substation

301.1.3.42 UDP– user datagram protocol

301.1.3.43 UPS– uninterruptible power supply

301.1.3.44 VMS– variable messaging sign

301.1.4 Definitions Classification

301.1.4.1 Availability: The proportion of time that a system or network will provide the intended service. Availability is the probability that a network is in service and available to users at any given instant in time.

301.1.4.2 Bandwidth: Indicates how much data, in bits or bytes, flows between two points in a given time, it is a transfer rate. The capacity of a data link is representative of the total amount of information transmitting at any one time.

301.1.4.3 Delay: The duration of time from when a signal transmits to when received.

301.1.4.4 Diversity: The implementation of multiple redundant elements or versions in which the elements and versions are deliberately different. The key goal served by diversity is avoidance of fate sharing amongst critical network elements. Diversity increases resilience by providing alternatives. Diversity requires geographic separation.

301.1.4.5 Error: A general term that refers to data that has altered in some fashion during transmission such that when received at a destination, it is different from that originally sent. Error rates, particularly bit error rates, typically appear as a percentage of the transmitted traffic. Characterized by corrupted data or out-of-sequence packets errors usually arise out of some problem along the transmission path.

301.1.4.6 Failover: The process of switching to a backup component, element, or operation while recovery from a disruption is undertaken. There are several types of failovers:

301.1.4.6.1 Hot or immediate failover requires a running duplicate of the production system as a backup to provide immediate recovery.

301.1.4.6.2 Cold failover is the least complex to implement but likely results in some disruption until the backup is able to initiate service.

301.1.4.6.3 Warm failover uses a backup system not provided with state information on the primary system until a failover takes place.

301.1.4.7 Fault tolerance (FT): A network's ability to recover automatically from problems. For this reason, FT is usually associated with availability in the range of four to five nines (or 99.99% to 99.999%).

301.1.4.8 Jitter: Variation in latency or delay.

301.1.4.9 Latency: The time it takes for a particular signal, often in the form of a data packet or voice signal, to get from a network origin point to a destination point, measured in units of time (usually milliseconds). In essence, latency is the cumulative delay posed by all the network elements in a transmission path. In an IP network, it is the time for data packets to go from a client to a server. Contributors to latency include the following:

i. Encryption and decryption.
ii. Propagation latency.
iii. Network hops.
iv. Peer points (POP sites).
v. Routers and firewalls.
vi. Impedance mismatch.

301.1.4.10 Loss: The fact or process of losing data or packets. Loss can arise out of network congestion or transmission problems. Loss would occur in the case of a buffer overflow in a device discarding overflowed data altogether, versus fragmenting it prior to retransmission. Loss can also occur when two or more devices attempt to seize simultaneously a network interface, trunk, or link (collisions in Ethernet networks).

301.1.4.11 Mean time between failures: A metric that conveys the mean or average life of a system based on the frequency of system outages or failures.

301.1.4.12 Mean time to failure: A metric used that characterizes the operating life of a system. It is the amount of time from the placement of an unrepairable system or component in service until it permanently fails.

301.1.4.13 Mean time to recovery: The time required for restoring operation in a component that has stopped operating or that is not operating to satisfactory performance level. It includes the time it takes to restore the component to full operation following processes such as diagnosing, repairing, replacement, reboot, and restart.

301.1.4.14 Metrics: are quantitative measures of system or network behavior.

301.1.4.15 Overhead: The conditions that must be factored in to convey the actual payload capacity of a network (may not be applicable for connectionless networks, such as Ethernet). The following are some of the variables that need consideration in overhead:

i. Duplexing.
ii. Collisions.
iii. Duty cycle.
iv. Impedance mismatch.
v. Protocol overhead.

301.1.4.16 Recovery: The activity of repairing a troubled component or system. Recovery activity may not necessarily imply that the element has returned to back to its operational state. At the system level, recovery activities can include automatic diagnostic or restart of a component or system, data restoration, or manual repair.

301.1.4.17 Redundancy: A network or supporting infrastructure feature whereby multiple elements (HVAC, power feeds, PDUs, power supplies, physical cabling, or pathway redundancy) are used so that if one element of the infrastructure cannot provide service, the other redundant element will. Redundancy is realized at many levels of a network to achieve continuity. Effective redundancy requires:

i. Elimination of single points of failure.
ii. Adequate failover process to the redundant element.
iii. Redundant element to provide an equivalent level of service.
iv. Redundancy be diverse to the extent possible.

301.1.4.18 Reliability: The probability that a network or component will perform satisfactorily during a specified period. It is measured by how long it takes for a network or system to fail (i.e., how long it continues to function until it ceases due to failure).

301.1.4.19 Response time: The time from sending a request to receiving a response. Response time is the round-trip latency from the perspective of the user, or the sending device.

301.1.4.20 Resumption: The process of transferring operations over to the repaired or restored element, either gradually or instantaneously once a recovery activity is completed.

301.1.4.21 Single point failure: Any single isolated network element that, upon failure, can disrupt a network's productive service.

301.1.4.22 Throughput: The theoretical carrying capacity corrected for overhead and other factors.

301.1.4.23 Utilization (capacity utilization): A measure of congestion, workload, or usage of a network element.

301.1.4.24 Service ready: Indication that all spare elements can be immediately put into service with no additional preparation or work. For spare physical network infrastructure, it must be installed, terminated, and tested enabling simple plugging in to begin service for cabling. For any kind of pathway capacity, it must be installed, with pull string, and ready for use. Innerduct or other preparation within spare conduit may be required by Sound Transit For network equipment spare capacity and ports must be available for use but ports must not be configured until connection is required for security reasons, similarly with cabinet capacity must be coordinated for space, power, and maintenance. Coordinate with architecture, electrical and mechanical designers that room also accommodates this spare capacity. fiber ports on switches must have the correct SFPs in place to allow use of spare fiber. See system guidance drawings for typical spare terminations. All spare elements must be able to be immediately put into service with no additional preparation or work.

301.1.5 References

301.1.5.1 Sound Transit Standard Specification References

301.1.5.1.1 27 13 23 Systems Optical Fiber Cabling.

301.1.5.1.2 27 15 13 Communications Copper Horizontal Cabling.

301.1.5.1.3 27 17 00 Testing of Communications Copper Horizontal Cabling.

301.2 STAKEHOLDER NEEDS

301.2.1 Passenger Experience (Not Used)

301.2.2 Operational Needs

301.2.2.1 Provide redundancy with unattended, automatic, self-healing capability in all layers (2,3) of ST networks. This includes associated network switches (router, distribution, and access layers) and network pathways. This includes all network supporting any Sound Transit mode of operation (EFN, TCN, Transit, TPSS, Radio or any other operational network). These include Sound Transit Link light rail, Sounder, and BRT systems. Level of redundancy to meet the level of risk associated with the systems on that network. Some network redundancies are prescribed in this document.

301.2.2.2 Provide load balancing to facilitate network resiliency, efficient growth, and scalability.

301.2.2.3 New network designs and implementations must incorporate into the existing network management, reducing downtime and providing monitoring (including for security breaches) and control of the entire network.

301.2.2.4 Coordinate with other disciplines (ST OET and IT) on network monitoring requirements for isolated networks (e.g. Radio, RIO, TPSS, Signals) to be monitored either via SCADA System or via system-specific head-end system.

301.2.3 Maintenance Needs

301.2.3.1 The communications network design must be readily maintainable by Sound Transit technicians to prevent lengthy down times of critical infrastructure.

301.2.3.2 Designs must provide spare replacement parts that are readily available to maintainers.

301.2.3.3 Designs must provide ease of replacing equipment with newer equipment, either upon failure or upon obsolescence, throughout the required nominated element and component service life.

301.2.3.4 Equipment design must minimize the time requirements for maintenance. Keep maintenance equipment and tools to a minimum.

301.2.3.5 Facilities, enclosures, and equipment design must allow for reconfiguration and growth because of regular maintenance and updates and refreshes.

301.2.3.6 Newly installed networks and equipment must be supportable for at least 5 years after the date of substantial completion. Verify with ST operations and IT to verify software and version numbers supported to avoid interoperability issues.

301.2.3.7 Accessible and Serviceable

301.2.3.7.1 Designs must provide unobstructed access and pathways for maintenance and service to and from network infrastructure and equipment in compliance with NEC and BICSI TDMM requirements. This must also include access for future replacement of the equipment such that equipment and panels can be easily removed and replaced within the provided space. Design and installation of network equipment must provide for adequate illumination and easy access in and out of the workspace. Designs must provide a safe exit in case of an emergency to enter or leave the workspace.

301.2.3.7.2 Comply with all BICSI TDMM Chapter 3 “Clearances” for workers to take measurements, check circuits, adjust or replace defective devices, and adjust connections. Network equipment must be accessible and located in an area with adequate working space which meets the following requirements:

301.2.3.7.2.1 Provide 1 meter (3.28 feet) of clear unobstructed space for the installation and maintenance of all cabling and equipment mounted on walls, racks, cabinets, or enclosures.

301.2.3.7.2.2 Provide space for an aisle of at least 1 meter (3.28 feet) wide in the front and rear of the space for each equipment rack (or rack lineup), cabinet, or enclosure. This clearance space must account for the depth of rack-mounted equipment as well as wall-mounted equipment and hardware. Aisle space of 3.28 feet must be maintained while swing out equipment is in the full “out” position.

Commentary: Simply providing 3.28-foot. clearance from the front of the equipment may not be adequate. The 3.28-foot aisle must be measured from the furthest out position of the swung or pulled out equipment. This would require clear space from the front or rear of a rack of 3.28 feet plus the greatest distance of the swing or pull out.

301.2.3.7.3 Comply with all BICSI TDMM Chapter 3 “Lighting” for the safety of the workers servicing the equipment. Installations housing network equipment must provide adequate lighting. Lighting fixtures must provide the proper foot-candles necessary to clearly illuminate the equipment and parts in service.

301.2.3.7.4 Lighting must be coordinated with equipment layout and overhead installations (cable tray, conduit) ensuring that lighting is not obstructed.

301.2.3.7.5 Coordinate lighting with rack, cabinet, and enclosure placements providing a minimum equivalent of 538 lux (50 foot-candles) at the point of cable terminations.

301.2.3.8 Designs must provide accessibility of equipment for regular service, routine maintenance, and troubleshooting:

301.2.3.8.1.1 Equipment must be accessible without the need to move other equipment to access.

301.2.3.8.1.2 Whenever possible, designs must provide one large access to equipment and infrastructure rather than a number of small ones.

301.2.3.8.1.3 Items most critical to system operation requiring rapid maintenance must be immediately accessible. When relative criticality is not a factor, items requiring most frequent access must be immediately accessible.

301.2.3.8.1.4 Cables must route to be readily accessible for inspection and repair. All cables must be rated for the raceway they are placed in.

301.2.3.8.1.5 Wire harness and cabling routed in cable trays and cable management systems must be located for ready access. Associated cabling must not impede access to equipment and must allow for full swing or pull-out functions designed within panels or racks.

301.2.3.8.1.6 Panel, console, and rack-mounted components must have slack cable lengths or service loops. These must be sufficient for removal of the connectors after component extraction from its installed location, unless providing adequate internal access (physical and visual).

301.2.3.8.1.7 Cables must not be route external to the face of the equipment rack.

301.2.3.8.1.8 Structural components of enclosures, racks, or chassis must not prevent access to or removal of equipment.

301.2.3.8.1.9 Maintenance support services (e.g., utility electrical outlets, test connections) must be provided and be accessible at potential problem locations nearby but not within each equipment enclosure.

301.2.3.8.1.10 Checkpoints, adjustment points, test points, cables, connectors, and labels must be accessible and visible during maintenance. Provide sufficient space for the use of test equipment and other required tools without difficulty or hazard.

301.2.3.9 All spare equipment and infrastructure (e.g., network cables, raceway, equipment) must be service ready requiring no additional terminations, testing, or modification prior to service.

301.2.4 Routine maintenance

301.2.4.1 Designs must support routine maintenance or device updates as required. Each device must have the ability to be shutdown individually for updating or be maintained such that there never is more than one device down at any time.

301.2.4.2 Systems must be capable of undergoing maintenance without the interruption of operating services. Maintain all availability, fault tolerance, and utilization performance requirements while performing routine maintenance.

301.2.4.3 Designed systems and subsystems must be as functionally, mechanically, and electronically independent as practical to facilitate routine maintenance and to accommodate Sound Transit's different maintenance groups.

Commentary: Designs must accommodate isolation of systems or subsystems such that common maintenance tasks must not affect other maintenance groups or unrelated systems. For example, an EFN access switch and a BMS PLC are in the same cabinet powered off the same circuits which could result in KCM SCADA maintenance opening a breaker in the cabinet to maintain a PLC. This would cause the EFN network to have a partial outage potentially disabling the EVS system. Also causing OT or IT to get involved who maintain the EFN network. This would cause confusion and downtime.

301.2.5 Physical Security and Safety Needs

301.2.5.1 All network equipment, media, and supporting devices/hardware/power must be secured in designated rooms, locked panels, and secured raceway systems per Sets 815 Telecommunication Spaces, 1203 Access Control, and 1006 Electrical Raceway.

301.2.5.2 Sound Transit's commitment to passenger safety and operational reliability requires design for reliability and maintainability in all network implementations.

301.2.5.2.1 Network designs backup power provisions must support full status memory and process recall.

301.2.5.2.2 Network implementations must tolerate equipment failures without loss of system service.

301.2.5.2.3 Designs must provide maintenance accessibility, clearances, and service ready spare capacity as defined in this Set 301.

301.2.5.2.4 Designs must provide the same level of availably, fault tolerance, and utilization during routine maintenance.

301.2.6 Environmental Needs

301.2.6.1 Designers must consider local government reports on climate change when specifying hardware and heating and cooling required to keep system operational to the availability requirements stated within this set.

301.3 SYSTEM REQUIREMENTS

301.3.1 Network Design Standards- Network Function and Topology

Commentary: Sound Transit requires a resilient, durable optical communications network serving all stations, garages, and facilities to ensure passenger safety and operational reliability. All network designs and implementations must comply with all applicable codes, regulations, industry standards, Sound Transit standards and performance criteria. Requirements for a network may also come from the system requirements being supported by that network.

Sound Transit standard network hardware supports up to PoE+; however, if more power is required, coordinate with Sound Transit to verify if available.

301.3.1.1 Network designs must incorporate open standards (non-proprietary) and proven and accepted communication industry methods and equipment.

301.3.1.2 Communications network capacity must accommodate network traffic across the entire Sound Transit system through ST3.

301.3.1.3 Spare capacity must support additional future expansion while maintaining low optimal bandwidth utilization.

301.3.1.4 Designs must be exponentially scale free and extensible supporting expandability and additional capacity gracefully.

301.3.1.5 Sound Transit operational needs require all network designs feature redundancy from router to router, router to distribution layers, and from distribution to access layers providing unattended, automatic, self-healing capability. See system specific requirements for system specific network redundancy, self-healing, and availability requirements.

301.3.1.6 Load balancing is required facilitating network resiliency, efficient growth and scalability.

301.3.1.7 New network designs and implementations must incorporate into the existing network management reducing downtime and providing monitoring (including for security breaches) and control of the entire network.

301.3.1.8 Network designs must provide high speed, highly available and responsive network implementations. Network design capabilities must match system, subsystem and component service requirements including critical real time transmissions across the entire Sound Transit system through ST3 and accommodate future expansion.

301.3.2 Architecture & Topology

301.3.2.1 All network designs must utilize the standard three-tier topology. The backbone provides a Layer 3 core routing while the fiber distribution layer provides Layer 2/Layer 3 Ethernet local connectivity to operational subsystems and components. The access layer provides Layer 2 Ethernet local connectivity.

301.3.2.2 The continuing expansion of Sound Transit service requires a robust network architecture employing a topology that provides the ability to expand and add capacity over time without sacrificing fault tolerance and survivability. Network designs require continuation of the Sound Transit standard hybrid layered mesh topology providing redundant access links, spatial diversity and excess capacity for loads displaced due to node failure.

301.3.3 Operational Sub-Systems and Components

301.3.3.1 The communications networks must simultaneously support the functional safety, operational, and reliability objectives for the multiple Sound Transit networked operational sub-systems and components, including the following systems:

i. Fire, life safety and emergency systems
ii. Phone systems (ETEL, PET, CES, PBX)
iii. Field Control Systems (TCS, EVS, BMS, FBMS)
iv. SCADA Systems (TCS, EVS, BMS)
v. Security Systems (ACS, CCTV, TIDS)
vi. PIMS
vii. Public address systems
viii. Fare collection systems
ix. TPSS
x. System networks
xi. Network monitoring
xii. Radio systems
xiii. Wind & wave, EMI, vibration, and gas monitoring
xiv. Yard and vehicle monitoring
xv. And any other system required to be connected to a ST communications network

301.3.4 IP Addressing

301.3.4.1 All networking equipment, headend equipment, and end devices must be addressed per Sound Transit Standard IP Schema. IP addressing must support designed functionality for system and networking of each system (layer 2 or 3 communications).

301.3.4.2 Use Sound Transit's IP schema on all networks regardless if networks are isolated from Sound Transit's main networks or not.

301.3.4.3 IP addressing must be assigned by Sound Transit. Sound Transit uses Active Directory for workstations and other end devices. Coordinate with Sound Transit IT and OT to determine whether static IP addressing or dynamic IP addressing is provided using Active Directory is required for specific systems.

301.3.5 Subsystem Usage Patterns

Table 301-1: Subsystem Network Usage Patterns

Sub-System	Typical Usage Patterns
Fire, Life Safety and Emergency Systems (FACP related)	• *Periodic* • *Intermittent* • *Short Bursts, etc.*
ETEL/PET	• *Continuous monitoring* • *Intermittent (calls, recording)*
BMS, FBMS	• Continuous reporting
Emergency Ventilation System (EVS SCADA)	• Continuous (SCADA) • Intermittent peer to peer comms.
Train Control System (TCS SCADA)	• Continuous (SCADA)
Building Management System (BMS SCADA)	• Continuous (SCADA)
Access Control	• *Periodic*

Sub-System	Typical Usage Patterns
CCTV	• Continuous Feed (local DVRs and remote)
PIMS	• Continuous
Fare Collection Systems	• Continuous monitoring • *Periodic*
Traction Power Substations (TPSS)	• Continuous (SCADA)
Radio	• Continuous monitoring *Periodic (remote session)*
Condition Monitoring (EMI, Vibration Monitoring, Gas Monitoring)	• *Periodic*
Yard and Vehicle Monitoring	• Continuous monitoring • *Periodic data exchange*
PBX	• *Intermittent*

301.3.6 Sub-system and Component Network Service Requirements

301.3.6.1 Jitter must not exceed 1 millisecond 99.9% of time and must not exceed ten 10 milliseconds maximum more than 0.1% of time.

301.3.6.2 Designs must provide the above network service while complying with the following bit error and packet loss standards:

301.3.6.2.1 IEEE 802.3.

301.3.6.2.2 ITU-T.

301.3.6.2.3 Rec. G.1050.

301.3.6.2.4 Rec. G.691.

301.3.6.2.5 Rec. G.957.

301.3.6.2.6 Rec. G.959.1.

301.3.7 Infrastructure Durability

301.3.7.1 Sound Transit operational reliability requires a highly durable network. Network infrastructure, appurtenances, and components require the following nominated service lives:

Table 301-2: Nominated Service Life

Network Element/Component	Nominated Service Life
Mechanical infrastructure such as: structural supports, maintenance holes, vaults, raceway, conduit, duct banks, fiber, copper, pedestals, racks, and enclosures.	50 years
Components and devices such as: switches, transceivers, power supplies, environmental appurtenances, protective devices, or other industrial electronics.	7 years

301.3.7.2 Design fiber and copper cables without unnecessary splicing, maximize protection, and use every means to extend cable life. This includes minimizing cable transitions, requiring special non-destructive cable installation methods, special protective jacketing or cable ways (innerduct), eliminating splices in right of way, and designing for the natural aging and signal loss of cables. Always provide innerduct for conduits containing fiber cables. See Sound Transit Standard Specifications 27 13 23 Systems Optical Fiber Cabling and 27 15 13 Communications Copper Horizontal Cabling for detailed requirements.

301.3.8 Backbone Redundancy and Diversity

Commentary: One of the most important design techniques to building reliability into a communications network for Sound Transit is redundancy. This means that if one part of the system fails (i.e., one communications path), there is an alternate path acting as a backup that does not increase latency. Redundancy significantly increases system reliability by multiple paths to critical devices or facilities.

Diversity is the implementation of multiple redundant elements or versions in which the elements and versions are deliberately different. The key goal served by diversity is avoidance of fate sharing amongst critical network elements. Diversity increases resilience by providing alternatives. Diversity requires geographic separation.

301.3.8.1 Provide path diversity and equipment redundancy within the network to meet the Sound Transit redundancy and reliability requirements defined within this section.

Commentary: Security policies and network equipment built to meet reliability standards can have a significant impact on improving network reliability. However, path diversity and equipment redundancy to protect from single points of failure will provide the greatest reduction in system down time. Network equipment will be down from time to time due to system problems or planned outages for network upgrade activities. The only way to make these inevitable occurrences invisible to Sound Transit passenger and the system users is to have an alternate path for the network traffic to use while the outage is occurring. Path diversity is the definition of a minimum of two separate paths for the information from each device or facility.

301.3.8.2 Sound Transit standardizes on two 144-fiber SMFO cables for its fiber optic backbone. Two paths are required when connecting all devices and facilities on the fiber optic backbone. This ensures each device has redundant communications to prevent loss of communications to the device if one path has a failure. This means that the paths are traveling through separate 144-fiber SMFO cables entirely, which must be separated as much as possible by running along opposing sides of the trackway as shown in below Backbone Fiber Diversity figures 301-1, 301-2, 301-2, and 301-3 to meet the intent of diversity. Within tunnels, use both tunnel bores to separate pathways.

301.3.9 Pathways

301.3.9.1 Communications network pathway designs must comply with all parts of the latest version of the following industry standards as well as Sound Transit standards and requirements. When there is a conflict or difference between standards, the designs must comply with the stricter standard.

301.3.9.2 Provide diversity of pathways within Sound Transit facilities per TIA-569 and per BICSI TDMM Chapter 3, “Telecommunication Spaces,” Chapter 4, “Backbone Distribution Systems,” and Chapter 5, “Horizontal Distribution Systems.”

301.3.9.3 Provide diversity of pathways outside/between Sound Transit facilities per TIA-758 and per TDMM chapter 12.

301.3.9.4 EFN and EVS pathways must meet requirements for Class N pathways with Survivability-Level 2 and Shared Pathways-Level 1 in accordance with NFPA 72.

301.3.9.5 EFN and EVS pathways must also meet the requirements of NFPA 70, Article 770 and be protected against physical damage in accordance with NFPA 70, Article 760.

301.3.9.6 Designs must employ only conduit as pathways for all network cabling outside the communications rooms and communications closets.

301.3.9.7 Designs must mitigate all physical hazards, threats, and vulnerability to network functionality in compliance with project hazard analyses, and threat and vulnerability assessments. This includes routing of pathways with duct banks, under protective barriers, and other types of physically protective mitigations.

301.3.9.8 Provide pathways and related infrastructure per Set 1006 Electrical Raceway and per Set 601 Fire–Life Safety for additional requirements for circuit and pathway performance characteristics.

301.3.9.9 All designs must employ the corresponding Sound Transit standard pathway diversity for core/backbone fiber optic cabling.

Figure 301-1: Backbone Fiber Diversity – Elevated Guideway

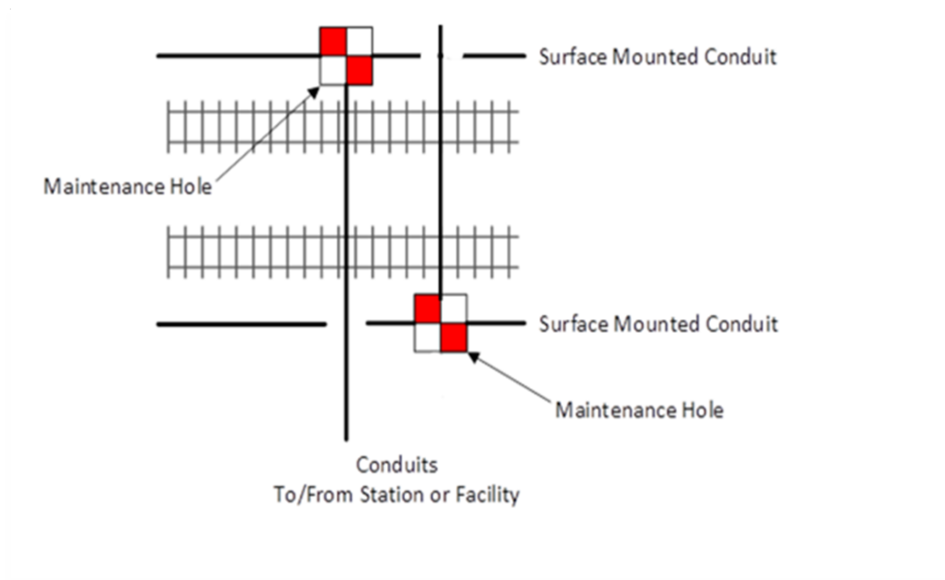


Figure 301-2: Backbone Fiber Diversity – Tunnel (Underground Alignment)

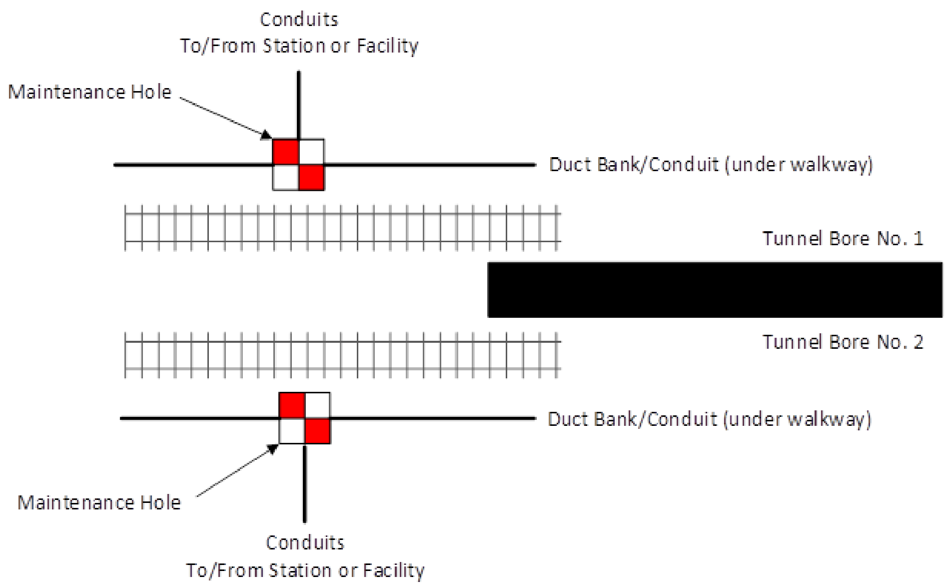
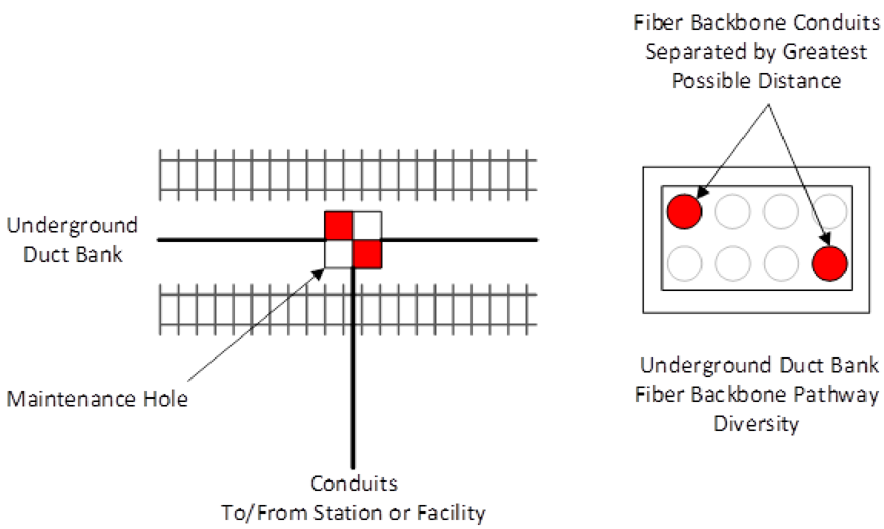


Figure 301-3: Backbone Fiber Diversity – Underground Duct Bank (At Grade Alignment)



301.3.9.10 All backbone fiber optic cable splices and end of line coiling must be within dedicated maintenance holes. Pull boxes do not provide adequate space accommodations for splicing and coiling. Design must not allow pull boxes for these purposes.

301.3.9.11 Maintenance holes must be adequately sized to accommodate service loops, cable bend radius, possible future splice enclosures when required (repair cable break), and inclusion of future cabling transiting through spare conduits to service future expansions per Set 1006 and TIA-758.

301.3.9.12 Designs must not allow sharing of maintenance holes between electrical and communications network cabling.

301.3.9.13 Designs must locate all maintenance holes outside of communication rooms. Maintenance holes, splices and end of line coiling must be located along the alignment away from network equipment and device locations to avoid single points of failure and providing the required resiliency.

301.3.9.14 Fiber optic cabling: Designs must utilize fiber optic cabling in compliance with Sound Transit Standard Specification 27 13 23 Systems Optical Fiber Cabling.

301.3.9.15 Copper cabling: Designs must utilize copper cabling in compliance with Sound Transit Standard Specification 27 15 13 Communications Copper Horizontal Cabling. Designs must support testing of cabling per Sound Transit Standard Specification 27 17 00 Testing of Communications Copper Horizontal Cabling.

301.3.10 Network Function & Topology

301.3.10.1 Sound Transit's network topology standard is a three-tier or collapsed core mesh reference topology for the TCN and EFN networks. This physical configuration follows the redundancy, separation, segmentation, and flexibility required to meet Sound Transit IT configuration and reliability standards. Functional requirements for the IT configuration standard and operations reliability needs are defined within this section. Technical configuration standards are available from ITARCH. Details of the existing communications network topology are available from Sound Transit ITARCH and PSO. Coordinate with these groups to design interfacing to existing networks which predate this standard.

301.3.10.2 The following defines ST's network topology standard. The two figures 301-4 and 301-5 show the physical requirements of the network. More detail can be found in the Sound Transit Systems Standard Drawings. Any variation from this standard must include PSO, IT, and OT buy in.

Figure 301-4: Standard Three-Tier Network Topology

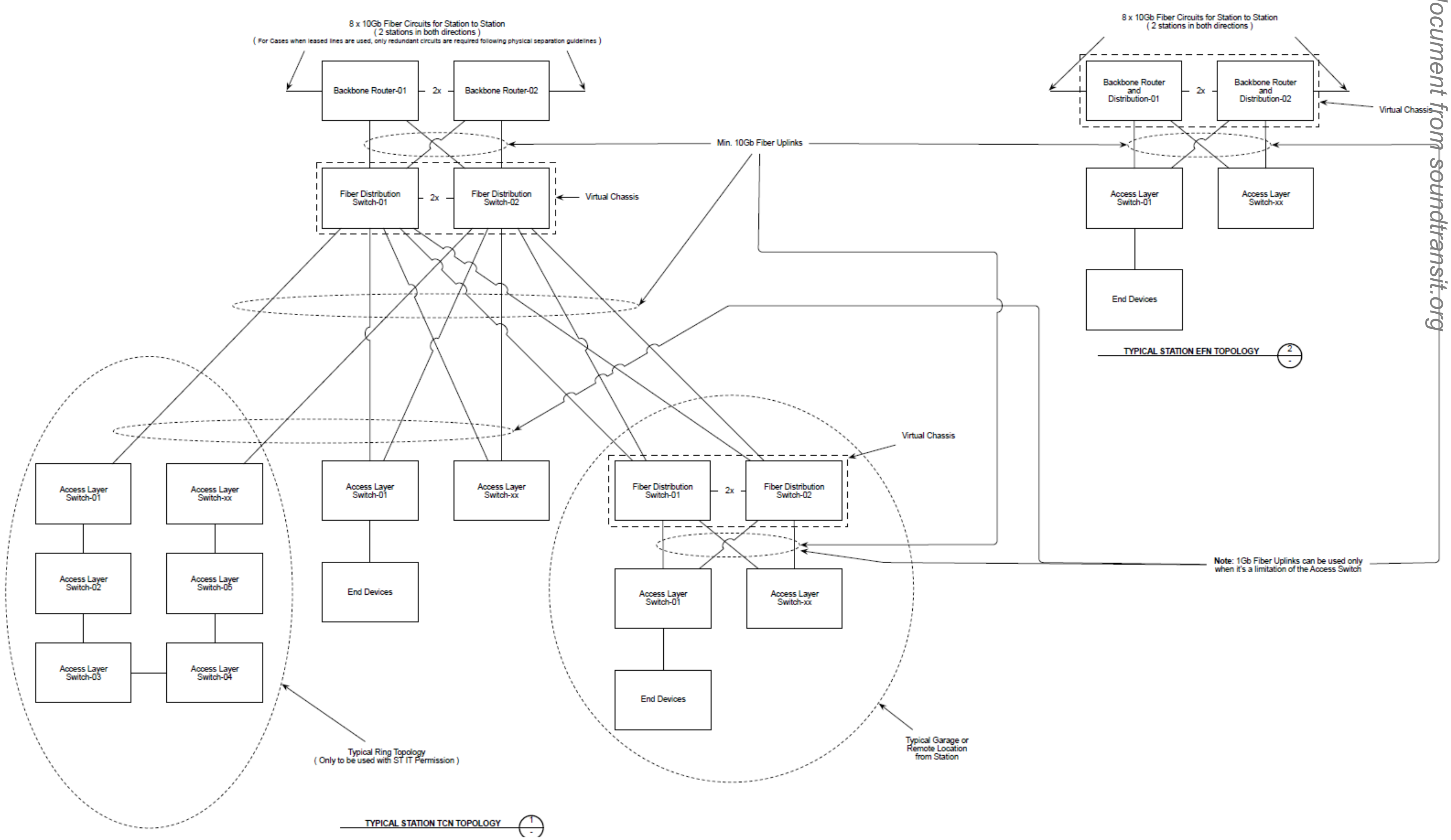
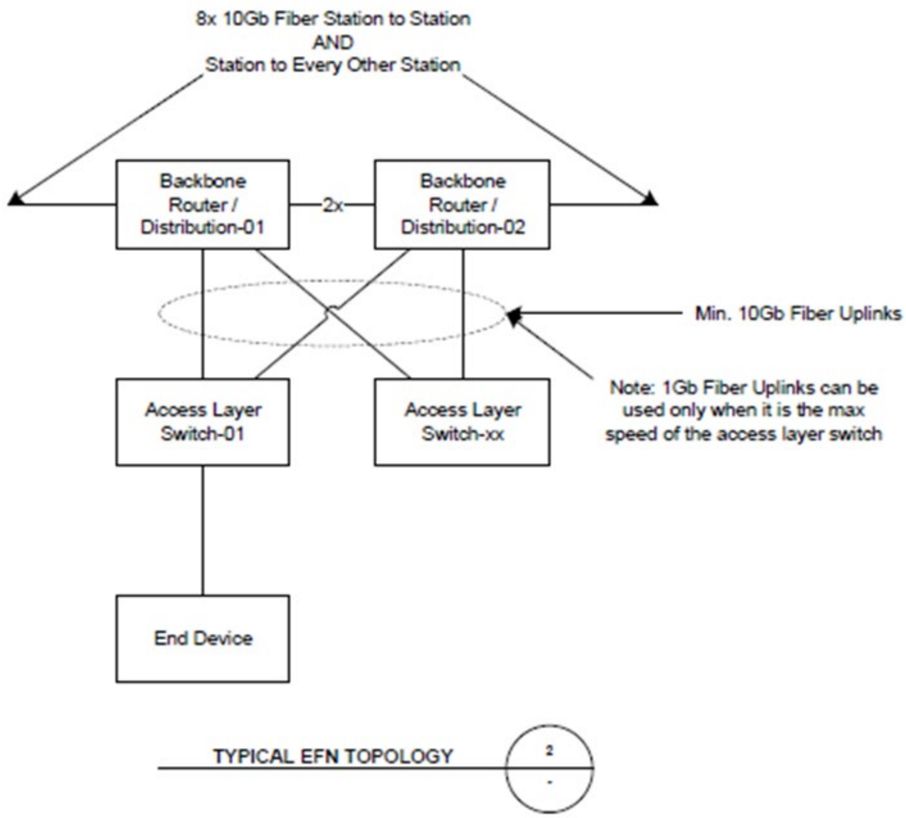


Figure 301-5: Standard Collapsed Core Network Topology



301.3.10.3 The three-tier topology is the most scalable and resilient network solution. The clear and simple design provides for effective management. Each layer, core/backbone, distribution, and access have a specific dedicated purpose. This is standard for light rail TCN networks for stations, maintenance facilities, and garages. The collapsed core topology is standard for smaller scale applications like light rail EFN networks, Tacoma Streetcar stations, Sounder stations, or similar.

301.3.10.4 TPSS Transfer Trip Networks

301.3.10.4.1 TPSS transfer trip networks must be isolated from other ST networks (like the TCN).

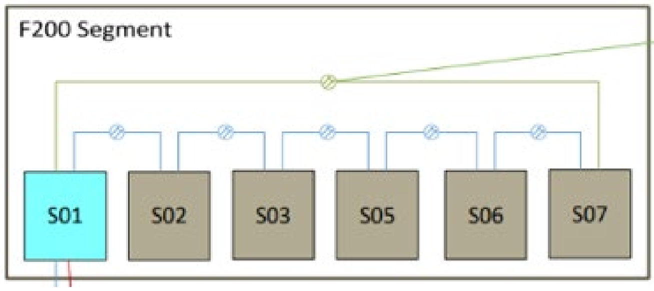
301.3.10.4.2 The network must be based on layer 3 (routing) connectivity between each TPSS sites. Each TPSS LCMS PLC must communicate with the neighboring TPSS (LCMS PLC to LCMS PLC) for transfer trip functionality. This requires the protocol used for PLC-to-PLC communications be routable.

301.3.10.4.3 The network must be redundant such that if a fiber or network port fails communication can fail over without interruption. This has typically been accomplished by a ring topology. See the below Figure 301-6 as an example.

301.3.10.4.4 Fiber pathways must follow the same rules for diversity as EFN/TCN.

301.3.10.4.5 See System Standard Drawings for more details.

Figure 301-6: TPSS Transfer Trip Network Ring Topology Example



301.3.10.5 Other systems specific standard network topologies like signals or similar must be specified in design to match Sound Transit systems guidance drawings or project requirements. Otherwise, networks must match existing network topology of the existing systems.

301.3.10.6 Network design requirements for networks not defined within this set must be discussed with and approved by ST ITARCH, Operations support group, PSO communications, and the PSO system design owner of the system on the new network.

301.3.11 Core/Backbone Layer (Sound Transit Fiber Plant)

Commentary: This applies to core systems networks TCN and EFN.

301.3.11.1 All designs are required to include redundancy for every core/backbone node. Backbone nodes must be made of in-life newly manufactured hardware and components. Designs must ensure compatibility with Sound Transit provided hardware and components including conformance with manufacturer documentation.

301.3.11.2 The bandwidth of all connections between backbone network nodes must be at least 20 Gbps (10Gbps for each of the minimum two connections).

301.3.11.3 Connections between all backbone network nodes are required to be fully geographically, physically, and logically diverse by using redundant 144 fiber SMFO optic cables running along both sides of the trackway.

301.3.11.4 Each location (e.g., station, facility.) must connect to the backbone nodes using two 96-fiber SMFO branch cables spliced into each of the two 144-fiber SMFO redundant backbone cables.

301.3.12 Core/Backbone Layer (Leased Circuit)

301.3.12.1 Where stations, garages, and facilities receive service via leased circuits, all designs must include redundant circuits. Circuits must be made of in-life newly manufactured hardware and components. Designs must ensure compatibility with Sound Transit provided inside plant hardware and components including conformance with manufacturer documentation.

301.3.12.2 Leased circuit availability 99.999% (5-9s) based on 24 hours a day, 7 days a week, and 365 days per year.

301.3.12.3 Leased circuit routers: 99.999% (5-9s) based on 24 hours a day, 7 days a week, and 365 days per year.

301.3.12.4 All leased circuits must be capable of providing the bandwidth for all subsystem and component network service requirements. All circuits must be capable of providing a minimum bandwidth of 1 Gbps. Throttling of these circuits are permitted if bandwidth demand is less but must be capable of the minimum bandwidth.

301.3.12.5 Redundant leased circuits must be fully geographically, physically, and logically diverse. Diversity must include pathways, cabling, power, provider, and customer edge devices.

301.3.12.6 Demarcation of leased circuit and Sound Transit inside plant network is dependent upon the circuit delivery.

301.3.13 Distribution Layer

301.3.13.1 All designs are required to include redundancy for every distribution node. Distribution nodes must be made of in-life newly manufactured hardware and components. Designs must ensure compatibility with Sound Transit provided hardware and components including conformance with manufacturer documentation.

301.3.13.2 A minimum of two distribution layer switches must be installed at each location (e.g., station, facility) requiring Ethernet connections to devices. Network designs must connect only access switches to distribution switches. Devices connect to the network access layer only and must not connect directly to distribution switches.

301.3.13.3 The bandwidth of all connections between distribution layer switches and core/backbone network nodes must be a minimum of 10 gigabits per second.

301.3.13.4 Every distribution layer switch must have two or more fiber paths to different nodes on the core/backbone layer.

301.3.14 Access Layer

301.3.14.1 Access layer nodes must be made of in-life newly manufactured hardware and components. Designs must ensure compatibility with Sound Transit provided hardware and components including conformance with manufacturer documentation.

301.3.14.2 Install a minimum of one access layer switch in each location requiring Ethernet connections to devices. Network designs must connect end devices to the nearest access layer switch. Devices connect to the network access layer only and must not be directly connected to distribution switches or the core/backbone router network.

301.3.14.3 The bandwidth of all connections between access layer switches and distribution network nodes must be a minimum of 1 gigabit per second.

301.3.14.4 Access switches must have two or more diverse paths to different distribution layer switches.

301.3.14.5 Control System Connectivity

301.3.14.5.1 Design and configure PLCs to communicate with the SCADA head ends located at Sound Transit's centralized datacenters at the Operations and Maintenance Facility Central and Operations and Maintenance Facility East via TCN/EFN for light rail.

Commentary: Throughout Sound Transit LINK stations, facilities, and wayside systems, there are control systems that are composed of PLCs, remote I/O, and other field control system hardware. These control systems are typically the field systems that make up the ST SCADA BMS, EVS, or TCS systems but could also be part of packaged specialty systems. Similarly, for Tacoma Link, PLCs and systems are designed to communicate with the SCADA and CAD/AVL head end at the Tacoma OMF. These specific PLCs exchange I/O information with the SCADA head ends for displaying on the SCADA system which are typically formalized via an SIDT.

301.3.14.5.2 If a need arises for PLC-to-PLC (peer-to-peer) communications which could require station to station communications, the PLCs must support layer three connectivity, the protocol used must be routable, and IP addressing must be developed in consultation with the Sound Transit IP addressing schema to support this communication.

301.3.14.5.3 High availability control system or industrial system communications (TCS, BMS, EVS, TPSS or other high availability systems) that are not required to be on the TCN/EFN for SCADA communications or other required operational needs must be on isolated networks from the main operational network (TCN/EFN), especially remote I/O communications. For these high availability isolated control system or other industrial system networks, the design and configuration must still follow Sound Transit network design and configuration standards, see this Set, 123 Train Control,1004 Building Monitoring Control, and 220 Traction Power for these specific control system requirements. This includes for network and processing redundancy, pathway diversity, IP addressing, and protocols. See System Standard Drawings for more details.

301.3.14.5.4 Control systems which are associated with fire/life safety operations and their associated networks must follow requirements provided in Sets 1004 Building Monitoring Control and 601 Fire-Life Safety in addition to this set.

301.3.14.6 Internet and Cloud Connectivity

301.3.14.6.1 Any system or device connected to Sound Transit's communications networks that requires internet or cloud service (Sound Transit currently uses Azure Cloud) connectivity must coordinate network security designs with Sound Transit ITARCH and Information Security to verify security strategy is in harmony with current network security design. Designs must not use one off network security solutions within existing networks.

301.3.14.7 Virtual Machines

301.3.14.7.1 Servers and/or computers required by contract may be required by Sound Transit to be virtualized. All virtual machines must be standardized and must use Sound Transit's approved virtual machine platform(s). The designer must coordinate with ST to establish virtualization, network configuration, and network security verification.

301.3.14.7.2 The designer must also collaborate with ST to verify if contract implementation requires expansion of virtual machine platform hardware or licensing. Sound Transit may require a contract to also provide spare capacity based on expansion required by the contract. This would be to the same percent spare capacity as had existing before the project changed anything or as stated in the project requirements.

301.3.14.8 Device Clock time Synchronization

301.3.14.8.1 Time stamping required for field devices, systems, or networks must be in synchronization with the ST communications network time clock.

301.3.14.8.2 All Sound Transit networks must be time synchronized. Coordinate with Sound Transit to know the level time precision provided by existing networks or ST configured networks. Coordinate with Sound Transit for all required time synchronization through ST networks.

301.3.14.8.3 For TPSS Transfer Trip Networks Time synchronization must accommodate the separation of networks (TPSS and TCN). Time synchronization is typically done via NTP, SNTP, or PTP network protocols. The LCMS PLC CPU will act as the time source for hardware inside each individual TPSS. The LCMS PLC CPU will receive its time source using the dedicated SCADA communications processor (network interface).

301.3.14.8.4 Coordinate system requirements with Sound Transit IT and OT for network or systems interfacing for time synchronization via ST-provided networks. See Sets 123 Train Control, 1004 Building Monitoring Control, and 220 Traction Power for systems requirements for time synchronization.

Commentary: Sound Transit's preferred method for time synchronization is via Network Time Protocol) NTP or Simple Network Time Protocol (SNTP) if application requirements permit it and is approved by vendor for the application. Where time synchronization spans isolated networks, Sound Transit prefers a field system, such as a PLC, that is local to the process being served to manage time from the main *communications network (like TCN) and to pass it to the isolated network (like TPSS). Local GPS clocks can also be used for an isolated network requiring timestamping like TPSS transfer trip networks when communications networks with a timeclock is not available.*

301.3.14.9 Field Systems Leased Circuit

301.3.14.9.1 Leased circuits or LTE (cellular) may be used as needed for locations where Sound Transit network fiber infrastructure is not available to support connectivity to the main Sound Transit fiber network. Leased Circuits must be double nutted to be connected and to communicate with Sound Transit network.

301.3.14.9.2 Leased network must be designed and configured to meet Sound Transit network security.

301.3.14.9.3 Leased circuits or LTE (cellular) may be used for noncritical applications and must not be used to support critical life safety systems or wayside operational systems such as TPSS, EVS, FLS related systems, and signal houses.. ST IT requires using private APN to secure cellular communications for this application.

301.3.14.10 Standards & Protocols

301.3.14.11 The communications network design must ensure that all network elements are compliant with industry standards required to meet the intent of the design, life expectancy, maintainability requirements, and are commercially available off the shelf. Connectivity between network equipment must not rely on proprietary protocols.

301.3.14.12 For systems that use the network to communicate with devices outside of the local station/facility LAN network, the system protocols used must be routable.

301.3.14.13 All network designs must be in full compliance with the IEEE 802 networking protocols for managed Ethernet, including:

301.3.14.13.1 802.1 Higher Layer LAN Protocols.

301.3.14.13.2 802.3 Ethernet.

301.3.14.13.3 802.11 Wireless LAN and Mesh.

301.3.15 Cybersecurity

301.3.15.1 Communications network cybersecurity must meet Set 1201 Cybersecurity requirements. Networks must be secured from public internet and security implemented must meet or exceed the policies and standards of Sound Transit Information Security, including:

301.3.15.2 Policy 1100 InfoSec Implementation Guidance and Controls.

301.3.15.3 Sound Transit Data Classification and Protection Standards.

301.3.15.4 Sound Transit Network Security Checklist.

301.3.15.5 Sound Transit Secure Design Standard.

301.3.15.6 Network security must conform to the requirements of IEEE 802.1X; it must support ACL and SSL encryption.

301.3.15.7 Designs must conform to APTA-SS-CCS-RP-002-13 Securing Control and Communications Systems in Rail Transit Environments.

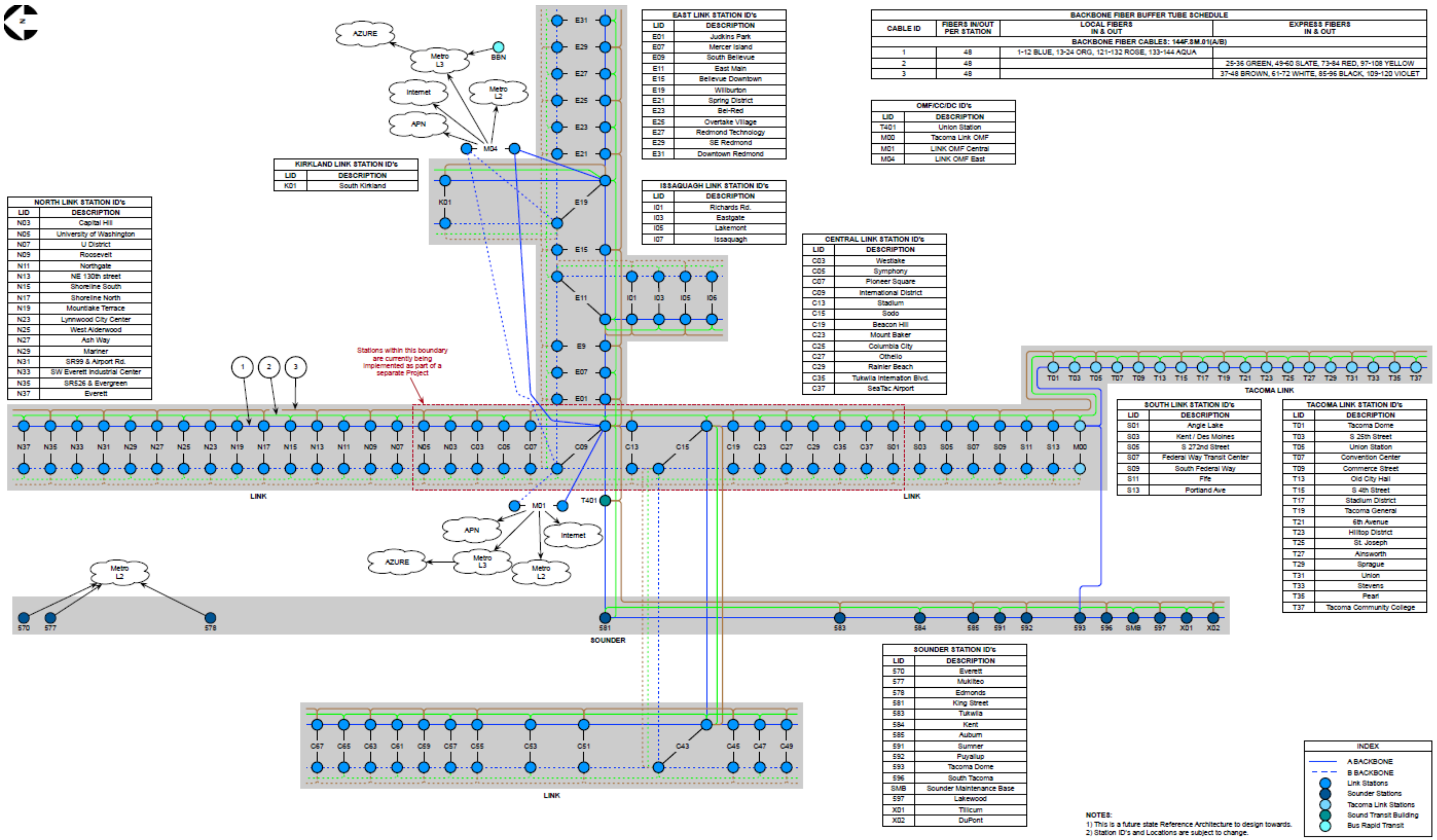
301.3.15.8 EFN must remain physically and logically isolated from other networks for reasons of reliability and cybersecurity unless approved by Sound Transit IT, OT, and PSO.

301.3.16 Fiber Plant Technology

301.3.16.1 Sound Transit standardizes on a hybrid mesh topology. Designs must follow this standard reference topology. Below are guidance reference drawings.

i. RA-JC100 Typical station back bone transit fiber backbone.
ii. RA-JC101 Typical station backbone topology.
iii. ST-EA Typical station network topology.
iv. RA-JC100 Typical station backbone transit fiber backbone.

Figure 301-7: Sound Transit Typical Station Backbone Transit Fiber Backbone



EAST LINK STATION ID's	
LID	DESCRIPTION
E01	Judkins Park
E07	Mercer Island
E09	South Bellevue
E11	East Main
E15	Bellevue Downtown
E19	Wilburton
E21	Spring District
E23	Bel-Red
E25	Overlake Village
E27	Redmond Technology
E29	SE Redmond
E31	Downtown Redmond

BACKBONE FIBER BUFFER TUBE SCHEDULE			
CABLE ID	FIBERS IN/OUT PER STATION	LOCAL FIBERS IN & OUT	EXPRESS FIBERS IN & OUT
BACKBONE FIBER CABLES: 144F.SM.01(A/B)			
1	48	1-12 BLUE, 13-24 ORG, 121-132 ROSE, 133-144 AQUA	
2	48		25-36 GREEN, 49-60 SLATE, 73-84 RED, 97-108 YELLOW
3	48		37-48 BROWN, 61-72 WHITE, 85-96 BLACK, 109-120 VIOLET

OMF/CC/DC ID's	
LID	DESCRIPTION
T401	Union Station
M00	Tacoma Link OMF
M01	LINK OMF Central
M04	LINK OMF East

KIRKLAND LINK STATION ID's	
LID	DESCRIPTION
K01	South Kirkland

ISSAQUAGH LINK STATION ID's	
LID	DESCRIPTION
I01	Richards Rd.
I03	Eastgate
I05	Lakemont
I07	Issaquagh

NORTH LINK STATION ID's	
LID	DESCRIPTION
N03	Capital Hill
N05	University of Washington
N07	U District
N09	Roosevelt
N11	Northgate
N13	NE 130th street
N15	Shoreline South
N17	Shoreline North
N19	Mountlake Terrace
N23	Lynnwood City Center
N25	West Alderwood
N27	Ash Way
N29	Mariner
N31	SR99 & Airport Rd.
N33	SW Everett Industrial Center
N35	SR526 & Evergreen
N37	Everett

CENTRAL LINK STATION ID's	
LID	DESCRIPTION
C03	Westlake
C05	Symphony
C07	Pioneer Square
C09	International District
C13	Stadium
C15	Sodo
C19	Beacon Hill
C23	Mount Baker
C25	Columbia City
C27	Othello
C29	Rainier Beach
C35	Tukwila Internation Blvd.
C37	SeaTac Airport

SOUTH LINK STATION ID's	
LID	DESCRIPTION
S01	Angle Lake
S03	Kent / Des Moines
S05	S 272nd Street
S07	Federal Way Transit Center
S09	South Federal Way
S11	Fife
S13	Portland Ave

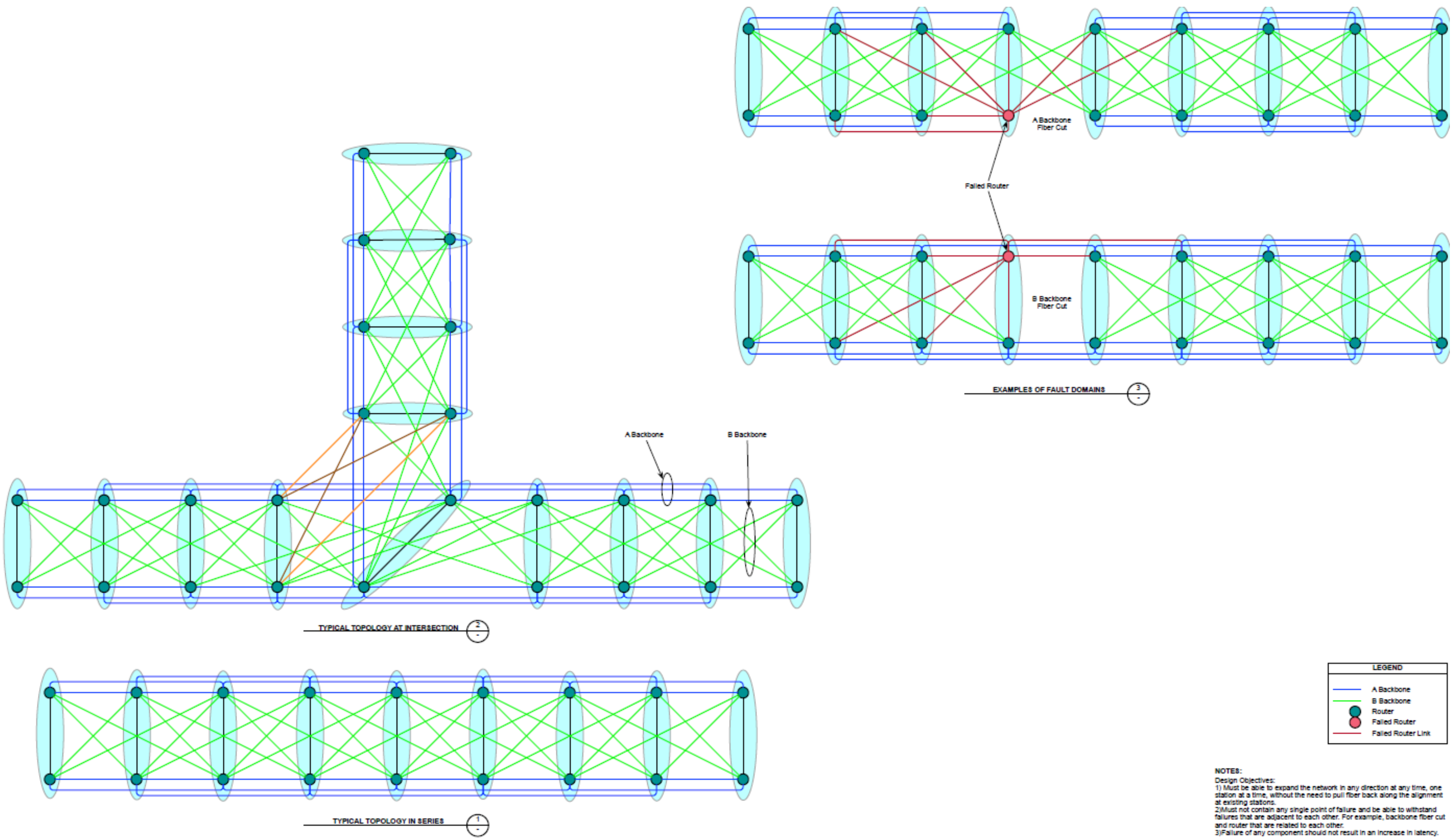
TACOMA LINK STATION ID's	
LID	DESCRIPTION
T01	Tacoma Dome
T03	S 25th Street
T05	Union Station
T07	Convention Center
T09	Commerce Street
T13	Old City Hall
T15	S 4th Street
T17	Stadium District
T19	Tacoma General
T21	6th Avenue
T23	Hilltop District
T25	St. Joseph
T27	Ainsworth
T29	Sprague
T31	Union
T33	Stevens
T35	Pearl
T37	Tacoma Community College

SOUNDER STATION ID's	
LID	DESCRIPTION
570	Everett
577	Mukilteo
578	Edmonds
581	King Street
583	Tukwila
584	Kent
585	Auburn
591	Sumner
592	Puyallup
593	Tacoma Dome
596	South Tacoma
SMB	Sounder Maintenance Base
597	Lakewood
X01	Tillicum
X02	DuPont

NOTES:
1) This is a future state Reference Architecture to design towards.
2) Station ID's and Locations are subject to change.

INDEX
- A BACKBONE
- B BACKBONE
- Link Stations
- Sounder Stations
- Tacoma Link Stations
- Sound Transit Building
- Bus Rapid Transit

Figure 301-8: Router to Router Stations Reference Topology-Typical Station Backbone Topology



Commentary: A mesh topology offers several significant benefits in networking and communication systems. Firstly, its inherent redundancy ensures high reliability and fault tolerance. In a mesh network, each node is interconnected with multiple nodes, creating multiple paths for data transmission. If one node or connection fails, data can automatically reroute through alternative paths, minimizing downtime and maintaining uninterrupted communication. This self-healing capability is particularly valuable in critical applications where uninterrupted connectivity is crucial, such as in emergency services or large-scale industrial environments which Sound Transit has.

Secondly, a mesh topology provides excellent scalability and flexibility. New nodes can be added to the network without significant disruption, and the load can be distributed across multiple paths, preventing congestion and improving overall performance. This scalability is particularly advantageous in large networks where the number of interconnected devices may vary and expand over time. Additionally, the decentralized nature of a mesh topology allows for efficient data transmission, as the network can dynamically adjust to changes and optimize routing paths based on real-time conditions. This flexibility and adaptability make mesh topologies well-suited for dynamic and evolving environments.

301.3.17 Network Reliability

301.3.17.1 Network Device Fault Tolerance

301.3.17.1.1 All communications network designs must be fault tolerant with no single points of failure within the core, backbone, or distribution layers.

301.3.17.1.2 No single network component failure within those layers may disrupt productive service of the network.

301.3.17.1.3 If one or more network devices fails within the core, backbone, or distribution layers, all access layer devices must maintain communications with the data center via a redundant communications path.

301.3.17.1.4 Network designs must provide self-healing automatic recovery from problems while maintaining Sound Transit network availability requirements.

301.3.17.1.5 Network designs must tolerate access equipment failures with loss of network access by no more than the maximum number of components connected (including spare ports) to a single access point.

301.3.17.2 Fiber Optic Conduit and Cable Fault Tolerance

301.3.17.2.1 If a fiber optic backbone conduit/cable is severed/cut (planned or unplanned) in a single location, then all devices (e.g., core/backbone router, distribution switch, access switch, PLC, VMS, CCTV camera) must maintain communications with the data center. A backbone fiber optic conduit/cable break at a single point within the conduit/cable path must not affect communications to any field device connected via the fiber optic conduit/cable plant.

301.3.17.2.2 If a fiber optic branch conduit/cable is severed/cut (planned or unplanned) then all other field devices must maintain communications with the data center. A fiber optic branch conduit/cable break must not affect communications to any field devices within the location connected by the branch conduit/cable and it must not affect the communications of the other devices within the network.

301.3.17.3 Power Loss Fault Tolerance

301.3.17.3.1 If the primary power to a network location is lost and there is no on-site generator with automatic transfer switch, then the UPS back-up power must maintain all network power loads within the location for a minimum of 90 minutes.

301.3.17.3.2 If the primary power to a network location is lost and there is a permanently installed on-site generator with an automatic transfer switch, then the UPS back-up power must maintain all network power loads within the location for a minimum of 15 minutes.

301.3.17.3.3 If both the primary and back-up power is lost at a network location, then all other locations must maintain full communications with the data center. A power failure at one location must only interrupt communications to that single location that has the power failure. All other locations must maintain full communications with the data center.

301.3.18 Scalability

301.3.18.1 The communications network design must be scalable to accommodate increases in network traffic and increases in capacity between equipment, including the backbone of the network through planned ST3 and future expansion.

301.3.18.2 Designs must accomplish addition of communication equipment or field devices with minimal disruption to the operating communication system.

301.3.19 Management

301.3.19.1 Network designs must be compatible and integrate seamlessly with the existing Sound Transit network management system used to monitor existing, new, and future devices. Designs must ensure that all the devices, equipment, materials, cabling, and any other items used in this network implementation fully integrate into the existing Sound Transit network management system to allow the whole of the management system to operate and control as one unified system.

301.3.19.2 Design documentation developed must provide all necessary information to integrate and configure new devices into the existing Sound Transit network management system.

301.3.19.3 All network equipment regardless of system or network must dedicate a single port for management regardless management tools are used or not for that network.

301.3.20 System Availability (TCN/EFN only)

301.3.20.1 The communications network must be designed to provide a resilient infrastructure with an availability of 99.9% as measured for continuous operation 24 hours a day, 365 days a year, excluding scheduled downtime and scheduled outages. Networks must provide resilience and redundancy within the core and access layers of the network to meet these requirements.

301.3.20.2 Overall network (network as a whole) availability 99.9% (3-9's) based on 24 hours a day, 7 days a week, and 365 days a year. This includes networks specific to subsystems and may or may not use Sound Transit's backbone network. Examples include Signaling, TPSS, and BMS RIOs.

301.3.20.2.1 Core/backbone routers must be redundant per station/location.

301.3.20.2.2 Distribution switches must be redundant per station/location, and access switches must have redundant fiber connections back to each side of the redundant distribution pair. If router and distribution functions are combined into one device, then the redundant fiber connection goes back to each side of the redundant combined router/distribution switches. Daisy chaining of access switches is not allowed.

301.3.20.3 Designs must be accompanied by an analysis (including leased circuits where used) in accordance with ITU-T Recommendation G.911 to demonstrate that the availability requirement is achieved. This analysis must include scenarios of failure events and demonstrate that network element failures or sequences of network element failures do not affect the availability of the network.

301.3.20.4 Downtime to update the device flash image or repair a component are acceptable reasons for downtime, but at least one core/backbone router must be operational at all times, even during downtime.

301.3.20.5 System availability requirements for other operational system-specific networks (i.e., TPSS Transfer Trip, PLC RIO, Radio, Signals, or similar) are defined by their respective system availability requirements. See the system specific requirements chapter for details.

301.3.21 System Response Time

301.3.21.1 Designs must meet the following response time requirements under maximum loading conditions:

301.3.21.2 Network cold restart/reboot time must not exceed 10 minutes.

301.3.22 Network Capability

301.3.22.1 The communication system network must support voice, video, and data applications using the following:

i. Prioritization of applications using a Quality of Service (QoS) strategy
ii. Multi-layer switching
iii. Multicast support and VLAN configuration

301.3.22.2 The network design must support the operational, functional and performance requirements specified. The network utilization must not exceed 40% of total available bandwidth under normal load conditions, when there are no faults present. The utilization must not exceed 80% of total available capacity at peak load, when there is any fault present.

301.3.22.3 The Communication System Network must support IP traffic for TCP/IP as well as UDP packets.

301.3.22.4 The Communication System Network must achieve the following QoS requirements:

301.3.22.4.1 Meet latency criteria under maximum loading conditions during normal operation. The latency time criteria must be the same as that for the System Response Time above and per table 3012.

301.3.22.4.2 Jitter must not exceed 1millisecond 99.9% of time and must not exceed =10= milliseconds maximum more than 0.1% of time.

301.3.23 Capacity

301.3.23.1 All network designs must meet the following bandwidth capacity requirements:

301.3.23.1.1 Router to router connections must be no less than 20 Gbps (10Gbps for each of the minimum two connections).

301.3.23.1.2 Router to distribution switch connections must be no less than 20 Gbps (10Gbps for each of the minimum two connections).

301.3.23.1.3 Access switch to distribution switch connections must be no less than 1 Gbps.

301.3.23.1.4 Access switch to component connections must be no less than 100 Mbps.

301.3.23.1.5 Above bandwidth requirements are per port connection. See topology requirements (this set) as some pathways require redundant connections or mesh connections which will increase the designed bandwidth based on the topology requirements.

301.3.23.2 The designed capacity of the network core, leased lines, metro commercial circuits and similar must meet the following requirements:

301.3.23.2.1 Switching capacity: 50% spare capacity.

301.3.23.2.2 Interface capacity: minimum 30% spare ports (of all ports on individual equipment – routers and access switches).

301.3.23.2.3 Communication link capacity: (see table in section 301.2.4 for minimum bandwidths)

301.3.23.2.4 Designs must provide spare capacity of physical media which must be service ready.

301.3.23.2.5 Spare capacity is already built into the redundant fiber backbone 96/144 strand fiber design but is only designed for TCN/EFN related usage and are not free spares for other systems/networks. Outside of the redundant 144 fiber design, other fiber designs must have at least 30% spare capacity. Spare capacity is not only related to the physical fiber count but also to FDPs to FDBs, maintenance holes, splice cases, and cable management. If fiber is used for an end device connection, provide at least one spare fiber pair per end device as a minimum. Spare capability must run the length from the networking device to the end device.

301.3.23.2.6 Provide a minimum of 25% spare copper (CAT6) cable run between communication cabinets (patch to patch). It is not required to provide spare copper from patch to each end device (e.g., to each phone or camera). Spare capacity must not be limited to patch panels, cable management, and maintenance spaces.

301.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

301.4.1 System Breakdown Structure

301.4.2 System Sites and Locations

301.4.3 System Architecture

301.4.4 System Layout

301.4.5 Concept of Execution

301.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 301-3: Interface Between Communications Infrastructure and Other Disciplines

SET SERIES	SET NAME	SET 301 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	X
400	Vehicle	X
500	Track	X
600	Fire/Life Safety	X
700	Structures	
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	X
1200	Security	X
1001	Raceway	X
1004	Building Monitoring and Controls	X
1006	Electrical Raceway	X

See Set 815 Telecommunication Spaces for spacing, power (circuits, PDUs), and HVAC.

301.5.1 Power

301.5.1.1 Each panel supporting network router, distribution, or access level infrastructure must have two UPS power feeds and two PDU per panel, each fed by a different UPS power feed, to allow for redundancy and ease of maintenance.

301.5.1.2 All network equipment must be supported by the communications UPS (not many small UPSs).

301.5.2 Space

301.5.2.1 See Set 815 Telecommunication Spaces for space requirements and maintainability requirements in this set.

301.5.3 Conduit, Raceway

301.5.3.1 Conduit/raceway diversity is covered in this set and set 815. Network diversity related to fire life safety is covered in set 601 Fire Life Safety.

301.5.3.2 General raceway requirements are covered in Set 1006 Electrical Raceway.

301.5.4 Installation

301.5.4.1 Connections, grounding, cabling, and installation must be per applicable NFPA codes NFPA 70, 72, 130 and BISCI ITSIMM Installation Methods Manual. ITSIMM applies to installing infrastructure for telecommunications such as cabling, support structures, pulling cable, fire stopping, cable terminations, installing PoE, and bonding and grounding.

301.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

301.7 ENGINEERING MANAGEMENT REQUIREMENTS

301.7.1 Interface and Integration Management

301.7.2 Design Management

301.7.2.1 Designers must provide the following documentation, but additional design documentation, design submittal phasing, and design detail may be required as defined in the Sound Transit Engineering Design Procedures, EP-03, based on the contract delivery methods. Designs are required for use by Sound Transit, other designers, contractors, vendors, and suppliers to achieve design approval and for post-IFC project activity. Designs must facilitate coordination between contractor and Sound Transit for any owner provided equipment for design coordination of interfaces, sufficient detail for ordering Sound Transit provided equipment, and proper construction phasing. See Sound Transit systems guidance drawings for reference.

301.7.2.1.1 ITU-T Recommendation G.911 Availability Analysis Report.

301.7.2.1.2 Fiber Cable Single-Line Diagram.

301.7.2.1.3 Backbone and Drop Cable Diagrams.

301.7.2.1.4 Fiber Backbone Allocation Schedules.

301.7.2.1.5 Fiber Backbone and Drop Cable Schedules.

301.7.2.1.6 Fiber Splice Enclosure Details.

301.7.2.1.7 Fiber Distribution Panel Wiring Details.

301.7.2.1.8 Network Schematics (specific to each facility).

301.7.2.1.9 Rack Elevations.

301.7.2.1.10 Rack Layouts.

301.7.2.1.11 Rack Grounding and Power Scheme Details.

301.7.2.1.12 Equipment Location Plans.

301.7.3 Manufacturing and Construction Management (not used)

301.7.4 Installation Management (not used)

301.7.5 Inspection and Testing Management (not used)

301.7.6 Training, Pre-Revenue Operations (not used)

301.7.7 Certification Management

301.7.7.1 Sound Transit safety certification related to fire/life safety systems must be completed prior to revenue service. For Link light rail, this includes SIT testing for TCN, EFN, TPSS, radio, and any other network networks supporting fire/life safety systems.

301.8 PROJECT MANAGEMENT REQUIREMENTS (NOT USED)

301.8.1 Scope Management

301.8.2 Quality Management

301.8.3 Risk Management

301.8.4 Other Management Requirements.

301.9 APPENDICES

END SET - 301

302 TELEPHONY

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TABLES

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SET - 302 TELEPHONY

302.1 INTRODUCTION

302.1.1 Document Scope

302.1.1.1 This requirement set serves as a Sound Transit standard for phone systems in all Sound Transit stations, right of way, facilities, and for all modes of transportation. Where there are conflicts between these requirements and adopted codes and standards, the most restrictive will apply.

302.1.1.2 This requirement set scope informs requirements for phone systems at any Sound Transit facility. This will cover end devices, interfaces, headend software function, operational function, system architecture and function, and maintenance needs.

302.1.1.3 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Sound Transit Design Requirements Set 302 owner to determine the technical source for the design criteria.

302.1.1.4 The system described in this requirement set is comprised of the phone system end devices, headend call servers, system operation, stakeholder requirements, and interfacing requirements like network and power. General network and associated power over Ethernet (POE) requirements for phone systems are covered in Set 301 Network Infrastructure. Location requirements for end devices are covered in their application chapters:

i. Set 821 Station Layout – Commuter Rail
ii. Set 822 Station Layout – Light Rail
iii. Set 823 Station Layout – BRT
iv. 824 Station Layout – URV
v. 830 Parking Facilities Layout.

Code requirements for systems and specific applications are provided in 601 Fire/Life Safety.

302.1.1.5 Closely related chapter sets include:

302.1.1.5.1 301 Network Infrastructure

302.1.1.5.2 601 Fire/Life Safety

302.1.1.5.3 821 Station Layout – Commuter Rail

302.1.1.5.4 822 Station Layout – Light Rail

302.1.1.5.5 823 Station Layout – BRT

302.1.1.5.6 824 Station Layout – URV

302.1.1.5.7 830 Parking Facilities Layout

302.1.1.6 Code references are based on 2020 NFPA 130 and 2019 NFPA 72.

302.1.2 Regulations, Codes, Standards, and Guidelines

302.1.2.1 International Regulations, Codes, Standards, and Guidelines (Not Used)

302.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

302.1.2.2.1 NFPA 70 National Electrical Code.

302.1.2.2.2 NFPA 72 National Fire Alarm and Signaling Code for emergency communications demands.

302.1.2.2.3 NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems for emergency communications requirements.

302.1.2.2.4 42 U.S.C. 12181 Americans with Disabilities Act of 1990 (Title III) (ADA).

302.1.2.2.5 Part 36, App. A ADA Accessibility Guidelines for Buildings and Facilities.

302.1.2.2.6 IEEE 802.1 Standard for LAN/MAN Architecture, Wide Area Networks, Security, Network Management, and Protocol Layers.

302.1.2.2.7 IEEE 802.3 Standard for Physical and Data Link layers of wired Ethernet. Local Area Network technology and some Wide Area Network applications. Standard for hubs, switches, and routers.

302.1.2.2.8 IEEE 802.11 Information Technology - Telecommunications and Information Exchange Between Systems Local and Metropolitan Area Networks - Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) And Physical Layer (PHY) Specifications.

302.1.2.2.9 ANSI/TIA-568 Telecommunications Cabling Standard.

302.1.2.2.10 ANSI/TIA-569 Telecommunications Pathway and Spaces Standard.

302.1.2.2.11 ANSI/TIA-607 Telecommunications Grounding Standard.

302.1.2.2.12 BICSI TDMM Building Industry Consulting Services International Telecommunications Distribution Methods Manual (most current version).

302.1.2.2.13 BICSI ITSIMM Building Industry Consulting Services International Information Transport Systems Installation Methods Manual (most current version).

302.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines (Not Used)

302.1.2.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

302.1.2.5 Other Jurisdictions (Not Used)

302.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

302.1.2.6.1 Sound Transit Equipment and Facility Numbering Standard.

302.1.2.6.2 Sound Transit System Guidance Drawings Set.

302.1.2.6.3 Sound Transit Standard Specifications.

302.1.3 Abbreviations and Acronyms

302.1.3.1 CES– customer emergency station

302.1.3.2 ETEL– emergency telephone

302.1.3.3 FCC– fire control center

302.1.3.4 FCR: fire control room

302.1.3.5 LCC– link control center

302.1.3.6 PBX– private branch exchange

302.1.3.7 PET– passenger emergency telephone

302.1.3.8 PoE– power over Ethernet

302.1.3.9 POTS– plain old telephone service

302.1.3.10 SIP– session initiation protocol

302.1.3.11 SOC– Security Operations Center

302.1.3.12 VoIP– voice over internet protocol

302.1.4 Definitions and Classification

302.1.4.1 CES: Customer emergency stations are emergency phones used primarily in Sound Transit garages for garage patron use. These are used to call the SOC.

302.1.4.2 ETEL: Emergency telephones are telephones used for emergency purposes primarily at Sound Transit Link light rail stations and facilities along the ROW for use by maintenance personnel.

302.1.4.3 PBX: Phones used in any Sound Transit facility (regardless of mode) for Sound Transit maintenance or staff use to call within and outside Sound Transit.

302.1.4.4 PET: Passenger emergency telephone are emergency telephones used for emergency purposes at Sound Transit Link light rail stations for rider use.

302.1.5 References (Not Used)

302.2 STAKEHOLDER NEEDS (NOT USED)

302.2.1 Passenger Experience

302.2.2 Operational Needs

302.2.3 Maintenance Needs

302.2.4 Safety Needs

302.2.5 Security Needs

302.2.6 Reliability, Availability and Maintainability Needs

302.2.7 Environmental and Sustainability Needs

302.3 SYSTEM REQUIREMENTS

302.3.1 General Requirements

302.3.1.1 The station designer must accommodate PETs in the station design.

302.3.1.2 ETEL devices are dedicated to maintenance, operations, and emergency personnel and must not be passenger facing. Provide ETEL for Link light rail stations, right of way, and other spaces used for the operations and maintenance of the light rail system. ETEL phones serve as “blue light stations” required and defined by NFPA 130.

302.3.1.3 Provide CES devices for emergency use at Sounder stations, BRT stations, and ST garages.

302.3.1.4 PBX devices are dedicated to maintenance, operations and emergency personnel and should not be passenger facing. PBX phones can be used at all Sound Transit facilities regardless of mode. PBXs are required in spaces used by operations and maintenance personnel and are intended for use during typical operations or maintenance tasks.

302.3.1.5 Elevator cab phones are provided by the elevator provider as part of the elevator package. See Set 805 Vertical Transportation for requirements.

302.3.1.6 For all public bathrooms, provide a system to allow for the public to request permission to use the bathroom and a remote security officer to provide access. Public bathrooms must support audio, visual, and remote locking/unlocking capability.

302.3.1.7 For public security office windows meant for interfacing with the public, provide an intercom system to serve both parties. The intercom system is not part of a typical ST phone systems and is a standalone system meant only to serve the public and the officer inside the security office.

302.3.1.8 All phones referred to in this set must use VoIP communications utilizing SIP. This includes PET, ETEL, CES, PBX, and elevator cab phones (if POTS line is not used).

302.3.1.9 All phones, associated stand assemblies, and their components must be low-voltage.

302.3.1.10 PET and ETEL phone system and new phones must meet NFPA 72 fault detection and notification, two-way communications, and power monitoring requirements as applicable for functional and location requirements of the design.

302.3.1.11 End device cabling must meet Sound Transit Standard Specifications 27 15 13 Communications Copper Horizontal Cabling or 27 13 23 Systems Optical Fiber Cabling, and be compatible with Set 301 Network Infrastructure, and Set 601 Fire/Life Safety for conductor survivability, flame spread, and smoke development.

302.3.1.12 Phone systems must meet the Emergency Communications code and standards requirements specified in Set 601 Fire/Life Safety, Section 601.6.2, “Fire/Life Safety Sites and Locations.”

302.3.1.13 See table 601-4, “Emergency Communication System Codes” in Set 601 Fire/Life Safety for appliable codes and standards for each system and specific applications.

302.3.2 Functional Requirements

302.3.2.1 PET phones must be hands-free operating device without cords or keypads. PET phone must have a built-in auto dialer and two LED indicators for Call Placed and Call Received status.

302.3.2.2 PET phones must be stainless-steel faceplate with a single red button for calling. PET phone must have a red accent outline around the faceplate with “EMERGENCY PHONE” written in white lettering within the outline located above the faceplate.

302.3.2.3 PET devices are configured to automatically call LCC once the emergency button is pushed.

302.3.2.4 CES phones, associated enclosures, and mounting pole or pedestal must be colored red with the word “EMERGENCY” in white lettering. Mounting pole or pedestal must have a blue light at the top of mounting pole or pedestal which illuminates when the phone is in use. CES may also be a wall mounted enclosure.

302.3.2.5 CES devices are configured to automatically call SOC once the emergency button is pushed.

302.3.2.6 CES phones must be hands-free operating device without cords or keypads. Built in Auto Dialer. Two LED Indicators for Call Placed and Call Received status.

302.3.2.7 PET and CES devices must be useable by all persons including people with hearing or vision disabilities. Each CES phone must be featured with raised letter and braille signage translation as required by ADA.

302.3.2.8 PET and CES installations require location be captured by CCTV. See Set 1202 CCTV/TIDS for requirements.

302.3.2.9 ETEL phones must have a handset phone with a keypad on the face of the phone and an internal pocket inside the cover for a phone directory.

302.3.2.10 The ETEL must be enclosed by a yellow call box with a blue light above the enclosure that illuminates when the phone is in use. This includes incoming and outgoing calls.

302.3.2.11 ETELs must have a speaker mounted above the yellow closure which “rings” when there is an incoming call.

302.3.2.12 ETEL phones are configured to call LCC automatically if no number is dialed.

302.3.2.13 ETEL phones must be able to call directly to other ETELs via keypad.

302.3.2.14 ETEL phones must be capable of a “party line” function where at least five people from the same or neighboring stations can participate in a conversation together with LCC or the station FCC/FCR/EMP.

302.3.2.15 PBX phones are a typical, off the shelf, office phone with a keypad and handset. PBX are configured like an office phone. Must allow 4-digit extension calling. Some PBXs may require external calling capabilities.

302.3.2.16 All PBX phones must have a preset autodial button that calls SOC.

302.3.2.17 PBX phones associated with Link light rail must have a preset autodial button that calls LCC.

302.3.2.18 For all public bathrooms, provide a phone, access control, and CCTV set up at the entry of each bathroom to facilitate a request to enter setup. CCTV and access control is interfaced with ST’s existing Genetec system and allow for remote viewing, approval, and unlocking of the bathroom via SOC. Phone must interface with ST Cisco Call Manager call server.

302.3.2.19 All phones must be connected to the network per Sound Transit IT’s IP Schema Standard. .

302.3.2.20 Equipment must be rated for their designed exposure. Emergency phones (PETs/ETELs/CESs) must be ANSI IP 67 rated, and enclosures must be NEMA 4X rated.

302.3.2.21 Elevator cab phones must be supplied with a POTS connection which either calls SOC or a third-party service, whichever Sound Transit prefers for the application. If a POTS line cannot be provided, the phone must have at least a 4-hour power backup provided. This backup power solution must back up all components of the elevator cab phone system such that calls can made during the full 4 hours.

Commentary: If the designer wants to use the Sound Transit network for the elevator cab phone, it should be noted that a light rail station communications UPS is designed to support critical loads, including the Sound Transit network, for only 90 minutes which means elevator cab phone design must not rely on the *station communications UPS alone for the 4 hours of required backup power for any part of the system required for calling unless a solution is provided that extends the station communications UPS to 4 hours.*

302.3.2.22 Sound Transit operational needs require designs featuring redundancy providing unattended, automatic self-healing capability. Phones must be able to connect to a backup central call manager server or servers if there is a failure to reach the primary call manager server because of a network or server issue.

302.3.2.23 PETs and ETELs are required to have at least a primary and a backup call server located at geographically diverse locations and network paths.

302.3.2.24 For tunnel stations, an additional local call server for emergency phones (PETs/ETELs) must be in the station communications room.

302.3.2.25 For PETs, if all remote/central call servers fail to connect the PET to LCC, then the local call server will direct the call to the station FCC room. See Emergency Phone related Standard Drawings for reference.

302.3.2.26 Call server and maintenance workstation software must be versioned one below the latest version released and run on a supported operating system.

302.3.2.27 Newly installed phone system platforms must be supportable for at least 5 years after the date of substantial completion.

302.3.2.28 Verify with ST operations to verify software and version numbers supported to avoid interoperability issues.

302.3.2.29 All phones must be configured to the same call servers and workstations used by each system, Link emergency phones, PETs/ETELs, Sound Transit Central Phone System, and PBXs and CESs. No one-off systems are permitted.

302.3.2.30 All LINK station emergency telephone conversations must be recorded for investigatory purposes of any emergency incident. This includes ETEL and PET only. Recordings must be kept for at least 14 days.

302.3.2.31 Expandability and compatibility. Telephone Systems capacity must be considered when designing new phone systems/end devices to be incorporated into the existing network across the entire Sound Transit system through ST3. Designs must integrate new phone with the existing system headend. The designer, with assistance from the vendor, must evaluate the impact of additional phones/systems on the alignment wide system and provide additional servers, storage, software, licensing, firmware, networking, and anything else required to accommodate the designed capacity. Make Sound Transit aware of all system limitations found.

302.3.2.32 The Phone System Network design must be scalable to accommodate increases in network and system traffic and increases in capacity through planned ST3 and future expansion. Hardware and software must be able to be integrated into the existing systems unless ST approves of a system wide change. All new systems or end devices must be interchangeable with devices already installed on the alignment for maintainability.

302.3.2.33 Connections, grounding, cabling and installation to be per applicable NFPA codes NFPA 70, 72, 130 and BISCI ITSIMM installation methods manual. ITSIMM applies to installing infrastructure for telecommunications such as cabling, support structures, pulling cable, fire stopping, cable terminations, installing PoE, and bonding and grounding.

302.3.2.34 Installation of all cabling must always be bottom fed to any phone enclosure unless not recommended by the vendor.

302.3.2.35 Installation. Phone cabling must accommodate the minimum cable bend radius per the cable manufacturer or if not provided follow TIA-568 or larger.

302.3.2.36 Follow TIA-568 when storing slack, sufficient maintenance service cable slack, no tension in cable connection to RJ-45. Phone enclosure must be grounded to the back box and to the communications conduit junction box per TIA-607.

302.3.2.37 Emergency phones (ETEL, PET, CES) must have a visual off hook indication (or PET/CES call button pressed) locally and an indication at LCC or SOC headend consoles.

302.3.3 Performance Requirements

302.3.3.1 System response time or maximum delay/latency must be better than 150miliseconds while system and network are normally loaded.

302.3.3.2 Call connection response time must be no longer than 5 seconds from the time the button is pressed until the call is made and ringing on the other end (not when operator picks up on the other side).

302.3.3.3 Call capacity of phone system and network must be verified by the engineer of record, Sound Transit IT architects, and system supporting vendors. Recommendations for expansion of central services or networks must be understood during the design phase. If there are no recommendations, a consensus of these parties must be reached that current infrastructure is sufficient for the proposed design.

302.3.3.4 For emergency phones (CES, ETEL, PET) operator consoles must allow at least three calls per console. Must allow for connecting a 911 operator into the same call with operator and passenger or an acceptable work around by Sound Transit operations and security.

302.3.3.5 Phone sound quality must be clear, strong, and understandable to the average user at both ends of a call with no background static or feedback induced by the phone system, supporting system, or nearby systems.

302.3.3.6 Emergency phone systems must record and store at least 15 days' worth of audio recordings (PET/ETEL only) and at least 90 days of system data at any time (PET, ETEL, and CES phones). System data includes call logs, system, and end device alarms and statuses. System data must include detailed information on workstations, servers, and emergency phones.

302.3.3.7 All phone systems must have redundant call servers centrally located at geographically diverse datacenter locations, fed by diverse power and network connections.

302.3.3.7.1 Phones (PET/ETEL/CES/PBX), servers, software, operating systems, power, cabling, network, and any associated hardware required for the complete phone system to work must meet the standard specification 27 80 00 for Communications Reliability. See Section 301 Network Infrastructure for network availability requirements to guide the phone systems design so submittals and reports required by 27 80 00 are more likely to meet the expectation of the designed system.

302.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

302.4.1 System Breakdown Structure (Not Used)

302.4.2 System Sites and Locations

302.4.2.1 PETs are required for passenger emergency or security use at Link light rail stations and associated public areas (not intended for other modes of operation, only light rail). The light rail station designers must accommodate these devices and incorporate them into the station design.

302.4.2.2 PETs must be installed at the followings locations as a minimum:

Table 302-1: PET location matrix (Only applicable to Link light rail stations and associated public areas)

Locations	Required by:	Notes
Stations		
Security Office Door	Sound Transit	Locate directly outside security office door. Where multiple doors exist, the PET must be located by the main door facing the public area.
Public Areas	Sound Transit	There must be one PET within 300 feet of any location in station public areas. Placement must be conspicuously located to be highly visible for security purposes on each platform and at each level. This includes a PET centrally located at each platform (typically at the center platform kiosk)
Elevator Lobbies	IBC, NFPA 130	
Areas of Refuge	IBC	When required by code. Typically, areas of refuge are only required for stations that are not fully sprinkler protected.
Areas of rescue assistance	Sound Transit	See Set 601 for definition and locations.
Fare Vending Areas	Sound Transit	
Bicycle Cages	Sound Transit	
Other Locations	AHJ and Sound Transit	As required by AHJ or ST Security

302.4.2.2.1 Additional locations may be required by AHJ or ST Security. Engineer of Record must work with AHJ, Sound Transit Security, and Sound Transit Portfolio Services Office fire/life safety to formalize an agreement on final locations of additional PETs if not already prescribed in project requirements.

302.4.2.3 ETELs are required at locations specified by NFPA 130 and as required by Sound Transit Maintenance and Operations. Generally, they are intended to be in back of house areas and areas for only maintenance, operations, or emergency personnel within the Link Light rail system. Station designers must accommodate these devices and incorporate them into the Light rail stations, facilities, and right of way design. ETEL system must be back-up communications for the Fire Department and other emergency personnel. Phones must not obstruct emergency egress access or walkways.

302.4.2.3.1 ETEL must be installed at a minimum in all the following locations:

Table 302-2: ETEL Location Matrix

Locations	Required by:	Notes
Stations		
Fire Command Centers	NFPA 130	Common to enclosed stations and the emergency access point for the fire department
Fire Control Room	NFPA 130 as the emergency access point	Common to grade-separated stations. This is the emergency access point for the fire department
Emergency Access Points (as defined by the AHJ)	NFPA 130	Egress stairway at landings within tunnel stations and other locations as defined by AHJ
TPSS	NFPA 130	Locate outside the main TPSS entry when TPSS is integrated into the station
Signal Room	Sound Transit	
Comm Room	Sound Transit	
Ancillary rooms required by the AHJ or ST Operations	NFPA 130 when identified by Fire Department. Sound Transit requires some ancillary rooms (see above).	Uncommon - confer with fire department
Trainways		
At the ends of station platform	NFPA 130	Locate just beyond platform end gate away from public access when possible
At cross passageways and fire fighter access doors	NFPA 130	Locate at entrance. Do not to obstruct emergency walkway
At Emergency access points (as defined by the AHJ)	NFPA 130 when required by Fire Department.	Tunnel portals and other locations as required by the AHJ. Seek AHJ concurrence to omit ETELS along limited access highways including on- and off-ramps where employees would be at risk to test and maintain the device.
Other locations along the trainway as determined by the AHJ	NFPA 130 when required by Fire Department.	Uncommon (e.g., fire apparatus access road crossing) confer with AHJ
Wayside TPSS	NFPA 130	Locate outside the main entry
Signal Bungalows	Sound Transit	

Locations	Required by:	Notes
Communications Bungalows	Sound Transit	
Maintenance Access Towers for Aerial guideways	Sound Transit	Locate just inside locked gate
High rail access points	Sound Transit	Required by Sound Transit Operations and may also be required by the AHJ
Operational Control Center		
LCC Locations (Primary and Backup LCC)	NFPA 130	Existing head end of system
OMF Facilities		
TPSS	NFPA 130	Locate outside the main entry
Other Locations	Sound Transit	As outlined in project requirements or as required by AHJ
Garages and other Facilities		
NA	Sound Transit	Not required. Sound Transit requires PBX phones in maintenance areas and CES in public areas within garages

302.4.2.3.2 All ETEL locations are required to be in secure locations away from the public and easily accessible by emergency and maintenance staff. ETEL enclosures must include a hinged cover that be locked and an independent latch that meets NEMA enclosure performance without being locked. Approval is required by Sound Transit where ETELs are not able to be in a secured location and accessible to the public.

302.4.2.3.2.1 ETELs may be removed from some locations if they are redundant to PBX phones within the provided room and not required by code or AHJ and approved by Sound Transit Operations.

302.4.2.4 CESs are public facing phones to be used in emergency circumstances at Sounder stations, BRT stations, garages, and other non-light rail locations as required by Sound Transit Security.

302.4.2.4.1 CESs are required at the following locations at a minimum:

2 Table 302-3: CES Location Matrix (Sounder, BRT, and Parking Facilities)

Locations	Notes
Security Offices	Locate directly outside security office door. Where multiple doors exist, the CES must be located by the main door facing the public area.
Station public areas	There must be one CES within 300 feet of any location in station public areas. Placement must be conspicuously located to be highly visible for security purposes
Parking garage public areas	One CES at each point of entry at each level

Locations	Notes
Elevator lobbies (station or parking garage)	As required by IBC for two-way emergency communications.
Areas of refuge	When required by IBC.
Fare vending areas (station) and parking payment areas (parking facilities)	
Bicycle Cages (station or parking garage)	
Stairwells (station or parking garage)	For parking garages, provide one CES at each stairwell entry on every floor (but not in the stairwell). For Sounder/BRT stations, provide similarly if area is not already covered by pubic area CESs. And any other CES placement near stairwells as required by Sound Transit Security.
At-grade parking lot	One CES at each main transition pathway between parking lot and station as a minimum
Other locations	As defined in a TVA or basis of design

302.4.2.4.1.1 Additional CESs for any of the above modes or facilities as determined by a threat and vulnerability assessment or basis of design. Engage Sound Transit Safety to verify the design has all CES phones required per the associated TVA or basis of design.

302.4.2.5 Sound Transit requires PBX telephones in any non-public room operations, maintenance, or safety personnel perform a task in any of our facilities associated with any mode or parking facilities. Install PBX phones at the following locations at a minimum:

302.4.2.5.1 LCCs (primary or backup)

302.4.2.5.2 FCC or FCR rooms

302.4.2.5.3 Comm rooms/bungalows

302.4.2.5.4 Datacenters

302.4.2.5.5 Signal rooms/bungalows

302.4.2.5.6 TPSS rooms/buildings

302.4.2.5.7 Electrical rooms

302.4.2.5.8 Mechanical rooms

302.4.2.5.9 Equipment rooms

302.4.2.5.10 Security rooms

302.4.2.5.11 Maintenance rooms

302.4.2.6 Additional PBX phones may be required by Sound Transit in Project Requirements.

302.4.2.7 Centralized call servers must be located at ST datacenters. Location diversity is required for redundant servers. Local call servers for tunnel stations must be located in the station communication rooms.

302.5 SYSTEM INTERFACE REQUIREMENTS

302.5.1 System interfaces identifies the coordination points between this requirement set and other requirement sets.

302.5.1.1 Locations of phones are highly coordinated with architecture (800 series) and fire/life safety (601) chapters.

Table 302-4: Interface Between Telephony and Other Disciplines

SET SERIES	SET NAMES	SET 302 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	X
400	Vehicle	X
500	Track	X
600	Fire/Life Safety	X
700	Structures	
800	Architecture	X
900	Civil	
1000	Mechanical/Electrical and Building Systems	X
1100	Technology	X
1200	Security (especially CCTV)	X

302.5.2 Network

302.5.2.1 Phone systems must be integrated into the existing network management system for the maintenance of Sound Transit networks and system networked assets. The Sound Transit network management software is SolarWinds as of 2023.

302.5.2.2 Phone systems must follow Sound Transit IT's IP schema and networking standards. Different phone systems may require different VLAN designations. Coordinate any network configuration support required by the design with ST.

302.5.3 Power

302.5.3.1 Phone power must be PoE. Auxiliary elements of the phone may be powered by non-PoE power but must be low voltage, like blue lights required for CES and ETEL phones. Coordinate appropriate PoE power budgeting and required network equipment accommodations based on design needs.

302.5.4 Lighting

302.5.4.1 Ensure sufficient lighting for all phone locations. See Set 1007 for Electrical Lighting for lighting requirements.

302.5.5 UPS

302.5.5.1 All phone system elements must be backed up by UPS power. This includes end devices, call servers, or other supporting systems. These are considered critical loads. See Set 1005 Electrical Power.

Commentary: Designer must consolidate UPS loads into the communications UPS design to prevent many small UPSs.

302.5.6 Spatial Needs

302.5.6.1 Public facing phones require a minimum of 2-foot clear buffer zone without advertising around devices. PET and CES phones must be accessible and follow ADA requirements. See Set series 800 Architecture requirements for mode specific station requirements around space requirements (822 Station Layout – Light Rail, 821 Station Layout – Commuter Rail, and 830 Parking Facilities Layout).

302.5.6.2 All phones must have space for proper maintainability to easily carry out maintenance tasks.

302.5.6.3 Each ETEL serving a blue light station per NFPA 130 must have adjacent information that identifies the location of that blue light station and the distance to an exit in each direction.

302.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

302.7 ENGINEERING MANAGEMENT REQUIREMENTS

302.7.1 Interface and Integration Management (Not Used)

302.7.2 Design Management

302.7.2.1 Prepare a code study at preliminary design in accordance with Engineering Procedure EP-03. The study must identify applicable codes including NFPA 70, NFPA 72, NFPA 130, state amendments, local amendments, and municipal codes.

302.7.2.2 Provide design submittals and associated detail per EP-03.

302.7.2.3 The design must provide overview drawings of phone systems as part of station or location. Include system risers and block diagram showing point-to-point connections key equipment and interfaces with the network. This must also include location plans for equipment, enclosures, and conduit/cables locations.

302.7.2.4 Provide Installation details for the phones. Include schedules showing conduit/cabling with connection source and destination information.

302.7.2.5 Provide enough information to build and maintain the system. Provide detailed information for configuration and maintenance via design submittals. Include hardware, configuration, and software documentation

302.7.2.6 Design elements must be commercially available and off the shelf. Connectivity between network equipment must not be based on proprietary protocols.

302.7.2.7 Provide a comprehensive drawing list of all ETEL system. Submit the drawing list with the preliminary, final, as-built, and any other major ETEL system submittals.

302.7.2.8 The initial drawing list must contain all anticipated phone system drawings that will be created as part of the contract as required by EP-03 and the designer's best judgment. Standard manufacturer drawings that are generally provided with the product or subsystem need not be included in the drawing list, even though they will be submitted for approval.

302.7.2.9 Include installation drawings with mounting details and proposed mounting method for each phone location.

302.7.2.10 Include cable-wiring schedule in the system riser diagram. Include estimated cable lengths in design. Cable lengths must be sufficient for installed equipment function.

302.7.2.11 Final as-builts, shop drawings, final design review design documents, and other documentation provided by submittal must constitute a 100% detail design sufficient to properly maintain systems without requiring field visits to obtain pertinent information.

302.7.3 Manufacturing and Construction Management (Not Used)

302.7.4 Installation Management

302.7.4.1 Installation verification, commissioning, and testing must be completed and approved according to the general commissioning and testing plan.

302.7.5 Inspection and Testing Management

302.7.5.1 Perform testing for all newly installed phone systems

302.7.5.1.1 Electrical grounding, network performance, voice recording, voice quality, jitter, latency and call operational performance must be tested. Testing must be signed off by Sound Transit engineering and accepted tests must be documented.

302.7.5.1.2 The designer must include the phones and cables with factory test performance to achieve following:

302.7.5.1.2.1 Circuits are free from static or other interference and have a clear signal.

302.7.5.1.2.2 The phone speaker or headset at the phone location are intelligible and the phone used by the operator at the security operations center, Link light rail control center, or any required control center is intelligible.

302.7.5.1.3 The resident engineer must have final approval on phone performance, clarity, and intelligibility under varying network conditions (e.g., peak and non-peak operations, loaded and non-loaded network conditions).

302.7.5.1.4 For emergency phones, verify off-hook (button functionality indications note from team) for each phone at the security operations center or Link light rail control center.

302.7.5.1.5 The verification of emergency call routing and display at the security operations center workstation or LCC for each emergency phone must demonstrate call routing during failure scenarios for phones.

302.7.5.1.6 Verify each health bit indication to the security operations center or LCC phone system workstation.

302.7.5.1.7 Verify no current flowing on safety ground cabling during testing device installation and operation.

302.7.5.1.8 Verify emergency phones delivered meet NFPA 72 (Sections 10.19 and 14) and NFPA 130.

302.7.5.1.9 See Set 601 Fire/Life Safety for additional emergency phones requirements.

302.7.5.1.10 Training, Pre-Revenue Operations (Not Used)

302.7.6 Certification Management (Not Used)

302.8 APPENDICES (NOT USED)

END SET - 302

303 RADIO

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TABLES

FIGURES

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SET - 303 RADIO

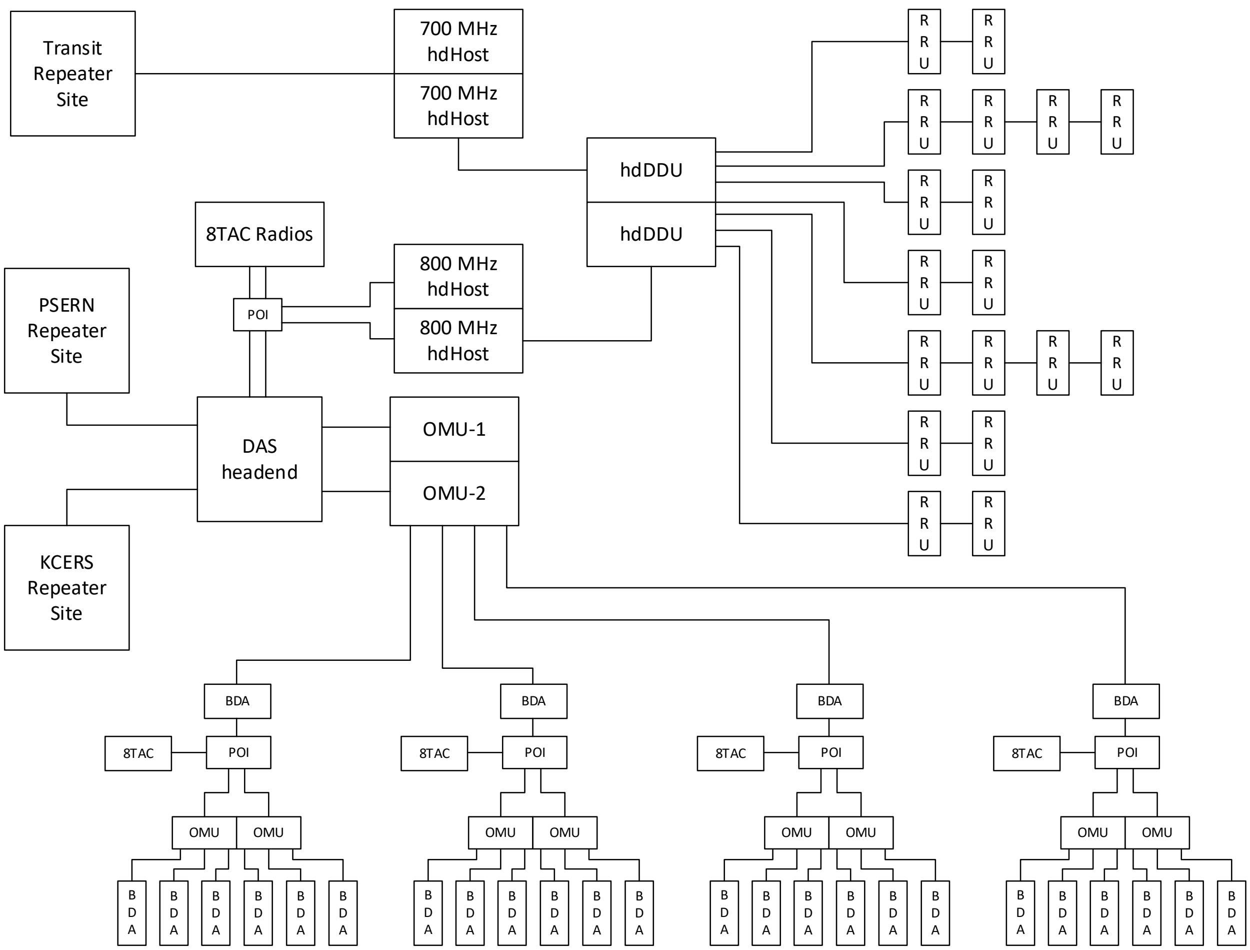
303.1 INTRODUCTION

303.1.1 Document Scope

303.1.1.1 This set provides the requirements for designing and implementing radio communications in Sound Transit facilities. Per FTA and NFPA regulations, reliable radio communications for public safety are required to operate a light rail system.

303.1.1.2 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 303 owner to determine the technical source for the design criteria.

Figure 303-1: System Context Diagram



303.1.1.3 Any new design must be integrated with the existing DAS headend. The commentary below is a snapshot in time and the engineer of record must develop a basis of design and obtain Sound Transit approval prior to commencing with the radio design.

Commentary: Sound Transit uses the following radio systems.

Link: Link light rail uses radio for its daily operational communications to provide support for all Public Safety radio communications inside all Sound Transit facilities. When Link started revenue service, it was decided *the best potion was leasing talkgroups from the County Public Safety radio system, and by meeting the fire code coverage requirements, support for Operations radio communication would be also provided.*

Since 2009 Sound Transit has leased 10 talkgroups from King County Emergency Radio System (KCERS) and have designed the below grade stations and tunnels to support KCERS. Currently, KCERS is being phased out and under replacement by Puget Sound Emergency Radio System (PSERN), a P25-phase 2 system under construction by the time of this writing. It is scheduled to be operational by 2023.

Link currently owns about 400 subscribers, mostly portables. Typically, mobiles are only installed as control stations, donor radios, or in the LRV.

Link has two repeater sites at OMF that feed the in-tunnel DAS. One is a legacy IntelliRepeater Site with ten Quantar Repeaters. It is kept for compatibility with older subscribers while PSERN is completely operational. The second Repeater Site is a PSERN-owned P25-phase 2 repeater site, connected via redundant fiber optic links to PSERN DSR Cores.

Link also has two dispatch sites located at 6th Ave and OMF-C. They have three and five consoles respectively. At both locations there are also Audio Loggers, required by FTA regulations to log all radio communications. Currently there are 10 talkpaths recorded but would be expanded soon to 17.

Tacoma Link Operations: Tacoma Link is a UHF Simulcast DMR system designed under the 2003 FCC license constrains (low power, no antenna gain). The requirement was for a single channel system that could cover the Tacoma Hilltop area to support the T100 expansion project.

The system provides Tacoma Link Operations with two talkpaths and provides coverage along the alignment by linking the repeaters via dedicated fiber optic. The system will be expanded to Tacoma Community College in the future (currently estimated for 2039-2041). At TL-OMF there is also an Audio Logger, where all three talkpaths are logged.

Security Radio: Security is a UHF DMR-II system using Motorola's IP Site Connect. It has repeater at each Sounder Station in the South area, with a central dispatch with 4 Zetron consoles at Union Station Security Operations Center. The system relies on Sound Transit IT network infrastructure to link each repeater to the Security Operations Center. Security Radio does not have audio logging.

Garages: All new garages are required by the fire code to provide Public Safety radio coverage inside the structure. Garages are being built in North and South of King County, so they must support all three public safety providers in the area.

RF Bands:

Sound Transit uses the following RF bands for their radio systems:

800 MHz Public Safety band (806-824 MHz & 851-869 MHz)

700 Narrowband (769-775 MHz & 799-805 MHz)

700 MHz Broadband (FirstNet, 758-769 MHz & 788-799 MHz)

Private Land Mobile Radio Ultra High Frequency (LMR UHF, 450-512 MHz)

Emergency Radio System: All underground stations were designed with a local emergency system that provides two conventional channels repeated at each RF hub. This has been enhanced by adding a Motorola MCD5000 Deskset system that allows accessing those repeaters from Link Control. At the point of this writing, the system is in the process to be expanded North of N00-Pine St, but eventually must be included in all underground facilities. The system provides a single frequency conventional repeater for 8TAC93 channel for SFD and another channel for Operations. It is intended to help in evacuating the stations but cannot be used for normal train operations.

303.1.2 Regulations, Codes, Standards, and Guidelines

303.1.2.1 International Regulations, Codes, Standards, and Guidelines

303.1.2.1.1 IEC 60169 Radio-frequency Connectors.

303.1.2.1.2 General System Design - ETSI TR 102 398 V1.4.1.

303.1.2.1.3 Part 1: DMR Air Interface (AI) protocol - ETSI TS 102 361-1 V2.5.1.

303.1.2.1.4 Part 2: DMR voice and generic services - ETSI TS 102 361-2 V2.4.1.

303.1.2.1.5 Part 3: DMR data protocol - ETSI TS 102 361-3 V1.3.1.

303.1.2.1.6 Part 4: DMR Trunking.

303.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

303.1.2.2.1 Title 47CFR 20.21.

303.1.2.2.2 Title 47 Subpart B.

303.1.2.2.3 Title 47CFR Part 90.

303.1.2.2.4 TIA TSB-102-D Project 25 TIA-102 Documentation Suite Overview.

303.1.2.2.5 TIA-561, Simple 8-Position Non-Synchronous Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange.

303.1.2.2.6 TIA-568.2-D, Balanced Twisted-Pair Telecommunications Cabling and Components Standard.

303.1.2.2.7 TIA-604-3-B, FOCIS 3 Fiber Optic Connector Intermateability Standard- Type SC and SC-APC.

303.1.2.2.8 TIA/EIA-455-4C, FOTP-4 Fiber Optic Component Temperature Life Test.

303.1.2.2.9 TIA-758-B “Customer-Owned Outside Plant Telecommunications Infrastructure Standard.

303.1.2.2.10 TIA-606-B, Administration Standard for Commercial Telecommunications.

303.1.2.2.11 TIA-607-B, Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises.

303.1.2.2.12 TIA-758-B, Customer-Owned Outside Plant Telecommunications Infrastructure Standard.

303.1.2.2.13 TIA-862-A, Building Automation Systems Cabling Standard.

303.1.2.2.14 TIA-942-A, Telecommunications Infrastructure Standard for Data Centers.

303.1.2.2.15 TIA TSB-88, Wireless Communications Systems - Performance in Noise and Interference - Limited Situations - Recommended Methods for Technology - Independent Modeling, Simulation, and Verifications.

303.1.2.2.16 TIA-102-D, Project 25 TIA-102 Documentation Suite Overview.

303.1.2.2.17 TIA TSB-140, Additional Guidelines for Field-Testing, Loss and Polarity of Optical Fiber Cabling Systems.

303.1.2.2.18 TIA TSB 102-C, Project 25 TIA-102 Documentation Suite Overview (the whole suite of TIA 102 documents).

303.1.2.2.19 UL 444, UL Standard for Safety Communications Cables.

303.1.2.2.20 UL 444 BULLETIN, UL Standard for Safety Communications Cables.

303.1.2.2.21 UL 2524 Standard for In-Building 2-Way Emergency Radio Communications Enhancement Systems.

303.1.2.2.22 UL Lightning Protection Marking and Application Guide

303.1.2.2.23 NFPA 70 National Electrical Code.

303.1.2.2.24 NFPA 72 National Fire Alarm and Signaling Code.

303.1.2.2.25 NFPA 731 Standard for the Installation of Premises Security Systems.

303.1.2.2.26 NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems.

303.1.2.2.27 NFPA 780 Standard for the Installation of Lightning Protection Systems.

303.1.2.2.28 NFPA 1221 Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems.

303.1.2.2.29 NFPA 1225 Standards for Emergency Services Communications (when adopted via the WA building code).

303.1.2.2.30 BICSI ITSIMM, Information Technology Systems Installation Methods Manual (ITSIMM) 8th Edition or later.

303.1.2.2.31 BICSI OSPDRM, Outside Plant Design Reference Manual 6th Edition or later.

303.1.2.2.32 BICSI TDMM, Telecommunications Distribution Methods Manual 13th Edition or later.

303.1.2.2.33 BICSI/NECA 568, Standard for Installing Commercial Building Telecommunications Cabling.

303.1.2.2.34 BICSI/NECA 607 Standard for Telecommunications Bonding and Grounding Planning and Installation Methods for Commercial Buildings 2011.

303.1.2.2.35 IEEE STD 81, Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System.

303.1.2.2.36 IEEE STD 446, Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book).

303.1.2.2.37 IEEE 269-2019–IEEE Standard for Measuring Electroacoustic Performance of Communication Devices.

303.1.2.2.38 IEEE SA 1588-2019, Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems.

303.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

303.1.2.3.1 RCW 82.14B.020, Definitions.

303.1.2.3.2 WAC 51-54A-0510, Emergency responder radio coverage.

303.1.2.3.3 SFD CAM5123.

303.1.2.3.4 IFC/SFC Section 510.

303.1.2.4 Industry Regulations, Codes, Standards, and Guidelines.

303.1.2.4.1 Fiber Optic Association (FOA) OSP Fiber Optics Civil Works Guide.

303.1.2.4.2 Motorola Standards and Guidelines for Communication Sites (68P81089E50).

303.1.2.5 ANSI/BICSI 006-2020, Distributed Antenna Systems (DAS) Implementation Best Practices.

303.1.2.6 Other Jurisdictions (Not Used)

303.1.2.7 Sound Transit Regulations, Codes, Standards, and Guidelines

303.1.2.7.1 Systems Standard Drawings.

303.1.2.7.2 Design Technology Manual Rev 1 (or later).

303.1.3 Abbreviations and Acronyms

303.1.3.1 8TAC–800-megahertz interoperability channel

303.1.3.2 BDA– bidirectional amplifier

303.1.3.3 BMS– building management system.

303.1.3.4 CAM– customer assistance memorandum

303.1.3.5 CATP– coverage acceptance test procedure

303.1.3.6 CCN –central communications network

303.1.3.7 CPRI– common public radio interface

303.1.3.8 DAQ– delivered audio quality.

303.1.3.9 DAS– distributed antenna system

303.1.3.10 DMR– digital mobile radio

303.1.3.11 ERCES– emergency responders communication enhancement system

303.1.3.12 ETSI– European Telecommunication Standards Institute

303.1.3.13 FACP– fire alarm control panel

303.1.3.14 FCC– Federal Communications Commission

303.1.3.15 FF– fiber fed

303.1.3.16 FirstNet– First Responder Network Authority

303.1.3.17 FTA– Federal Transportation Agency

303.1.3.18 GROL– general radiotelephone operator license

303.1.3.19 hdDDU– Avari Packet Switching unit.

303.1.3.20 hdHost – Avari RF host unit

303.1.3.21 HTTP– hypertext transfer protocol

303.1.3.22 HTTPS– secure hypertext transfer protocol

303.1.3.23 HVAC– heating ventilation & air conditioning

303.1.3.24 IFC– International Fire Code

303.1.3.25 IP– internet protocol

303.1.3.26 ISM– industrial scientific medical

303.1.3.27 ITAC– interoperability channel

303.1.3.28 KCERS– King County Emergency Radio System

303.1.3.29 LAN– local area network

303.1.3.30 LCC– link control center

303.1.3.31 LMR– land mobile radio

303.1.3.32 LRV– light rail vehicle

303.1.3.33 MAC– modifications, additions, and changes

303.1.3.34 MIB– management information base

303.1.3.35 NFPA– National Fire Protection Association

303.1.3.36 NGLE– Northgate link extension

303.1.3.37 NMS– network management system

303.1.3.38 NRV– non-revenue vehicle

303.1.3.39 OID– object ID

303.1.3.40 OMF– operations and maintenance facility

303.1.3.41 OMU– optical master unit

303.1.3.42 OSPD– outside plan designer

303.1.3.43 OTA– over the air

303.1.3.44 P25– project 25

303.1.3.45 PIM– passive intermodulation

303.1.3.46 POI– point of interface

303.1.3.47 PSERN– Puget Sound Emergency Radio Network

303.1.3.48 RCDD– registered communications distribution designer

303.1.3.49 RCW– Revised Code of Washington

303.1.3.50 RF– radio frequency

303.1.3.51 RGU– radio gateway unit

303.1.3.52 RRU– remote radio unit

303.1.3.53 SCADA– system control and data acquisition

303.1.3.54 SFC Seattle Fire Code

303.1.3.55 SFD Seattle Fire Department

303.1.3.56 SFTP secure fire transmission protocol

303.1.3.57 SNMP simple network management protocol

303.1.3.58 SSH– secure shell

303.1.3.59 TCN– train control network

303.1.3.60 TCP– transmission control protocol

303.1.3.61 TCN– train control network

303.1.3.62 TCP– transmission control protocol

303.1.3.63 TIA–TSB TIA telecommunications service bulletin

303.1.3.64 TPSS– traction power substation

303.1.3.65 UDP– user datagram protocol

303.1.3.66 UHF– ultra-high frequency

303.1.3.67 U-Link– University Link extension

303.1.3.68 UPS– uninterruptable power supply

303.1.3.69 VLAN– virtual LAN

303.1.4 Definitions and Classifications (Not Used)

303.1.5 References (Not Used)

303.2 STAKEHOLDER NEEDS

303.2.1 Passenger Experience (Not Used)

303.2.2 Operational Needs

303.2.2.1 Coverage testing: System coverage must be tested and shown to meet or exceed the predicted coverage maps using TSB-88.

303.2.2.2 Coverage pass/fail criteria must be:

303.2.2.2.1 According to TSB-88 Table A-1 per modulation.

303.2.2.2.2 Delivered Audio Quality = 3.4.

303.2.2.2.3 Test signals per TSB-8 Table A-2.

303.2.2.3 Perform DAQ testing using random phrases from 269-2019 –IEEE Standard for Measuring Electroacoustic Performance of Communication Devices.

303.2.2.4 Present a CATP to Sound Transit in advance for approval. The CATP must provide:

303.2.2.4.1 Proof of equipment calibration.

303.2.2.4.2 Equipment test setup with an explanation of how the setup would provide a testing environment similar to coverage simulation.

303.2.2.4.3 Test grid proposal: A proposed tile distribution following the code guidelines but adapted to the structure, so spaces are defined within individual tiles and tiles sharing dissimilar spaces are avoided.

303.2.2.4.4 Testing procedure: A detailed description of equipment configuration to be used, crews with their professional certifications, and testing procedures.

303.2.2.4.5 Test results must be provided to Sound Transit in tabular and graphic format.

303.2.2.5 Equipment installation: System equipment must be installed in adequate telecommunications spaces as defined in Set 815 Telecommunication Spaces.

303.2.2.6 Testing environment: The contractor must perform the coverage testing in the following areas:

303.2.2.6.1 Station areas

303.2.2.6.2 Inside the backroom facilities with the door closed.

303.2.2.6.3 Along the trackway and yard facilities.

303.2.2.6.4 Inside the TPSS Communications and Signal Houses with the door closed.

303.2.2.6.5 Inside the LRV, Heavy Rail or Bus while moving along the trackway or road.

303.2.2.6.6 Inside a NRV at hip level along the trackway and yard facilities.

303.2.2.7 Redundancy: Whenever a DAS is designed to support radio coverage inside any ST facility, it must redundant.

303.2.2.7.1 Must be fed from a minimum of two donor sites

303.2.2.7.2 Must be fed via redundant fiber optic pathways

303.2.2.7.3 Fiber optic must be single mode fibers, terminated in LC/UPC connectors unless otherwise specified

303.2.3 Maintenance Needs

303.2.3.1 Sound Transit operational reliability requires a highly durable design, the system must be designed to withstand the time and foreseeable future MAC.

Commentary: Currently, Sound Transit does not maintain or service its subscribers. Sound Transit has a contract with the City of Seattle Radio Shop to configure, provision, and service the subscribers supported by PSERN. PSERN owns and operates its infrastructure located at OMF and 6th Ave. LCC.

303.2.3.2 Use the following table to guide the design:

Table 303-1: Design Service Life

Telecommunication Space/Component	Design Service Life
Mechanical infrastructure, structural supports, maintenance holes, vaults, raceway, conduit, duct banks, pedestals, racks, and enclosures	50 years
Components and devices, doors, ventilation fans, HVAC, and AC power distribution	See Series 800 & 1000

303.2.4 Safety Needs

303.2.4.1 Personnel safety: Radio personnel are only qualified to work with low voltages. Any design that requires radio personnel accessing areas not rated for low voltage is prohibited.

303.2.4.2 Fall protection: Ensure that equipment is in areas accessible without the need of ladders or any other similar method. If the equipment must be installed in a location above 3 feet, provide fall protection.

303.2.5 Security Needs (Not Used)

303.2.6 Reliability, Availability and Maintainability Needs

303.2.6.1 Maintenance plan: Propose a five-year warranty and support extension plan of the system.

303.2.6.1.1 Develop a maintenance plan that details preventative maintenance, outage repair, and administration procedures required for radio system equipment prior to substantial completion.

303.2.6.1.2 List personnel, equipment, and duration required for each maintenance procedure developed. Include necessary frequency for preventative maintenance procedures.

303.2.6.1.3 Provide a maintenance and support plan for the first year of operation, after substantial completion date. Describe all resources required for implementing the plan (i.e., spare parts, storage, software/firmware plans and updates, and training.)

303.2.6.1.4 Provide an optional five-year plan extension for supporting the system operation. Describe how the fleet would be maintained and updated in case of equipment being phased out by the manufacturer.

303.2.7 Environmental and Sustainability Needs (Not Used)

303.3 SYSTEM REQUIREMENTS

303.3.1 General Requirements

303.3.1.1 Sound Transit requires the design of a resilient, redundant RF signal enhancement system that reliably distributes RF signal from the system base stations into the indoor facilities. There are four scenarios:

303.3.1.1.1 Below grade facilities: Facilities located underground where RF signal is not propagated and must be enhanced to reach the coverage defined by IFC and NFPA requirements.

303.3.1.1.2 At or above grade facilities: Facilities where the RF signal propagates. In that area, coverage is provided by the FCC licensee. Sound Transit must be a compliant user and meet all requirements to avoid generating any interference with any radio system.

303.3.1.1.3 Operationally critical areas: Critical areas for radio coverage include those outlined in IFC 510, NFPA 1221 (or NFPA 1225 when adopted) and the following:

i. Station indoor areas
ii. Fire control room/center
iii. Security room
iv. Traction power substations
v. Signal houses
vi. Communications Room
vii. Electrical room
viii. UPS room
ix. Wiring closets
x. End of line room/building
xi. Operator rest areas
xii. Any other area defined as critical for Sound Transit Operations

Commentary: Note that in those areas considered operationally critical, design requirements for providing coverage are the same as those required in IFC and NFPA, except for those intended for remote reporting to the FACP and/or power backup time. In those cases, unless otherwise instructed by the AHJ, alarms will be reported to BMS, and power backup is limited to the station's power. If the AHJ provides any guidance, it must be documented with the AHJ signing and stamping.

303.3.1.1.4 Parking garages: Parking garages must have ERCES, which are intended to improve the signal coverage inside the facility. Requirements are in IFC510 and NFPA1221 (or 1225 when adopted), but designers and contractors must use SFC CAM5123 document to guide them to file the system design within King County and obtain licensee approval before building any system.

Commentary: Note that different from stations, garages may not have access to any Sound Transit communications network, and for an extended period operate as a stand-alone facility.

Commentary: Note that CAM5123 applies only to King County and PSERN. Other counties have their own radio system and may use the same procedure. Designers must specifically address the licensee in the facility location to use their particular filing procedure.

303.3.1.1.5 Public safety radio service provider operates the radio system intended to support Public Safety operations in the County. Providers in the Puget Sound area currently are:

i. King County: Currently, it is KCERS. The system is in transition to PSERN.
ii. Pierce County: CCN.
iii. Snohomish County: SNO911/SERS.

Commentary: Each project must obtain a written agreement with the local operator for support, interoperability and coverage.

303.3.2 Performance Requirements

303.3.2.1 The Sound Transit radio system is intended to provide reliable RF signal coverage within Sound Transit facilities, regardless of whether they are below, at or above grade. The Sound Transit radio system must be the primary means of voice communications for all Link mobile personnel and provide support for emergency services such as fire, police, and emergency medical services.

Commentary: At and above grade RF signal is provided by KCERS, and later will move to PSERN. Sound Transit has a DAS at all facilities fed from a repeater site located at OMF facility in SODO, distributed via fiber optic to all Sound Transit tunnels and below grade stations. OMF repeater site and both dispatch sites at LCC and OMF are connected to KCERS/PSERN radio core via a dedicated redundant fiber optic connection.

303.3.2.2 Sound Transit radio system has an RF hub at each below grade station that is connected to the OMF headend via redundant single-mode dark fiber optic links. The dark fiber strands are lit by the hub and OMF headend in full-duplex mode.

303.3.2.3 Along the tunnel bores, the RF signal is repeated by the RRU. The RRU are connected to the station hubs via redundant fiber optic link.

303.3.2.4 RF signal enhancements must take signal off the air at a minimum of two sites, and feed remote BDA via dedicated redundant fiber optic links at parking garages and at or above grade stations.

303.3.2.5 Provide resources to either expand the existing audio loggers, which includes NICE audio logging system with OTA donor radios as LCC and OMF, or provide extra equipment needed to continue logging all radio communication.

303.3.2.6 Logging metadata must be considered by either gathering it from the control channel or directly from the system core. Either way, provide the licensing, hardware, and software to accomplish similar or better data/audio logging.

303.3.2.7 Sound Transit is configuring an off-band remote management system for all DAS active components. All components must be able to be connected to an Ethernet network as described in 303.3.3.11 below.

303.3.2.8 Any new design, especially if it is using the CPRI-based system, must ensure the GPS-disciplined, IEEE1588-compliant clock is provided to guarantee proper time synchronization to the DAS devices in the system.

303.3.2.9 Sound Transit has a contract with a neutral host to provide cell phone service inside tunnels and below grade stations. Any design must ensure no interference is generated in the designed system that may affect the operation of any band of the cellular system.

Commentary: The neutral host is excluded from radiating in the ISM and public safety bands below 3 gigahertz.

303.3.3 Design Requirements

303.3.3.1 Incorporate the following design requirements:

303.3.3.2 Low PIM: All components used in Sound Transit radio system must be low PIM certified.

Commentary: Sound Transit considers low PIM a device that shows IM components under -155 decibels relative to carrier measured with 2 x 20 watts carriers' method.

303.3.3.3 Low PIM connectors: Along with stated in 303.3.3.2, Sound Transit have selected standardize to:

303.3.3.3.1 For DAS infrastructure:

303.3.3.3.1.1 4.3/10 mini-DIN connectors, as specified in IEC-61169-54

303.3.3.3.2 For Narrow band and subscriber applications:

303.3.3.3.2.1 N, As defined in IEC-61169-16.

303.3.3.3.2.2 Mini-UHF: As defined in AMP 108-12034

303.3.3.3.2.3 SMA: As defined in IEC-61169-15.

303.3.3.3.3 Adapters: RF adapters between different connector types are not acceptable

303.3.3.3.4 Materials: Acceptable materials for connectors are brass body with silver platting

303.3.3.3.5 Torque: All connectors must be tightened to the manufacturer's recommendation.

303.3.3.4 Watertight sealing: By design, Sound Transit tunnels are wet tunnels, therefore any connector must be weatherized with at least two layers of silicone tape.

303.3.3.5 ITAC/8TAC channels: Sound Transit's radio system must comply with KCRS/PSERN operational and emergency procedures. This includes access to PSAP talkgroup and ITAC/8TAC channels.

303.3.3.6 Subscriber programming: Any existing or new facility must provide programming and provisioning for each subscriber it plans to add to the system. Currently, Sound Transit subscribers are programmed and provisioned by the City of Seattle Radio Shop.

303.3.3.7 FirstNet: FirstNet is the nation-wide public safety interoperability network. It is intended to operate in broadband mode in Band 14, but not limited to it. Any new or existing RF signal enhancement must coexist with FirstNet and may be required to provide FirstNet support at Band 14, or any other band FirstNet agrees to use with its licensees.

303.3.3.8 RF coverage modeling: Any RF signal enhancement design must be modeled using COST-231 (for indoor areas) or Okumura-Hata (for outdoor areas) propagation models and presented in "heat maps" verifying required coverage area is met. Any other method must be submitted to Sound Transit for approval. For subscribers, modeling must use a hip level location, DAQ=3.4, with standard ¼ wavelength antenna.

303.3.3.9 Facility Type: Sound Transit defines all its facilities as Type B1 as defined in R56 4.3.3. Lighting protection must meet NFPA 780

Commentary: As minimum, each donor antenna pole must be fitted with a NFPA 780 compliant air terminal with a direct path to the grounding electrode as defined in UL Lightning Protection Marking and Application Guide.

303.3.3.10 Emergency radio system: Any existing or new below grade station hub must include two repeaters configured in conventional analog mode intended to support 8TAC and designated Operations channel. The repeaters must be connected to a local RGU, which will be connected to TCN and configured to use a radio subnet. RGU configuration and provisioning must be included in the project. The new repeaters must be configured to be shown in LCC and OMF MCD5000 Deskset system.

Alarm signaling: The radio system must be monitored by the fire alarm system when a fire alarm system is provided, and by BMS for link stations. A single summary alarm to the fire alarm system may be provided when allowed by IFC 510. When monitored by the fire alarm panel, BMS monitoring is not required. Where there is no fire alarm system, radio monitoring must be via the BMS SCADA as described in System Standard Drawings JRS100.

303.3.3.11 Equipment installation

303.3.3.11.1 Equipment location: Active equipment can only be installed in low voltage rated areas. Installation in medium or high voltage rated areas is prohibited.

303.3.3.11.2 Ceiling mounting: Active equipment installation in unreachable places like ceilings is prohibited.

303.3.3.11.3 Wall mounting: Active equipment wall-mounting is not permitted, even if the manufacturer allows it as installation procedure.

303.3.3.11.4 Cabinet mounting: All active equipment must be installed in a cabinet, meeting seismic requirements to ensure equipment survivability.

303.3.3.11.5 Branching equipment: When installed in a cabinet, branching equipment must be installed in equipment trays. Branching equipment must be installed secure to the tray and with enough cable slack to me maintained.

303.3.3.11.6 Jumper cables: Whenever an equipment will be connected to a coaxial cable or another equipment, a jumper cable must be used.

Commentary: The minimum length for a jumper cable is 2 feet and must be secured to avoid vibration. When connecting an antenna, a drip loop and a service loop must be provided.

Any RF jumper must have a complete loop meeting the minimum bending radius defined by the manufacturer. The loop must be physically secured to avoid vibration.

303.3.3.12 Equipment installation: Any active equipment must be installed in a Telecommunications Room as defined in Set 815 Telecommunications Spaces, inside a cabinet.

303.3.3.12.1 Wall or pole mount: wall or pole mounting is not allowed, even if the manufacturer says it is an acceptable mounting procedure

303.3.3.12.2 Donor antenna mounting: Antennas may not be mounted in ballasted structures in the roof. Antenna masts require structural attachment at any location meeting Set 701 Geotechnical and FAA regulations.

303.3.3.13 Remote Management for DAS active components

303.3.3.13.1 Network connection: All active radio components must be provided with an Ethernet (as defined in IEEE 802.3) network connection intended for remote management.

303.3.3.13.2 Network connector: Active radio components must have an 8P8C connector exposed outside the enclosure and protected with a cap.

303.3.3.13.3 Connection speed: Ethernet connection must support 1000BASE-T as defined in IEEE-802.3ab or better.

303.3.3.13.4 Minimum Protocols: The active radio components must support at least the following protocols:

303.3.3.13.4.1 IP

303.3.3.13.4.2 TCP and UDP

303.3.3.13.4.3 SNMP (v3 or later), including traps

303.3.3.13.4.4 SFTP

303.3.3.13.4.5 SSH

303.3.3.13.4.6 Telnet

303.3.3.13.4.7 HTTP

303.3.3.13.4.8 HTTPS

303.3.3.13.5 Network addressing: All active devices are required to support IP protocol version 6 and version 6 and must be configured to support layer 3 addressing.

303.3.3.13.6 IP Addressing schema: All active devices in the radio system must be able to be programmed with the addressing schema provided by Sound Transit.

303.3.3.13.7 Network manager: Provide an NMS to support the radioactive components provided by the project. If the project plans to integrate with an existing NMS, then enough licenses for the delivered components, plus 50 percent must be provided as part of the design.

303.3.3.13.7.1 Management protocol support: The NMS must provide at least SNMP (version 3 or later) and MIB-II (RFC1213) support.

303.3.3.13.7.2 Private OID: If the equipment has private OID, the project must include manufacturer support to incorporate the private components into the NMS.

303.3.3.13.8 Web server: All active radio components must also provide an internal web server supporting HTTP and HTTPS.

303.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

303.4.1 System Breakdown Structure

Figure 303-2: Link DAS Diagram

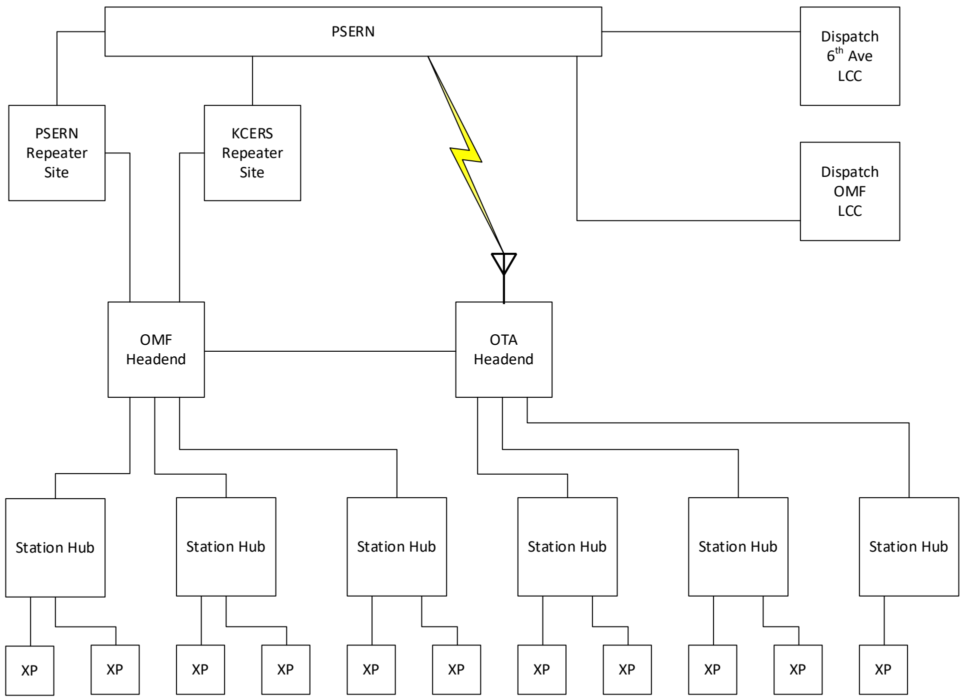


Figure 303-3: Link Station RF Hub Diagram

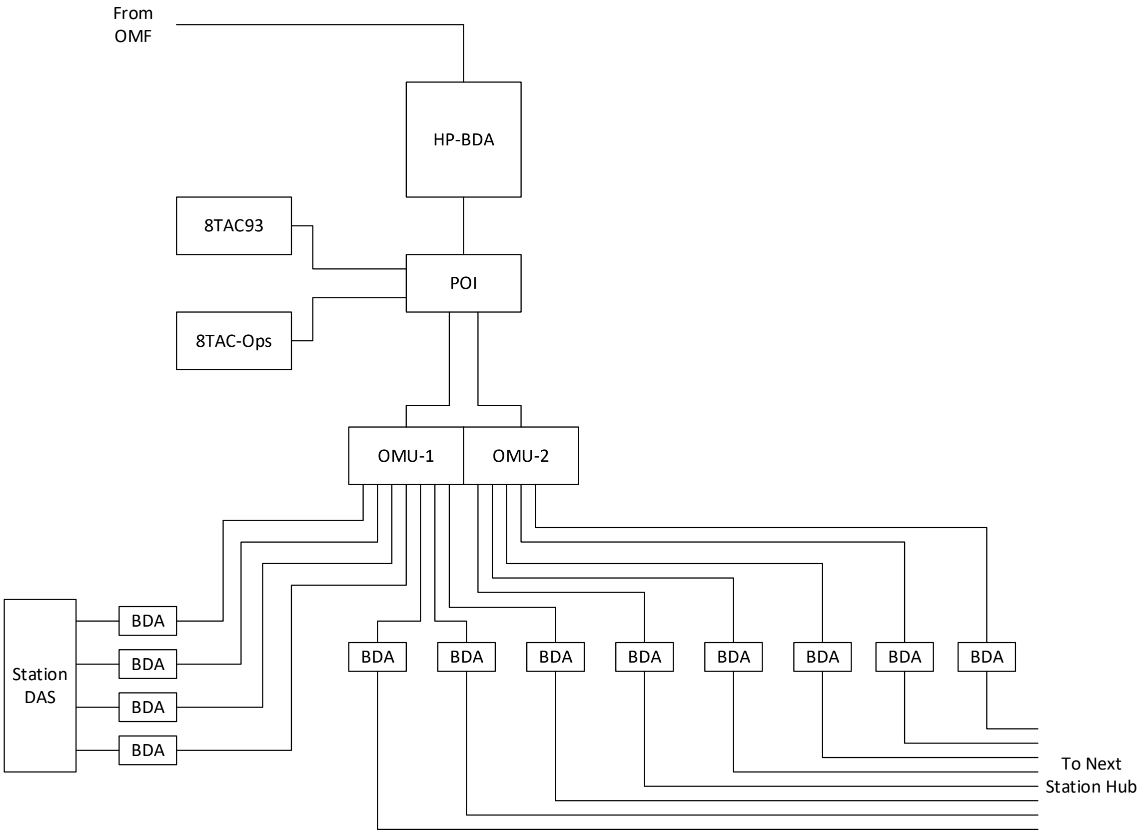


Figure 303-4: CPRI Based DAS

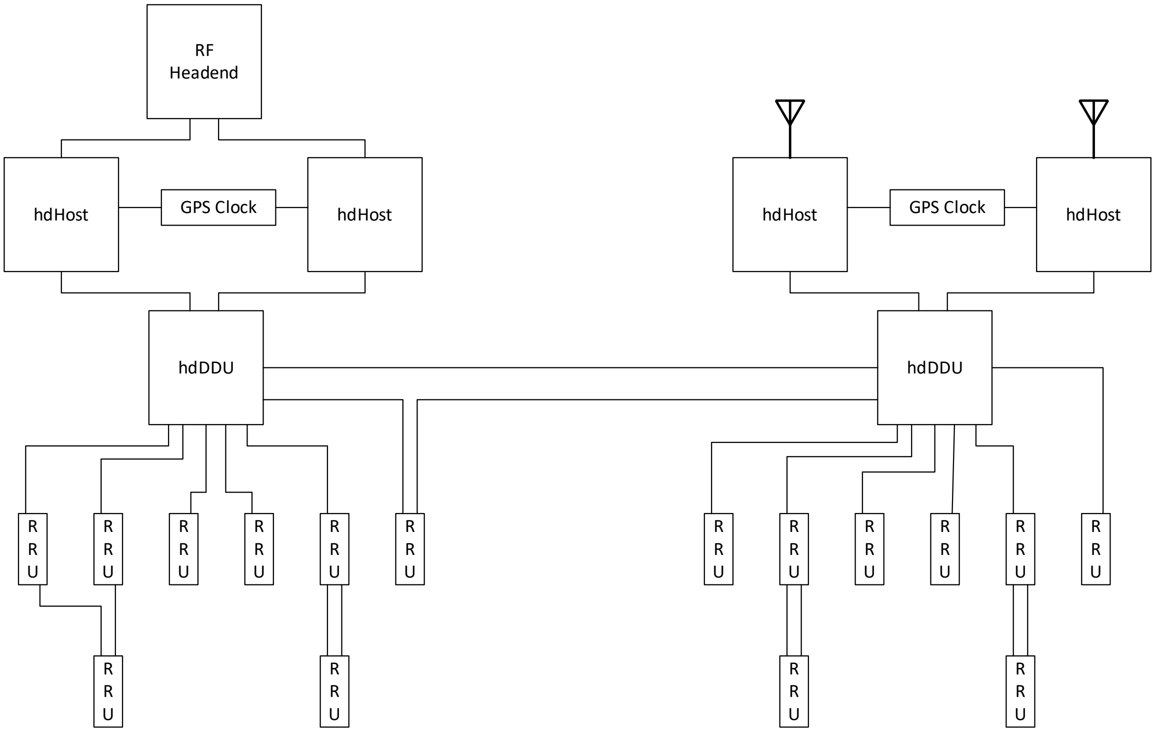
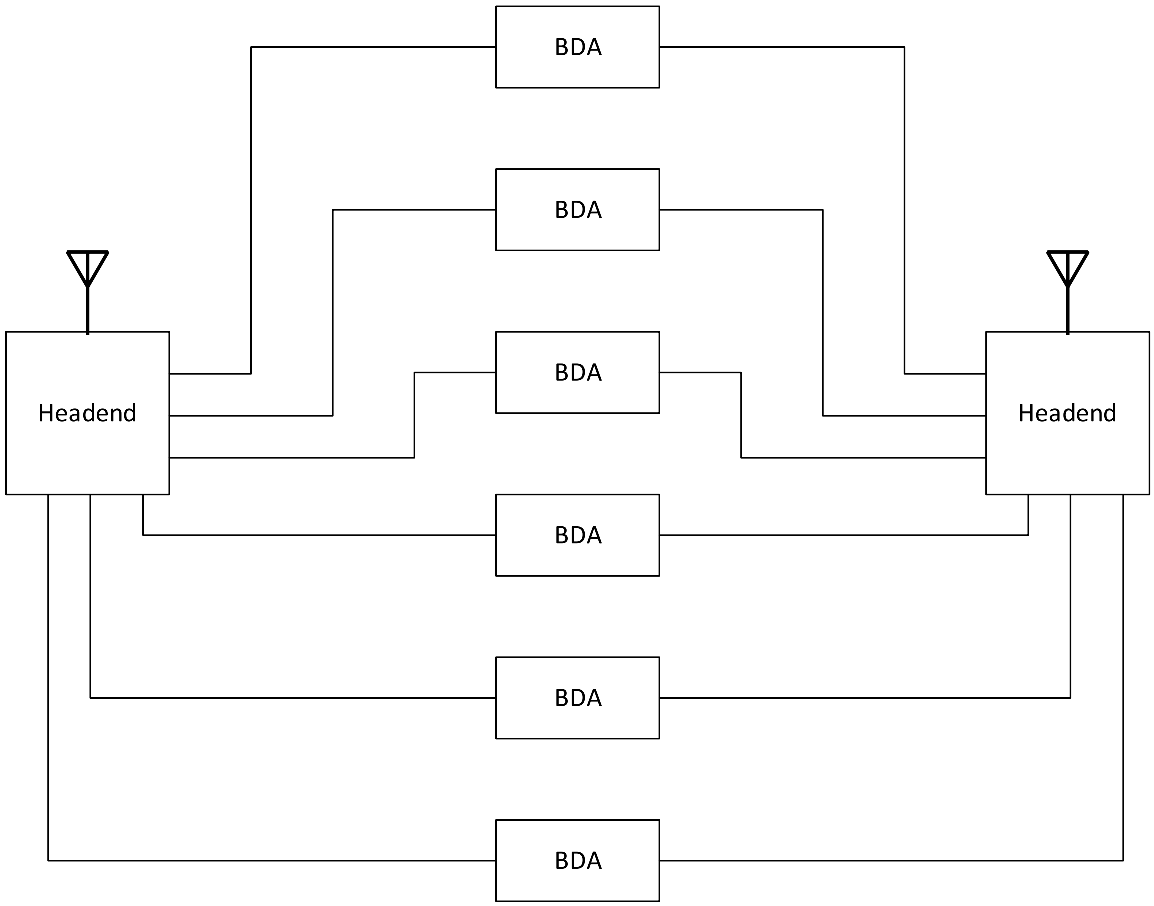


Figure 303-5: C-Link TPSS & Signal Houses



303.4.2 System Sites and Locations

Figure 303-6 Tacoma Link Fiber Optic Network

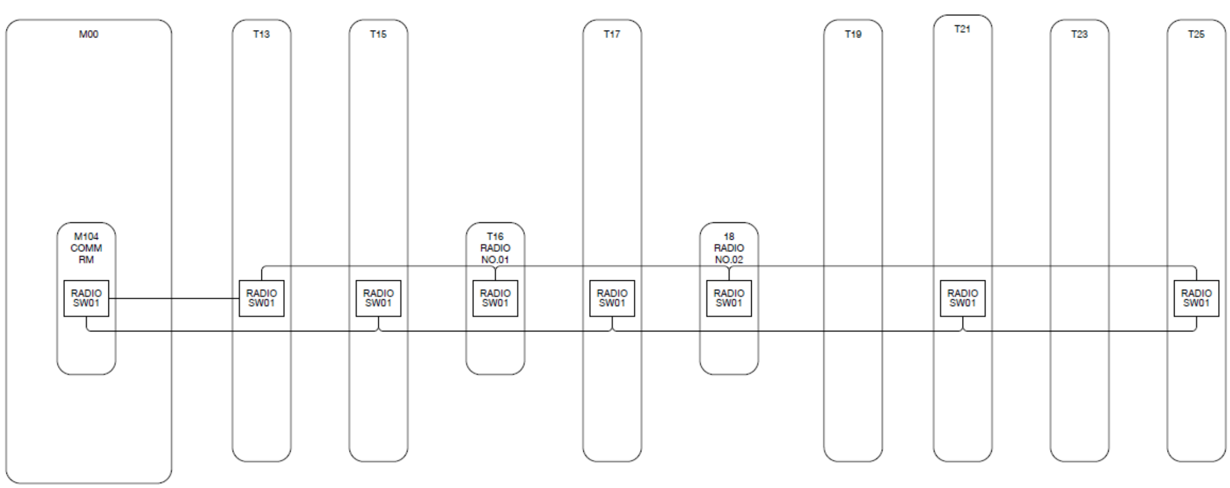


Figure 303-7: Tacoma Link Station Diagram

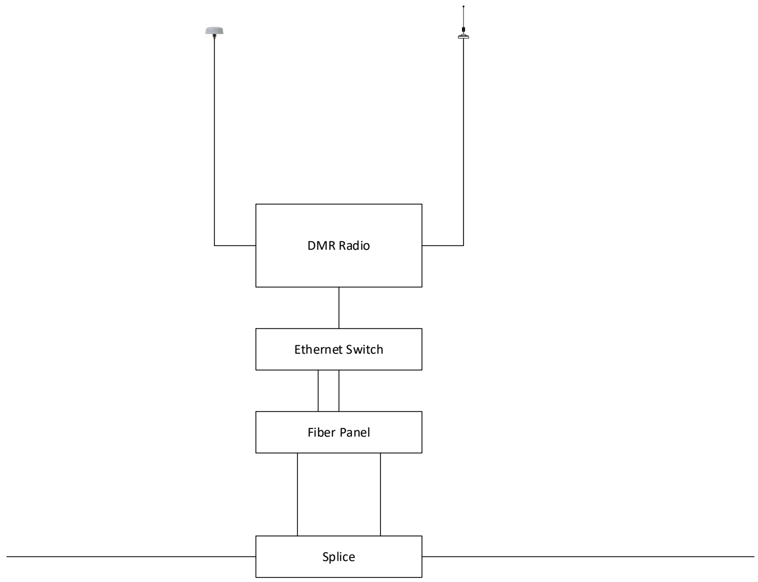
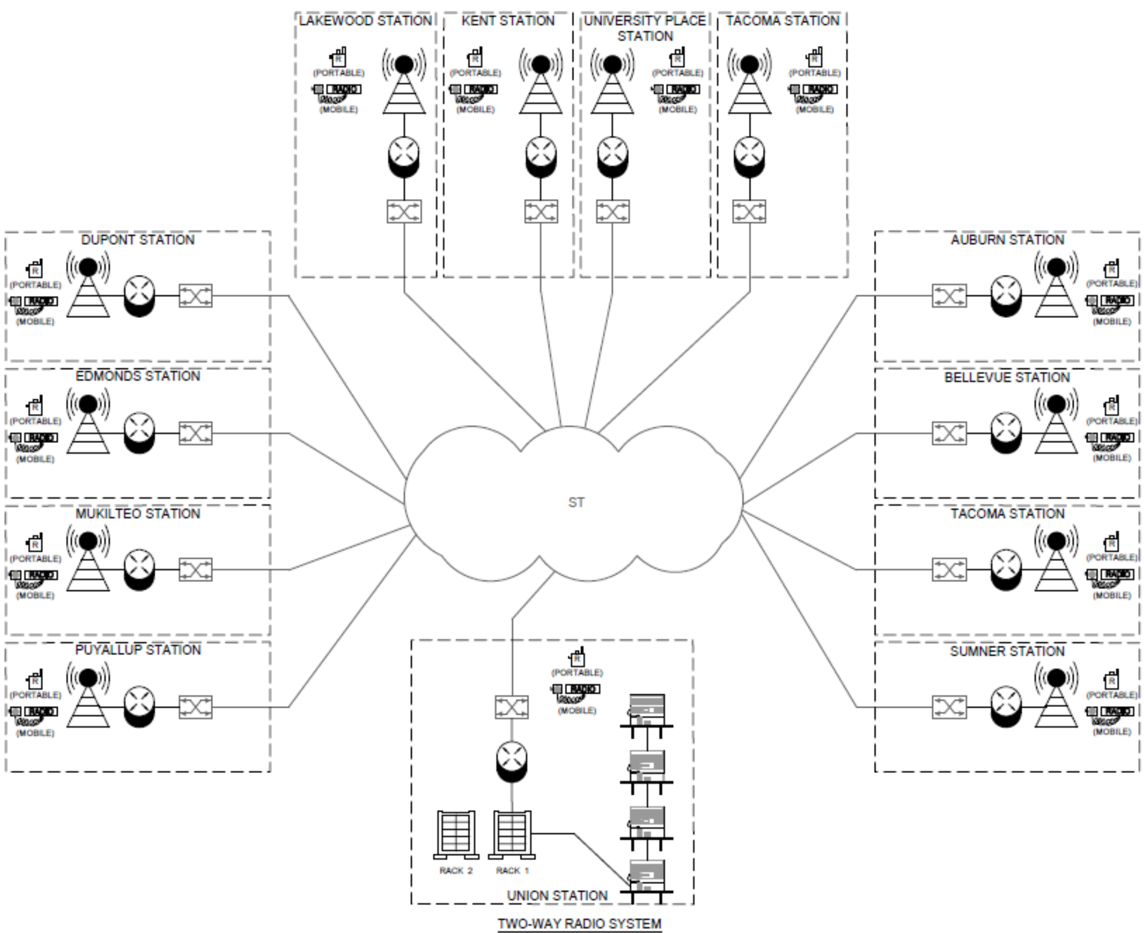


Figure 303-8: Security Radio



303.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Figure 303-9: Interface Between Radio and Other Disciplines

SET SERIES	SET NAMES	SET 303 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	
300	Operational Communications	X
400	Vehicle	
500	Track	X
600	Fire-Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

303.5.1 Architectural

303.5.1.1 Set 801 Architectural Materials Elements and Furnishings.

303.5.1.2 Set 815 Telecommunication Spaces.

303.5.1.3 Set 821 Sounder Station Layout.

303.5.2 Civil and Train Control

303.5.2.1 Set 102 Train Control.

303.5.2.2 Set 902 Utilities.

303.5.3 Civil Systems Integration

303.5.3.1 Set 1001 Electrical Raceway.

303.5.3.2 Set 1002 Lighting.

303.5.3.3 Set 1004 Mechanical HVAC.

303.5.3.4 Set 1005 Electrical Power.

303.5.3.5 Set 1020 Building Management Systems.

303.5.3.6 Set 1221 Access Control Systems.

303.5.3.7 Set 601 Fire and Life Safety.

303.5.4 Communications (Sounder Requirements Sets)

303.5.4.1 Set 1120 Sounder Station PIMS.

303.5.4.2 Set 1220 CCTV Requirements.

303.5.4.3 Set 301 Communications Infrastructure Requirements.

303.5.4.4 Set 303 Emergency Telephone-CES.

303.5.4.5 Set 304 PBX Requirements Sounder Systems.

303.5.5 Structural and Geotechnical

303.5.5.1 Set 720 Building Structural.

303.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

303.7 ENGINEERING MANAGEMENT REQUIREMENTS

303.7.1 Interface and Integration Management (Not Used)

303.7.2 Design Management (Not Used)

303.7.3 Manufacturing and Construction Management (Not Used)

303.7.4 Installation Management

303.7.4.1 Installer Expertise

303.7.4.1.1 Installers must have the following certifications at minimum

303.7.4.1.1.1 FCC GROL.

303.7.4.1.1.2 Manufacturer installer certification. Certification from the manufacturers of the equipment (active and passive) the project will be installing.

303.7.4.1.1.3 Motorola R56.

303.7.4.1.1.4 BICSI Installer 1 and 2 (copper and fiber optic).

303.7.5 Inspection and Testing Management

303.7.5.1 Inspector Certifications

303.7.5.1.1 Inspectors must have at least the following certifications

303.7.5.1.2 FCC GROL.

303.7.5.1.2.1 Manufacturer installer certification. Certification from the manufacturers of the equipment (active and passive) the project will be installing.

303.7.5.1.2.2 BICSI RCDD.

303.7.5.1.2.3 BICSI OSPD.

303.7.6 Training, Pre-Revenue Operations (Not Used)

303.7.7 Certification Management (Not Used)

303.8 APPENDICES (NOT USED)

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304 AUDIO SYSTEMS

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SET - 304 AUDIO SYSTEMS

304.1 INTRODUCTION

304.1.1 Document Scope

304.1.1.1 This Requirements Set establishes PA audio system design requirements for Sound Transit Link light rail and applies to all passenger station types—at-grade, grade separated, and underground stations. This design criteria includes requirements for public address system components as well as Operations and its interfaces to other sub-systems, including fire alarm system, VES, EVS, BMS, and headend train control system, generally referred to as SCADA system.

304.1.1.2 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 304 owner to determine the technical source for the design criteria.

304.1.1.3 This Requirements Set establishes minimum design requirements for audio system operation, message initiation, priorities of message played over VES or PA speakers in various emergency events, status monitoring, and display of messages on VMS.

304.1.1.4 Refer to emergency response matrix for specific emergency messages to be played on PA speakers and displayed on VMS signs.

304.1.1.5 Refer to Set 601 Fire/Life Safety for specific requirements for PA used as EVACS.

304.1.2 Regulations, Codes, Standards, and Guidelines

304.1.2.1 Audio system design must conform to latest editions of following Regulations, Codes, Standards and Guidelines:

304.1.2.1.1 International Regulations, Codes, Standards, and Guidelines

304.1.2.1.1.1 International Fire Code (IFC)

304.1.2.1.2 Federal and National Regulations, Codes, Standards, and Guidelines

304.1.2.1.2.1 NFPA 70 (National Electrical Code, NEC).

304.1.2.1.2.2 NFPA 72 (National Fire Alarm and Signaling Code).

304.1.2.1.2.3 NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems, applicable only when audio system is used as EVACS system.

304.1.2.1.2.4 Underwriter’s Laboratories (UL).

304.1.2.2 State and Local Regulations, Codes, Standards, and Guidelines

304.1.2.2.1 Local regulations, as applicable.

304.1.2.3 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

304.1.2.4 Other Jurisdictions (Not Used)

304.1.2.5 Sound Transit Regulations, Codes, Standards, and Guidelines (Not Used)

304.1.3 Abbreviations and Acronyms

304.1.3.1 AHJ-Authority Having Jurisdiction

304.1.3.2 BMS–building management system

304.1.3.3 DSP–digital signal processing

304.1.3.4 EMP–emergency management panel

304.1.3.5 ERM–emergency response matrices

304.1.3.6 EVACS–emergency voice/alarm communications system

304.1.3.7 EVS–emergency ventilation system

304.1.3.8 FCC–fire command center

304.1.3.9 FCR–fire control room

304.1.3.10 LCC–Link control center

304.1.3.11 PA–public address

304.1.3.12 SCU–station control unit

304.1.3.13 VMS–variable message sign

304.1.3.14 TCN–train control network

304.1.3.15 VES–voice evacuation system

304.1.4 Definitions and Classifications

304.1.4.1 FACP: Monitors station fire/smoke detection equipment and initiates notification and emergency event sequences.

304.1.4.2 VES: A sub-component of the FACP and consists of strobes and speakers. Refer to Set 601 Fire/Life Safety for details.

304.1.4.3 EVS: A system that manages emergency mode responses at the stations and any adjacent tunnels in accordance with Sound Transit emergency response matrix. The EVS PLC interfaces with the SCADA system via the Sound Transit emergency fire/life safety network.

304.1.4.4 PA: The public address system is comprised of multiple components that manage and broadcast audio messages in public areas only and can serve as EVACS per the IFC and NFPA 72 requirements. Refer to Set 601 Fire/Life Safety for further details. Key interfacing elements of the public address systems for purposes of this document are as follows:

304.1.4.4.1 SCU: The station control unit stores and runs the software to control the station message signs (VMS) and to broadcast the audio messages that originate from the LCC/FCR and SCU. It also outputs alarms notification to logic box interface and BMS PLC.

304.1.4.4.2 DSP: The audio digital signal processor is used to process and prioritize audio from multiple input sources. DSP also synchronizes PA and VES when simultaneous messages are being played on VES and PA speakers.

304.1.4.4.3 Logic Box Interface: The logic box is a programmable control device used to provide custom control functionality of the integrated PA/VMS system. The logic box also provides alarms I/O to/from SCU, BMS, and VES.

304.1.4.5 VMS: The variable message signs display messages received as an input from the SCU via network connections.

304.1.4.6 BMS PLC: The building management system PLC reports PA system status to the LCC via connection to the TCN.

304.1.4.7 SCADA EVS System: The SCADA EVS system serves as the command and control center office system (central HMI) for the emergency ventilation system. The SCADA EVS is able to activate emergency modes at the stations and tunnels via direct input from the command and control center operator workstations.

304.1.4.8 Passenger Information Management System (PIMS): The PIMS system serves as the command and control center office system (central HMI) for the public address and customer information system. PIMS is used to create and manage PA and VMS messages for ad-hoc, emergency, and normal routine events. The PIMS system provides direct interface to the station public address speakers and variable message signs to provide regular station announcements as well as to display emergency messages on VMS signs during an emergency event.

304.1.4.9 EVACS: Refer to Set 601 Fire/Life Safety for emergency voice/alarm communication system.

304.1.4.10 Ad-Hoc Messages: Station, List of available pre-recorded messages to be played at a certain location(s), generated at LCC, FCR, or stations. These pre-recorded messages interrupt all messages currently being played.

304.1.4.11 Pre-Recorded Messages: Messages that are played at regular, user-defined intervals and generated at LCC or FACP. These have lower priority than live and ad-hoc messages.

304.1.4.12 Live Messages: Generated at LCC, FCC, FCR or station platforms microphones, these messages are the highest priority and suspend all current messages being played.

304.1.5 References

304.1.5.1 Emergency response matrices (ERM).

304.1.5.2 Directive drawings: EFS202, EFS204, JBS512.

304.1.5.3 VESS_PA_VMS_SGG whitepaper.

304.1.5.4 NFPA 130.

304.2 STAKEHOLDER NEEDS

304.2.1 Passenger Experience (Not Used)

304.2.2 Operational Needs

304.2.2.1 UPS backup: Refer to Set 1005 Electrical Power for UPS backup requirements when used as a stand-alone PA system. Refer to NFPA 130 and Set 601 Fire/Life Safety when PA is used as an EVACS system.

304.2.3 Maintenance Needs (Not Used)

304.2.4 Safety Needs (Not Used)

304.2.5 Security Needs (Not Used)

304.2.6 Reliability, Availability and Maintainability Needs (Not Used)

304.2.7 Environmental and Sustainability Needs (Not Used)

304.3 SYSTEM REQUIREMENTS

304.3.1 Functional Requirements

304.3.1.1 This designer must coordinate with Sound Transit and AHJ regarding usage of VES speakers versus PA speakers, or both, and interface between VES and PA system.

304.3.1.2 When the PA system is used as an EVACS, the system must be designed, tested, and commissioned to demonstrate compliance with the IFC and NFPA 72 requirements. Refer to requirements Set 601 Fire/Life Safety for additional requirements.

304.3.1.3 When the PA system is not used for emergency notification and the station is equipped with a ES that meets NFPA requirements for EVACS) as part of the fire alarm system, activation of the fire alarm system must send a signal to the PA system to immediately stop audio messages originating from the PA system and disable PA system microphones.

304.3.1.4 The PA audio system must work independently of VES and continue to deliver stored messages as well as live messages to public areas including platforms, concourses, elevator lobbies, and entries, plus the communications room and FCC/FCR.

Commentary: The designer must determine if the PA system, including the interface between the fire alarm system and the PA system, can be designed to meet the requirements of NFPA 72 to perform reliably as a system without being compromised by routine programming/modification of the PA system or other interface equipment including DSPs and SCUs. If a reliable interface meeting UL 864, or equal, with AHJ concurrence cannot be achieved, a VES must be provided as part of the fire alarm system as outlined in 304.3.1.3.

304.3.1.5 PA audio system must work independently of TCN connection availability. Upon failure to connect to TCN, audio system must continue to deliver SCU/FACP stored messages as well as live messages from station platform, communications room, FCC/FCR, or any other location with microphone installed.

304.3.1.5.1 Supplemental platform microphones for use by ST crowd management staff must be provided for each platform for stations serving major public event venues. Platform microphones are not required at other stations.

304.3.1.5.2 PA designer must perform acoustic analysis to determine PA speaker locations, ambient noise sensors, redundant speaker circuits, power amplification and network redundancy.
The contractor must measure average ambient sound pressure from the station platform for a 24-hour period on a weekday to use as a baseline for setting PA system sound pressures.

The contractor must measure average ambient sound pressure for enclosed rooms. A momentary measurement is acceptable for enclosed rooms with a consistent ambient noise.

The temporal tone must exceed the average ambient sound pressure by 15 dBA except for elevators where 10 dBA is acceptable (private mode allowance per NFPA 72), and restrooms when approved by the AHJ.

Audio files must be developed such that the temporal tone produces sound pressure that is 3 to 5 dBA above emergency messages and 5 to 7 dBA above the public messages. Sound pressure must be measured between speaker locations on the platform and at least every 30 feet.

Commentary: This criterion allows for public messages to be about 8 dBA above ambient, which ST has determined to be adequate for intelligibility but not so loud as to be disruptive to residential neighbors. The temporal tone for a station emergency must be louder to meet NFPA 72.

When the average ambient noise level on the platform exceeds 75 dBA, the record sound pressure of at least 80 dBA is acceptable regardless of the ambient sound pressure when approved by the AHJ.

Commentary: NFPA 72 has an allowance for high ambient areas when the system is equipped with visual alarms. Platforms are equipped with fire alarm strobe lights and visual message boards. Note, a sound pressure of 80 dBA would be measured between speakers and the lowest recorded point on the platform. Other areas, near speakers for example, are expected to be as high as 90 dBA.
Sound pressure for elevator cars must be measured with the elevator car door open and the sound pressure originating from the elevator lobby speaker(s).

304.3.1.5.3 Coordinate with structural, power, and communications designers for placement and connections to PA equipment.

304.3.1.5.4 PA must be provided in all public areas of all stations, access and emergency stairs, and restrooms. No PA coverage is required for parking garages.

304.3.1.5.5 PA speakers must have at least four wattage tap settings to allow volume to be adjusted as needed during commissioning.

304.3.1.5.6 PA audio files must be ".wav" format with emergency messages using the distinctive evacuation signal (temporal tone) as outlined in NFPA 72 with three pulses, repeated three times, followed by the emergency voice message. The emergency voice message must follow the temporal tone by one second. The temporal tone and evacuation message must repeat until manually interrupted at the fire alarm control panel. The temporal pattern must meet NFPA 72.

304.3.1.5.7 PA in stations must be divided into zones in all reasonable separable station areas. PA systems must be designed for a minimum of eight audio zones; coordinate with ST PSO about zone classification and quantity during the design. See zone examples below.

i. Side A of the center platform.
ii. Side B of the center platform.
iii. Concourse, plaza, and other public areas.
iv. Crew areas.
v. Elevator cars (when speakers are provided) for each elevator bank.
vi. Enclosed stairs (when speakers are provided) all may be combined into one zone).

304.3.1.5.8 Each zone must be designed to support operating and emergency evacuation plans and procedures. For each speaker zone, speaker groups A and B must be interleaved such that failure of any speaker, speaker wiring, amplifier, or amplifier signal feed, will affect not more than half of the speakers of that zone.

304.3.1.5.9 Each speaker zone must meet local noise ordinance requirements for sound levels. Final noise ordinance requirements and PA configuration must be documented and provided to ST for review, prior to 100% design completion.

304.3.1.5.10 PA speakers provided in elevator cars, enclosed stairs, and exit passageways must not produce public messages, atemporal tones, or emergency messages but function when those zones are selected at the fire alarm panel when the microphone is used.

304.3.1.5.11 PA must support operations and emergency evacuation plans and procedures. Refer to Set 601 Fire/Life Safety for specific requirements for additional requirements.

304.3.1.5.12 PA pre-recorded and ad-hoc messages must be deliverable from following locations:

i. LCC.
ii. Local PA/VMS workstation at FCC, EMP, or at communications room.

304.3.1.5.13 PA must dynamically self-adjust volume for non-emergency announcements to compensate for ambient noise.

Commentary: Designer must add to Specifications 27 51 13: Contractor must measure the ambient noise for each zone for at-least 24 hours.

304.3.1.5.14 PA must be designed for OSHA and NFPA 72 intelligibility and audibility requirements under all known conditions.

304.3.1.5.15 PA must be capable of automatically announcing train arrivals and other scheduled based messages. In areas without accurate signal information, this must be based upon available information.

304.3.1.5.16 Refer to Set 601 Fire/Life Safety for conductors/circuits supervision, wire/cable survivability, fire resistance, flame spread, smoke development and insulation temperature requirements.

304.3.1.5.17 The table below describes how messages or alarm outputs are being generated from various sources, under various scenarios, and input/output to/from various components of PA, VMS, EVS, and FACP systems. The table also describes the action related to a particular event, for example, when to turn the VES strobe on, or select a PA or VES speaker, or both.

Table 304-1: Audio Scenarios

	OPERATIONAL RESPONSE							
Message Source	**EVS PLC**	**FACP**	**BMS PLC**	**SCU**	**VES STROBE ACTIVE**	**VES SPEAKER ANNCMENT**	**PA SPEAKER ANNCMENT**	**VMS SIGN DISPLAY**
Recurring and ad-hoc messages. All Systems Normal – no alarm or trouble conditions	**N/A**	**N/A**	**N/A**	• SCU plays audio message on PA speakers, and visual message on VMS	**NO**	**NO**	**YES**	**YES**
VES Microphone (where required) – Live Audio by Emergency Responders	N/A	VES sends 'VES Priority' signal to SCU	N/A	• Normal mode announcements and messages from the SCU are suspended • PA DSP sends live VES audio to SCU, to be played on PA speakers	**NO**	**YES**	**YES**	**NO**
Platform or Comm. Room Microphone – Live Audio	**N/A**	**N/A**	**N/A**	• Normal mode announcements and messages from the SCU are suspended • SCU sends live PA audio to PA speakers	**NO**	**NO**	**YES**	**NO**
FCR PA Microphone via PA speakers	**N/A**	**N/A**	**N/A**	• Normal mode announcements and messages from the SCU are suspended • SCU sends live PA audio to PA speakers	**NO**	**NO**	**YES**	**NO**
Automatic Active Emergency Recorded Message – via VES Priority Input to Logic Box	• EVS PLC sends MODE X active alarm to both FACP and SCU	• VES audio output to VES speakers, and to SCU • FACP determines that an automatic alarm is active via direct device input to the FACP. (i.e., automatic water flow sensor) • FACP transmits mode to the EVS PLC via discrete dry contact signal.		• Normal mode announcements and messages from the SCU are suspended • SCU plays pre-recorded emergency audio • SCU displays message on VMS • VES audio must be synchronized to be played on VES and PA speakers simultaneously	**YES**	**YES**	**YES**	**YES**
Operator Initiated Event from LCC (EVS Operator Workstation)	• EVS PLC sends MODE X active alarm to both FACP and SCU	• VES audio output to VES speakers, and to SCU	**N/A**	• Normal mode announcements and messages from the SCU are suspended • SCU plays audio message on PA speakers, and visual message on VMS • VES audio must be synchronized to be played on VES and PA speakers simultaneously	**YES**	**YES**	**YES**	**YES**
LCC Live PA Message via LCC Microphone	• N/A	N/A	N/A	• SCU outputs live audio to Site PA System	**NO**	**NO**	**YES**	**NO**
FACP Field Device Event Initiated Supervisory or Trouble Indication	• Alarm input from FACP		• Alarm input from FACP		**NO**	**NO**	**NO**	**NO**

	OPERATIONAL RESPONSE							
SILENCE at FACP	• EVS PLC outputs Emergency SILENCE message to SCU	• FACP outputs Emergency SILENCE Cancel to EVS PLC	N/A	• SCU suppresses all PA audio to PA speakers. VMS display continues	**YES**	**NO**	**NO**	**YES**
Station PA Trouble	• EVS receives trouble alarm from PA Logic Box	• VES delivers audio to BOH VES speakers, if available	• PA component failure (DSP, SCU, Amplifier, Speaker) is reported to BMS/Communications PLC	• SCU continues to deliver audio and visual messages • PA audio will/may not be played due to PA trouble	**YES**	**YES**	**NO**	**YES**

304.3.1.5.18 The table below describes the priority of live message from microphones at various locations, use of VES strobe, and selection of PA or VES speaker, or both.

Table 304-2: Microphone Priority

Priority	Message Source	VES STROBE ACTIVE	VES SPEAKER ANNOUNCEMENT	PA SPEAKER ANNOUNCEMENT
1	VES Microphone– Live Audio by Emergency Responders	**NO**	**YES**	**YES**
2	Platform or Comm. Room OR FCC/FCR SCU connected Microphone – Live Audio	**NO**	**NO**	**YES**
3	LCC Live PA Audio via LCC Microphone	**NO**	**NO**	**YES**

304.3.2 Microphone Priorities

304.3.2.1 Emergency mode always takes precedence over live, ad-hoc, and normal mode messages

304.3.2.2 Live announcement, whether via VES microphone or PA microphone, takes precedence over ad-hoc and normal mode messages

304.3.2.3 Ad-hoc messages take precedence over normal messages.

304.3.2.4 VES microphone audio is via the VES speakers only.

304.3.2.5 PA microphone audio (from platform, communications room and FCC/FCR) is via the PA speakers only.

304.3.2.6 Cancel/Silence Mode: The below sub-sections describe the sequence to cancel emergency mode messages to be played on PA/VES speakers and strobes and concurrent message display on VMS signs. There are two options available to cancel audio playing, and silence VES speakers and strobes.

304.3.2.6.1 From FACP: Pressing this button creates the following results.

304.3.2.6.1.1 Cancels the emergency mode messages.

304.3.2.6.1.2 Silences VES speakers and strobes.

304.3.2.6.1.3 Sends message to EVS PLC to be relayed to SCU.

304.3.2.6.1.4 SCU in turn cancels all current emergency mode messages, suppresses PA audio, and display on VMS signs.

304.3.2.6.1.5 Fire alarm notification devices (VES speakers, strobes) and PA speakers and VMS display signs return to normal operation.

304.3.2.6.2 From LCC EVS workstation:

304.3.2.6.2.1 Cancels the emergency mode messages.

304.3.2.6.2.2 Silences VES speakers and strobes.

304.3.2.6.2.3 Sends message to EVS PLC to be relayed to SCU.

304.3.2.6.2.4 SCU in turn cancels all current emergency mode messages, suppresses PA audio, and display on VMS signs.

304.3.2.6.2.5 Fire alarm notification devices (VES speakers, strobes) and PA speakers and VMS display signs return to normal operation.

304.3.3 Sub-System Interfaces

304.3.3.1 Identify wiring demarcation between SCU, PA logic box, FACP, and EVS PLC in their respective connection diagrams. Coordination with other discipline designers of various elements is required. An interface control document must be developed since two or more sub-systems are involved, designed by different engineer(s). Include required intermediate devices such as interposing relays, power supplies, or interface control cabinet.

304.3.3.2 For interface details between passenger information management system and audio system, refer to Set 1102 Passenger Information Management System.

304.3.3.3 PA SCU to PA DSP.

Table 304-3: PA SCU Interfaces to the PA DSP

PA SCU Connection Description	PA DSP Connection Description	Station
IP Audio Out	IP Audio In	All Stations

304.3.3.3.1 PA SCU to PA logic box: Refer to directive drawing EFS204 for related I/O points

304.3.3.4 PA logic box to VES: Refer to directive drawing EFS204 for related I/O points

304.3.3.4.1 VES system is responsible for prioritizing and synchronization of VES messages to PA system. Audio output from VES to PA system enables PA system to supplement VES.

304.3.3.5 PA Audio DSP to VES: Refer to directive drawing EFS204 for related I/O points.

304.3.3.5.1 Audio output from VES to PA DSP enables station PA to play audio messages simultaneously to VES speakers. Both VES and PA speakers play the same message.

304.3.3.5.2 Audio input to VES is used to broadcast SCU emergency and ad-hoc messages in areas that do not have PA speakers, generally in the back of house areas.

304.3.3.5.3 PA SCU/logic box to BMS PLC: BMS is to monitor fault alarms from SCU and logic box. Refer to directive drawing EFS204 for related I/O points.

304.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

304.4.1 System Breakdown Structure

304.4.2 System Sites and Locations

304.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 304-4: Interface Between Audio Systems and Other Disciplines

SET SERIES	SET NAMES	SET 304 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	
300	Operational Communications	X
400	Vehicle	
500	Track	
600	Fire-Life Safety	X
700	Structures	
800	Architecture	X
900	Civil	
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	X
1200	Security	

304.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

304.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

304.7.1 Interface and Integration Management

304.7.2 Design Management

304.7.3 Manufacturing and Construction Management

304.7.4 Installation Management

304.7.5 Inspection and Testing Management

304.7.6 Training, Pre-Revenue Operations

304.7.7 Certification Management

304.8 APPENDICES (NOT USED)

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324.1 INTRODUCTION

324.1.1 Document Scope

324.1.1.1 This section includes general description of existing CCS which is the office end of the EVS, TCS, TPSS, and the BMS. The section also briefly states the requirements for expansion of the system for future light rail extensions.

324.1.1.2 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Sound Transit Design Requirements Set 324 owner to determine the technical source for the design criteria.

324.1.2 Regulations, Codes, Standards, and Guidelines

324.1.2.1 International Regulations, Codes, Standards, and Guidelines (Not Used)

324.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines (Not Used)

324.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines (Not Used)

324.1.2.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

324.1.2.5 Other Jurisdictions (Not Used)

324.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines (Not Used)

324.1.3 Abbreviations and Acronyms

324.1.3.1 AIM–advanced information management

324.1.3.2 BHT–Beacon Hill tunnel

324.1.3.3 BMS–building management system

324.1.3.4 CCS–central control system

324.1.3.5 CDRL –contract data requirements list

324.1.3.6 CSV–comma separated values

324.1.3.7 DSTT –Downtown Seattle Transit Tunnel

324.1.3.8 EFN - Emergency fan/fire life network

324.1.3.9 ELEV –elevator

324.1.3.10 EMP–emergency management panel

324.1.3.11 ERM –emergency response matrix

324.1.3.12 ERS –emergency response scenario

324.1.3.13 ESC –escalator

324.1.3.14 ETEL–emergency telephone

324.1.3.15 EVS –emergency ventilation system

324.1.3.16 FACP –fire alarm control panel

324.1.3.17 FBMS – Facility building management system

324.1.3.18 FCC–fire command center

324.1.3.19 FCS –field control system

324.1.3.20 FEP –front-end processor

324.1.3.21 FMS –facility management system

324.1.3.22 GUI –graphical user interface

324.1.3.23 HOA –hand-off auto

324.1.3.24 ID –Identification (train ID)

324.1.3.25 I/O –input/output

324.1.3.26 IP –internet protocol

324.1.3.27 LAN –local area network

324.1.3.28 LCC –Link control center

324.1.3.29 LR –light rail

324.1.3.30 LRV –light rail vehicle

324.1.3.31 MDS –monitoring and detection system

324.1.3.32 MEP – Mechanical, Electrical and Plumbing

324.1.3.33 NEF –non-emergency fans

324.1.3.34 NRB –non-reporting block

324.1.3.35 NVR –network video recorder

324.1.3.36 OCC –operations control center

324.1.3.37 OCS –overhead catenact system

324.1.3.38 OMFE –operations and maintenance facility East

324.1.3.39 OMFC – operations and maintenance facility Central

324.1.3.40 PET –passenger emergency telephone

324.1.3.41 PLC –programmable logic controller

324.1.3.42 QC –quality code

324.1.3.43 RUG –roll-up grill

324.1.3.44 SCADA –supervisory control and data acquisition

324.1.3.45 SIDT–system interface data table

324.1.3.46 TCN – Train control network

324.1.3.47 TCS –train control system

324.1.3.48 TBD –to be determined

324.1.3.49 TPSS –traction power subsystem

324.1.3.50 TWC –train wayside communication

324.1.3.51 VHLC –vital logic controller

324.1.3.52 VIPI –mode in progress indication

324.1.4 Definitions and Classifications (Not Used)

324.1.5 References (Not Used)

324.2 STAKEHOLDER NEEDS (NOT USED)

324.2.1 Passenger Experience

324.2.2 Operational Needs

324.2.3 Maintenance Needs

324.2.4 Safety Needs

324.2.5 Security Needs

324.2.6 Reliability, Availability and Maintainability Needs

324.2.7 Environmental and Sustainability Needs

324.3 SYSTEM REQUIREMENTS

324.3.1 CCS Overview

Commentary: Refer to guidance drawing JBS400 for additional details.

The current CCS is based on Wabtec (previously Rockwell Collins) AIM system and consists of three separate SCADA systems as below:

i. The TCS handles functions such as track switches, signals, train routing, traction power, track intrusion, wayside systems, and train location.

ii. The EVS manages the tunnel ventilation, fire alarm, and fire suppression systems. The EVS also controls the defined tunnel emergency scenarios during a fire to determine how to use the connected tunnel devices to properly evacuate passengers and suppress the fire. An ERM defines EVS ventilation modes for DSTT and the University Link tunnel.

iii. The BMS monitors and/or controls station/building systems such as HVAC equipment, station electrical, access control entry, intrusion detection, lighting, fire systems, communications equipment, radio, and UPS. The BMS also includes communications equipment, monitoring of flood detectors, and pumps.

a. There are two types of BMS. One is for Link stations and the other is for maintenance buildings and garages known as facility building management system.

b. The Link station "local" BMS is for newer stations (since U-Link) which is based on a GE cimplicity system). This system shares associated PLCs to feed the Wabtec BMS SCADA system.

c. The facility building management system (FBMS) does not feed the Wabtec BMS SCADA but is its own standalone system. See Set 1004 Building Monitor and Control for more information about BMS systems.

Main interface from field systems to the associated SCADA system headend (TCS, BMS, EVS) is the SIDT. See systems directive drawings JBS401 for standard SIDT format and application notes. Also see directive drawings JBS503 thru JBS512, JRS100, JCS701, and JTS305 for standard points lists for typical systems that come from field system to the SCADA headend. Note that I/O headend destination can change depending on the maintaining group or operating procedure. For example, wayside systems typically go to TCS headend while similar systems within stations go to BMS. Consult with Sound Transit PSO and OT for clarification of SCADA headend destination of I/O points.

324.3.1.1 Any expansion of the current CCS system must preserve the division and scope of systems for EVS, BMS, and TCS.

324.3.1.2 Any change from currently accepted SCADA operating procedures is not allowed unless agreed to and approved by ST Portfolio Services Office, Operations Engineering Technology, and LINK Operations or if stated in ST provided project requirements.

324.3.2 Central Control System Servers

324.3.2.1 Any expansion of the current CCS system must preserve the existing server applications and operational features of the system servers.

324.3.2.2 All individual server applications must have a primary and backup server to allow for automatic failover operation, diversity in network pathways, and geographical diversity in network and processing.

324.3.2.3 Expansion of the system must require expansion of resources, redundancy, and/or failover operations to meet the intent of the current system. Coordination must be done with Sound Transit vendor and Sound Transit Operations to ensure current system redundancy and failover operation is met with the newly expanded system.

Commentary: The Sound Transit CCS system uses various servers for TCS, EVS, and BMS as listed below; see Figure 324-1 for graphical representation:

- *i. Web server*
- *ii. FEP server*
- *iii. Application server*
- *iv. Historian server*
- *v. Simulation server*

Two application servers that host the AIM application (primary and backup): Each AIM application server is connected to local area networks (LAN) A and B. The AIM application servers operate in a primary and backup configuration. If the primary fails, the backup automatically continues the processing as the new primary. This process is called failover.

Two communication servers, which host the FEP (primary and backup): Each FEP is responsible for interpreting or calculating data to and from the field and AIM application servers. The FEP servers operate in a primary and backup configuration. Should the primary FEP fail, the backup FEP automatically continues the processing as the new primary FEP. This process is called FEP failover.

Two database servers that host the MS SQL server database (primary and backup); these servers store the database files.

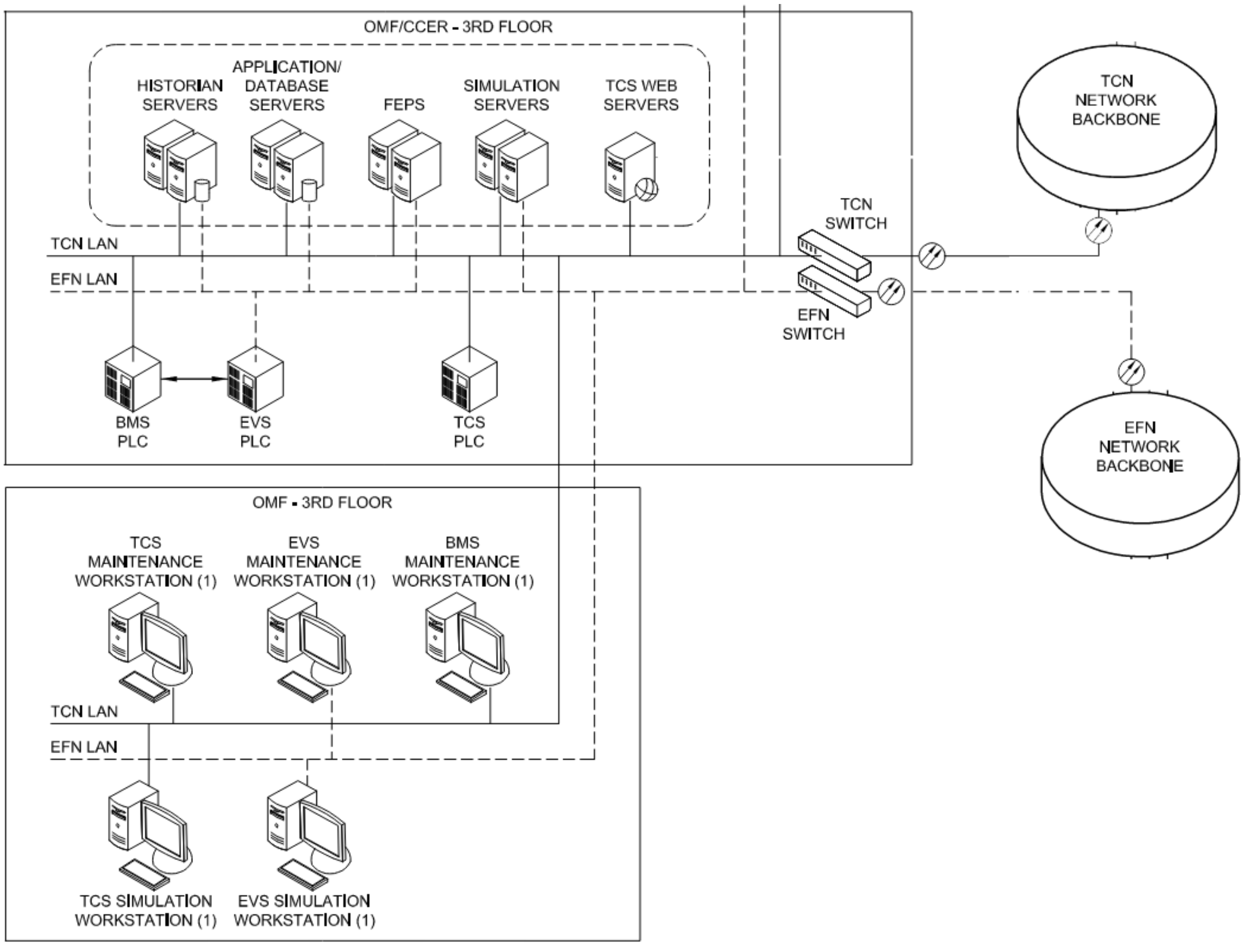
One historian database server that stores all historical alarms, events, and user actions.

In addition to the redundant (application, communications, and database) servers each, there are also a set of cold backup SCADA servers located in the backup datacenter at OMFE. If primary and backup systems fail, SCADA can failover to the backup datacenter servers if servers at OMFC are offline.

One virtualized simulation server that communicates with simulation workstations using the same network as the operational servers but using a different server group so as not to impact the real-time operations.

In the normal course of operations, the servers aggregate and record field data and send updates to the workstations. The servers also receive and process control requests from the workstations.

Figure 324-1: TCS Server Overview



324.3.3 Rail Controller Workstations

324.3.3.1 For new projects, the designer must perform human factors engineering study, and coordinate with Sound Transit Operations to determine Control Center Consoles needs, usability and layout. Provide Rail Controller workstations similar to those shown in Figure 324-2 at the OMF, at the LCC, and at backup LCC.

324.3.3.2 Provide rail controller workstations and consoles similar to those shown in Figure 324-3 at all underground station FCC rooms for local TCS, BMS, and EVS emergency response by Sound Transit Operations and/or emergency personnel.

Figure 324-2: OMF/OCC Workstation Overview

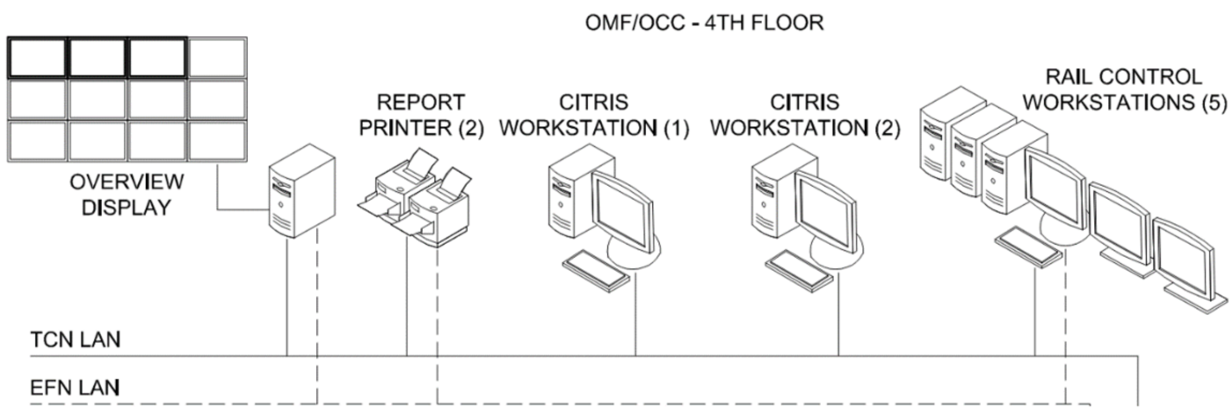
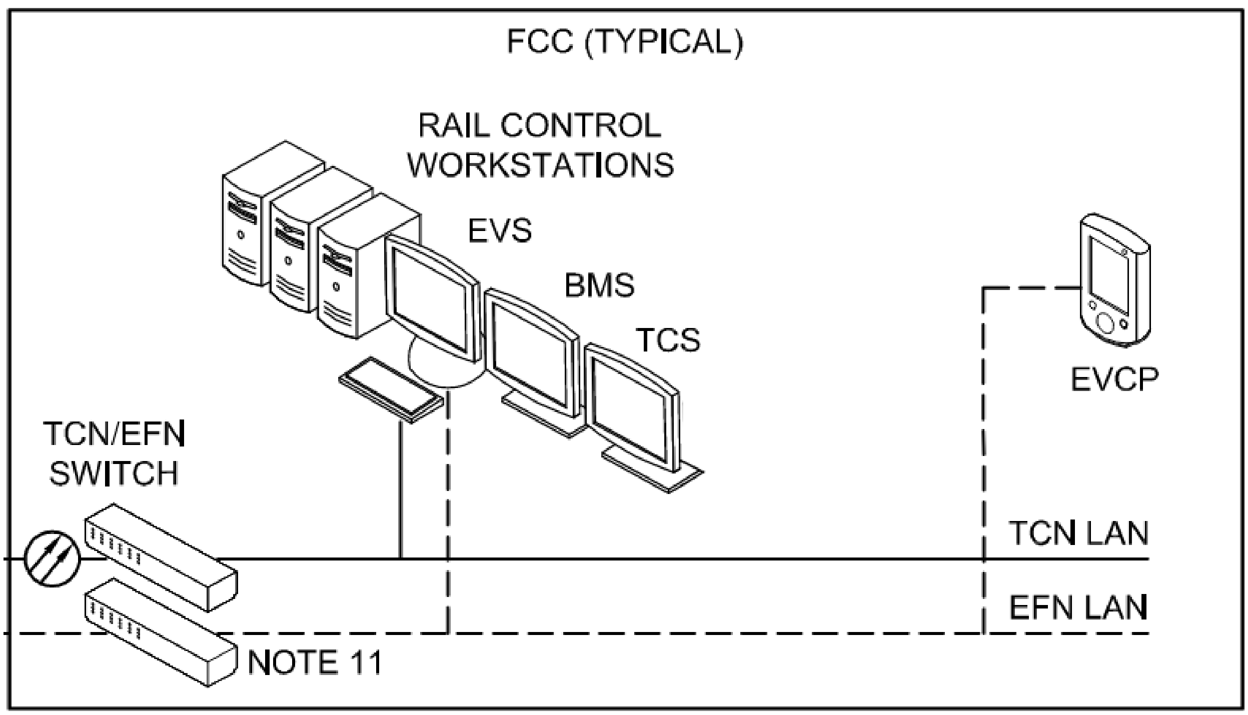


Figure 324-3: FCC Workstation Overview



324.3.3.3 Each rail controller console must have three workstations, dedicated for each system as below:

- **i.** One for TCS
- **ii.** One for EVS
- **iii.** One for BMS

324.3.3.4 All TCS, EVS, and BMS workstations must display the same TCS, EVS, and BMS main menus, respectively, as existing.

324.3.4 Maintenance Workstations
Provide maintenance workstations, one for each system below at OMF for monitoring the system components.

i. TCS
ii. EVS
iii. BMS

324.3.5 Simulation Workstations

324.3.5.1 Provide one virtualized simulation server with two simulation workstations:
i. One for TCS
ii. One for EVS

324.3.6 EMP Workstations

324.3.6.1 For future light rail extensions beyond Lynnwood, Federal Way, and Downtown Redmond, there will be no new EMPs. Only provide updates to graphics to existing EMPs as system expands. The functionality requirement for new stations regarding EMPs is met by the installing Rail Controller Workstations at tunnel station FCC rooms as required above.

Commentary:

EMP workstations are installed inside the drop-down panels or small closets at the following locations:
i. Westlake
ii. University Street
iii. Pioneer Square
iv. International District

For each EMP location listed above, there is one workstation installed for each system: TCS, EVS, and BMS.

The EVS EMP has full EVS workstation functionality. The EMP workstation territorial partition allows controlling the DSTT territory.

The EMP user interface is similar to the regular user interface available at LCC for each system, but with touchscreen displays and no mouse or keyboard.

324.3.7 Overview Display Workstations

Commentary: Overview Display Workstations are located at the primary LCC, backup LCC, and select maintenance locations. The overview display workstations run the AIM applications for TCS and EVS overviews and allows viewing of CCTV cameras for the entire system. Authorized users log on this workstation with a view-only login credentials. From the TCS train control menu, users call up the TCS track overview graphic display. This display is projected on the video wall in view-only mode and shows the entire Link alignment track territory. Similarly, for EVS operators can view the EVS overview graphic display for emergency mode operation alignment wide. Lastly, the overview display is also required to provide CCTV feeds for the whole alignment for operations, emergency, and security purposes.

324.3.7.1 A study must be performed by the designer in coordination with Sound Transit to layout new light rail alignments on overview display and determine need for expansion.

324.3.8 CCS User Interface Menus
Below sections define minimum requirements for TCS, BMS, and EVS user menus.

324.3.9 TCS Menu

324.3.9.1 TCS windows must display information in the form of graphical symbols which represent the data received from the TCS field interfaces, signal system, TWC, and traction power interfaces.

324.3.9.2 Users must access TCS displays from the Train Control and TPSS menus and they appear on the dedicated TCS monitor.

324.3.9.3 The TCS displays must serve as a base to initiate TCS specific functionality, such as controlling and supervising statuses of switches and signals.

324.3.10 BMS Menu

324.3.10.1 BMS displays must show information in the form of graphical symbols using data received from the BMS PLCs.

324.3.10.2 Users must open BMS displays from the building management main menu, and they appear on the dedicated BMS monitor.

324.3.10.3 The BMS displays must serve as a base to initiate BMS specific functionality, such as controlling and supervising statuses of doors, lighting, etc.

324.3.11 EVS Menu

324.3.11.1 EVS displays must provide information in the form of graphical symbols using data received from the EVS PLCs.

324.3.11.2 EVS displays must be called from the emergency ventilation main menu and appear on the dedicated EVS monitor.

324.3.11.3 The EVS displays must serve as a base to initiate EVS specific functionality including controlling fans, managing, and reviewing fire and smoke alarms, and initiating ventilation scenarios.

324.3.12 Requirements For Expansion of Central Control System for Future Extensions

324.3.12.1 Every future light rail extension must extend the current functionality of CCS for each TCS, BMS, and EVS systems. Although no new EMP is required for future light rail extensions, any change in CCS system or EMP workstations software must ensure the current functional of EMP continues to function.

324.3.12.2 Each of the three CCS components, EVS, BMS and TCS must be expanded with an HMI dedicated to the monitoring and control of that subsystem.

324.3.12.3 Integration of the CCS is required for the following sub-systems:

i. Link central telephone system (PETs/ETELs, Emcom Emvista software as of 2023)
ii. PIMS (Wabtec as of 2023)
iii. Fire alarm control panel (Fireworks as of 2023)
iv. Overview display (Cinemassive Software as of 2023).
v. Track intrusion detection system
vi. Radio system
vii. Building management systems (MEP)
viii. Noise, Vibration and EMI interference
ix. Bridge Monitoring System
x. Any other system as required by project requirements (PRs)

324.3.12.4 Refer to following specifications to provide an integrated SCADA solution for all interfacing systems.

324.3.12.4.1 Section 25 00 00 Integrated Automation which gives general requirements for the office and field requirements for the EVS, TCS, BMS, and Communications.

324.3.12.4.2 Section 25 10 20 Field Control Systems further defines the general requirements for the field equipment for the EVS, TCS, BMS, and Communications.

324.3.12.4.3 Section 25 20 10 Emergency Ventilation System specifically defines the office requirements for the EVS.

324.3.12.4.4 Section 25 20 20 Train Control System specifically defines the office requirements for the TCS.

324.3.12.4.5 Section 25 20 30 Building Management System specifically defines the office requirements for the BMS.

324.3.12.4.6 Section 27 75 00 Operations Control Center Requirements further defines the control center theater requirements.

324.3.12.4.7 TCS field systems are defined in Set 123 Train Control. Network requirements for TCS communication of field systems and SCADA communication are found in Sets 301 Network Infrastructure and 123 Train Control.

324.3.12.4.8 BMS field systems are defined in Set 1004 Building Monitoring and Control. Network requirements for BMS communication of field systems and SCADA communication are found in Sets 301 Network Infrastructure and 1004 Building Monitoring and Control.

324.3.12.5 EVS field systems are defined in Sets 1004 Building Monitoring and Control and 601 Fire/Life Safety. Network requirements for EVS communication of field systems and SCADA communication are found in Sets 301 Network Infrastructure, 601 Fire/Life Safety and 1004 Building Monitoring and Control.

324.3.12.6 PIMS system integration requirements into SCADA TCS, EVS, and BMS is found in Set 1102 Passenger Information Management System.

324.3.12.7 System Architecture (High-Level Design) Requirements

324.3.13 System Breakdown Structure (Not Used)

324.3.14 System Sites and Locations (Not Used)

324.4 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 324-1: Interface Between TCS-LRT and Other Disciplines

SET SERIES	SET NAME	SET 324 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	X
400	Vehicle	
500	Track	
600	Fire/Life Safety	X
700	Structures	
800	Architecture	
900	Civil	
1000	Mechanical/Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

324.5 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

324.6 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

324.6.1 Requirements Management

324.6.2 Interface and Integration Management

324.6.3 Design Management

324.6.4 Manufacturing and Construction Management

324.6.5 Installation Management

324.6.6 Inspection and Testing Management

324.6.7 Training, Pre-Revenue Operations

324.6.8 Certification Management

324.7 APPENDICES (NOT USED)

END SET - 324

520 VEHICLE CLEARANCES AND TRACK SPACING

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SET - 520 TABLE OF CONTENTS

TABLES

FIGURES

EQUATIONS

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SET - 520 VEHICLE CLEARANCES AND TRACK SPACING

520.1 INTRODUCTION

520.1.1 Document Scope

520.1.1.1 This set establishes the minimum requirements for horizontal and vertical clearance and track spacing.

520.1.1.2 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 520 owner to determine the technical source for the design criteria.

520.1.2 Regulations, Codes, Standards, and Guidelines (Not Used)

520.1.2.1 International Regulations, Codes, Standards, and Guidelines

520.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

520.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

520.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

520.1.2.5 Other Jurisdictions

520.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

520.1.3 Abbreviations and Acronyms

520.1.3.1 AREMA –American Railway Engineering and Maintenance-of-Way Association

520.1.3.2 AMTRAK –American Track (National Railroad Passenger Corporation)

520.1.3.3 AASHTO–American Association of State Highway and Transportation Officials

520.1.3.4 AHJ –authority having jurisdiction

520.1.3.5 CE –clearance envelope

520.1.3.6 CT–construction tolerances

520.1.3.7 CW –chorded wall construction factor

520.1.3.8 CS –point of change from circular curve to spiral

520.1.3.9 DOR–designer of record

520.1.3.10 LLR –Link light rail

520.1.3.11 LRV–light rail vehicle

520.1.3.12 MT –maintenance tolerances

520.1.3.13 NFPA–National Fire Protection Agency

520.1.3.14 OCS–overhead contact system

520.1.3.15 OMF–operations and maintenance facility

520.1.3.16 OWF–other wayside factors

520.1.3.17 PC –point of change from tangent to circular curve

520.1.3.18 PT –point of change from circular curve to tangent

520.1.3.19 RC –running clearances

520.1.3.20 ST –point of change from spiral to tangent

520.1.3.21 SC–point of change from spiral to circular curve

520.1.3.22 TOR–top of rail

520.1.3.23 TPSS–traction power substation

520.1.3.24 TS –point of change from tangent to spiral curve

520.1.3.25 VDE –vehicle dynamic envelope

520.1.3.26 WSDOT –Washington State Department of Transportation

520.1.4 Definitions and Classifications

520.1.4.1 Rail Gauge Side: The gauge side is the rail head side facing the track center.

520.1.4.2 Rail Field Side: The field side is the rail head side facing outside of the track.

520.1.4.3 Rail Gauge: See Set 001.

520.1.4.4 Pantograph: See Set 001.

520.1.5 References (Not Used)

520.2 STAKEHOLDER NEEDS (NOT USED)

520.2.1 Passenger Experience

520.2.2 Operational Needs

520.2.3 Maintenance Needs

520.2.4 Safety Needs

520.2.5 Security Needs

520.2.6 Reliability, Availability and Maintainability Needs

520.2.7 Environmental and Sustainability Needs

520.3 SYSTEM REQUIREMENTS (NOT USED)

520.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

520.4.1 System Breakdown Structure

520.4.1.1 Track Clearances Calculations

520.4.1.2 Clearance Envelope Calculation

520.4.1.2.1 Clearance Envelope Equation

520.4.1.2.2 Clearance Envelope Transition

520.4.1.2.3 Vehicle Dynamic Envelope

520.4.1.2.4 Other Wayside Factors

520.4.1.2.5 Running Clearances

520.4.1.2.6 Clearance Envelope Special Conditions and Exceptions

520.4.1.3 Track Vertical Clearances

520.4.1.3.1 Overhead Clearances

520.4.1.3.2 Vertical under Clearance to Elevated Guideway

520.4.1.3.3 Overhead Utilities Clearances

520.4.1.4 Track Spacing

520.4.1.4.1 Track Spacing Calculations

520.4.1.4.2 Mainline Track Spacing

520.4.1.4.3 Yard Track Spacing

520.4.1.4.4 Track Inspection and Maintenance Clear Space

520.4.1.4.5 Minimum LINK Track Spacing When Paralleling Other Tracks

520.4.2 System Sites and Locations

520.4.2.1 Mainline Track

520.4.2.2 Non-mainline Track

520.4.2.2.1 Yard Track

520.4.2.2.2 Shop Track

520.4.2.2.3 Secondary Track

520.4.2.3 Special Trackwork

520.4.2.4 Track Type

520.4.2.4.1 Ballasted Track

520.4.2.4.2 Direct Fixation Track

520.4.2.4.3 Embedded Track

520.4.2.5 Track Structures

520.4.2.5.1 Elevated Guideway

520.4.2.5.2 Tunnel

520.5 SYSTEM INTERFACE REQUIREMENTS

Table 520-1 lists requirement sets that are typically coordinated and may have dependencies with this set.

The description of the interfaces below are provided to highlight only the major interface elements between Track and the other discipline sets. The list is not intended to capture all interface elements. The DOR must review and coordinate all interface requirements between Set 500 Track and the other disciplines at each phase of the design and construction.

Table 520-1: Interface between Track and Other Disciplines

SET SERIES	SET NAMES	SET 520 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	X
500	Track	X
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	
1100	Technology	
1200	Security	

520.5.1 Train Control and Signals

520.5.1.1 The signals designer must verify and coordinate track clearances with the signal design and wayside equipment using the Clearance Envelope during each phase of their design.

520.5.2 Traction Electrification

520.5.2.1 Coordinate that the overhead clearance calculation provides enough vertical room for the installed OCS and other designated structural components.

520.5.2.2 Coordinate the design of the OCS to ensure the pole locations are clear of the Clearance Envelope.

520.5.3 Vehicles

520.5.3.1 Coordinate any current and future Sound Transit light rail vehicles will conform to the Vehicle Dynamic Envelope as defined by the figures and tables in this set.

520.5.4 Track

520.5.4.1 Coordinate track clearances at maintenance-of-way access points and to maintenance-of-way vehicles.

520.5.4.2 Coordinate track clearances with the maintenance walkway location.

520.5.5 Fire-Life Safety

520.5.5.1 Coordinate track clearances to emergency walkways with the National Fire Protection Agency (NFPA) 130 standard.

520.5.6 Structures

520.5.6.1 Coordinate all structures are clear of the Clearance Envelope.

520.5.6.2 Coordinate any vertical clearances from top of rail to overhead bridge structures.

520.5.7 Architecture

520.5.7.1 Coordinate track clearances to any station platform appurtenances, including the outswing of any doors or gates on the station footprint.

520.5.7.2 Coordinate track clearances to OMF's mezzanine and OMF maintenance pit platforms.

520.5.8 Civil

520.5.8.1 Coordinate any vertical under clearances to the elevated guideway with the civil design, as well as other applicable codes and jurisdictions.

520.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

520.6.1 Track Clearances Calculations

520.6.1.1 This section establishes the clearances for LRVs and maintenance vehicles to operate along the tracks safely.

520.6.1.2 The DOR must prepare a track clearance and spacing calculation for each unique condition of the track at the following locations:

520.6.1.2.1 Different types of tangent track.

520.6.1.2.2 Different track curve radii.

520.6.1.2.3 Each turnout lead curve radius.

520.6.1.2.4 Different edge conditions where the Other Wayside Factors change.

520.6.1.2.5 Vertical clearance to overhead structure at each location.

520.6.1.2.6 Specific clearance calculation where objects are located within the clearance envelope transition and not meeting both the adjacent tangent and full curve calculation.

520.6.1.2.7 Track spacing.

520.6.1.3 All objects must be installed outside of the Clearance Envelope.

520.6.1.3.1 For specific clearance exceptions, see “Clearance Envelope Special Conditions and Exceptions” in this set.

520.6.1.4 Track clearance calculations must show objects within 3 feet of the Clearance Envelope.

520.6.1.5 Clearance Check Line

Commentary: The clearance check line is used to verify on the plan set that adjacent objects to the tracks, including any civil and system elements, are clear of the operating LRVs.

520.6.1.5.1 Define a line that delineates the left and right maximum X values in the track plan from the Clearance Envelope calculation.

520.6.1.5.2 Any object within the limits of the clearance check lines must be shown on the specific location Clearance Envelope calculation.

520.6.2 CE Calculation

Commentary: The CE defines the required space for the safe passage of trains and maintenance vehicles free of obstructions. The CE is composed of the Vehicle Dynamic Envelope plus the effects of Other Wayside Factors including construction and maintenance tolerances for track and various facilities, plus Running Clearances. Included in the CE calculation is a provision for maintenance-of-way vehicle tire loads, which exist on the field side of the rail.

520.6.2.1 Equation 520-1 must be used for the calculation of the CE.

Equation 520-1: Calculation of CE

CE = VDE + OWF + RC

Where:

CE = Clearance Envelope

VDE = Vehicle Dynamic Envelope

OWF = Other Wayside Factors

RC = Running Clearances

520.6.2.1.1 The points defining the Clearance Envelope must be referenced from the centerline of track at the top of low rail.

520.6.2.1.2 Figure 520-1 “Light Rail Clearance Envelope Calculation Sheet” defines how each track clearance calculation is drawn.

520.6.2.1.3 All Clearance Envelope calculation sheets must be labeled with the date, project name, curve number, all VDE parameters, OWF, and RC values.

520.6.2.1.4 All structures installed above the top of rail must be set either at, or beyond, the offsets shown in Figure 520-2 “Light Rail Clearance Diagram.”

520.6.2.2 Clearance Envelope Transition

Commentary: As the vehicle traverses between the tangent, spiral and curve portions of a curve set the vehicle clearance envelope also transitions. The following requirements define how to determine the transition and how to calculate points within a spiral curve or simple curve.

520.6.2.2.1 Spiral Curve Transition

520.6.2.2.1.1 Clearance Envelope calculations within the transition zone through a spiral curve must be calculated linearly between the adjacent Clearance Envelope calculations as defined by Figure 520-5 “Clearance Envelope Spiral Curve Limits.”

520.6.2.2.2 Simple Curve Transition

520.6.2.2.2.1 Clearance Envelope calculations within the transition zone through a simple curve must be calculated linearly between the adjacent Clearance Envelope calculations as defined by Figure 520-6 “Clearance Envelope Spiral Curve Limits.”

520.6.2.3 Vehicle Dynamic Envelope

Commentary: The VDE is a part of the Clearance Envelope and is the clearance required for the train and its vehicle’s overhang due to combinations of loading, lateral motion, or suspension failure.

Commentary: The VDE Tables 520-5 to 520-32 are based on a theoretical design vehicle shown in Figure 520-7 “Vehicle Static Outline” and Figure 520-8 “Vehicle Dynamic Envelope.” All Sound Transit current and future LRVs will conform to the Vehicle Dynamic Envelope defined by these figures and tables.

Commentary: The VDE tables define dynamic half width of the vehicle towards the center of curve and the dynamic half width of the vehicle away from center of curve. The half width of the vehicle that is toward the center of curve is defined by the tables listed with “Inside of Curve.” The half width of vehicle that is away from center of curve is defined by the tables listed with “Outside of Curve.”

Commentary: The x and y values from the VDE tables are based upon centerline of track and top of low rail.

520.6.2.3.1 All VDE and pantograph points’ dimensional values must be presented in tabulated format with the track type, curve radius, and superelevation.

520.6.2.3.2 Tables 520-5 through 520-32 must be used for the calculated VDE points for the track conditions in terms of cross level variation, superelevation, and curve radius as follows:

520.6.2.3.2.1 Select a cross level variation value based upon track type. Use 0.5 inches for direct fixation and embedded track, and 1.0 inch for ballast track.

520.6.2.3.2.2 Select the inside of curve and outside of curve table to use.

520.6.2.3.2.3 For superelevation and intermediate curve radii values not listed in the VDE tables, straight line interpolation between adjacent values must be used.

520.6.2.3.3 Draw the VDE using the calculated points from the VDE tables as shown in Figure 520-1. All points must be labeled with the point ID and their X, Y values.

520.6.2.3.3.1 Draw the VDE by connecting the points of WL1IN, WL4IN, WL5IN, WL6IN, WL6OUT, WL5OUT, WL4OUT, and WL1OUT in sequence.

520.6.2.3.3.2 Points WL1IN and WL1OUT must extend vertically down (plumb) to the top of rail plane.

520.6.2.3.3.3 The top of rail plane VDE must account for the maintenance-of-way vehicle tires by drawing a line 0.5 inches below top of rail plane that starts at the field side of each rail and extends to 51 inches from centerline of track.

Commentary: Points WL2IN and WL2OUT represent the vehicle door thresholds and are not shown on the VDE schematic drawing.

520.6.2.3.3.4 The vehicle camera VDE must be drawn by connecting the points M1IN, M2IN, M1OUT, and M2OUT. These points must then be laterally extended to the line between WL1 and WL4.

520.6.2.3.3.5 Pantograph points must be calculated using the contact wire height provided by the OCS designer.

520.6.2.3.3.6 The pantograph VDE must be drawn by connecting the pantograph points in sequence from left most point to the right most point: P1in, P#in, P#MAXx in, P#MID in, P#MAXy in, P#CEN, P#MAXy out, P#MID out, P#MAXx out, P#out, and P1out, where the # represents the calculated pantograph values.

Commentary: Example pantograph VDE connection points P1in, P4in, P5MAXx in, P5MID in, P5MAXy in, P6CEN, P5MAXy out, P5MID out, P5MAXx out, P4out, and P1out.

520.6.2.4 Other Wayside Factors

Commentary: OWF are the sum of construction tolerance, maintenance tolerance plus a chorded wall construction factor, where chorded wall construction is adjacent to track.

Commentary: Construction tolerance is the allowed variation in a dimension, construction limit, or physical characteristic of a material in the finished construction work. In Table 520-2, "All Other Proposed Structures" includes all wayside structures not listed in the table, such as communication equipment, boxes, or duct banks.

Commentary: Light rail tracks will wear and move over time. To account for this lateral movement, a maintenance tolerance is provided for each type of track. Maintenance tolerance is the allowed variation caused by track geometry changes, such as railhead and fastener wears, rail position adjustment, and track lateral shift.

520.6.2.4.1 Equation 520-2 must be used for the calculation of the OWF.

Equation 520-2: Calculation of the OWF

OWF = CT + MT + CW

Where:

OWF = Other Wayside Factors

CT = Construction Tolerances must be per Table 520-2

MT = Maintenance Tolerances must be per Table 520-3

CW = Chorded Wall Construction Factor must be per Figures 520-3 and 520-4

Table 520-2: Construction Tolerances

Construction Tolerances (CT) for	Tolerances in inches
Proposed Soldier Pile and Lagging Wall	6
Tunnel Boring Machine (TBM) Construction	4*
Platform Canopy Structures	1
All Other Proposed Structures	2
Poles or Signal Equipment	1.5
Embedded or Direct Fixation Track	0.25
Mainline, Ballasted Track	0.50
Ballasted Yard Tracks	0.50
Apron and Shop Track	0.25
Tunnel Cast-in-Place Walkways	0.25
Floating Slab	0.25

* Note: For TBM construction, 4 inches is the minimum construction tolerance and may increase based upon the type of TBM selected.

Table 520-3: Maintenance Tolerances

Maintenance Tolerances (MT) for	Tolerances in inches
Embedded or Direct Fixation Track	0.25
Mainline, Ballasted Track	2
Ballasted Yard Tracks	0.50
Apron and Shop Track	0.25

520.6.2.5 Running Clearances

Commentary: To provide clear passage for an LRV, which has moved to the extreme position within the Dynamic Envelope, the minimum horizontal clearance to any structure, or part of a structure, must always include a horizontal Running Clearance. Clearance for the OCS components are described in Set 221 Overhead Contact System.

520.6.2.5.1 Running Clearance must be used as defined in Table 520-4.

Table 520-4: Running Clearances

Running Clearances (RC)	Clearance in inches
At OCS poles, signals, signs, and other non-structural members	2
Along soldier pile and lagging walls and other structures that are normally constructed with liberal construction tolerances	6
Along cast in-place, precast, and masonry walls and other structures that are normally constructed with strict construction tolerances	2
For adjacent LRVs (total between vehicles)	2
Clearance for the pantograph	See Set 221 Overhead Contact System

520.6.2.6 Clearance Envelope Special Conditions and Exceptions

Commentary: In addition to the Clearance Envelope requirements, there are several special clearance situations warranting further definition. These special situations include the vehicle interface at station platforms, through girder bridges, at the OMF's mezzanines and platforms, paved track for drainage, special trackwork, gates and doors within the track guideway, and maintenance and emergency evacuation paths.

520.6.2.6.1 Station Platform Edge Angle

520.6.2.6.1.1 For station platform horizontal and vertical clearances, including any construction tolerances, see Set 822 Station Layout–Light Rail.

520.6.2.6.2 Through Girder Bridges

520.6.2.6.2.1 The lateral distance from centerline of track to the nearest point on the girder of a through girder bridge must be a minimum of 9 feet.

520.6.2.6.3 Operations and Maintenance Facility's Mezzanine

520.6.2.6.3.1 At OMF mezzanines access walkways to the LRV, the distance from the centerline of track to the edge of mezzanine platform must be 45.2 inches.

520.6.2.6.3.2 The horizontal construction tolerance for the mezzanine access walkways must be +0.25 inches and -0.0 inch.

520.6.2.6.3.3 Mezzanines must be built at an elevation of 12 feet above top of rail.

520.6.2.6.4 Embedded Track Exceptions

Commentary: To improve drainage flow in embedded track, the embedded track surface is allowed to encroach slightly into the clearance envelope.

520.6.2.6.4.1 The crown for drainage on the gauge side of the rail is allowed to be up to 1/2 inch above the top of rail plane.

520.6.2.6.4.2 Paved track must be designed to be below top of rail plane on the field side in accordance with the Standard Drawings.

520.6.2.6.5 Special Trackwork

520.6.2.6.5.1 Special trackwork and switch machines must not be greater than 1/2 inch above top of rail plane.

520.6.2.6.6 Gates and Doors

520.6.2.6.6.1 All gates and doors along the guideway must open away from the track.

520.6.2.6.6.2 All doors and gates within the station footprint, including platform end gates, room doors, etc., must conform to the requirements in Set 801 Architectural Materials, Elements, and Furnishings and Set 822 Station Layout–Light Rail.

Commentary: Examples of doors within the tunnel include access doors, equipment doors, and hatches.

520.6.2.6.6.3 All doors within tunnels must open away from the tracks.

520.6.2.6.6.4 Cross passage doors within the tunnels must open into the cross passage.

520.6.2.6.7 OMF Maintenance Pit Platform

520.6.2.6.7.1 See Set 836 Operations and Maintenance Facility–Light Rail for maintenance pit platform clearances.

520.6.2.6.8 NFPA 130 Static Clearance Envelope

520.6.2.6.8.1 The static envelope for pedestrian emergency egress must be developed using the VDE plus OWF minus 2.717 inches for lateral motion per NFPA 130.

520.6.3 Track Vertical Clearances

Commentary: Vertical clearances defines the required overhead clearance above the tracks and the minimum vertical under clearance to the elevated guideway.

520.6.3.1 Overhead Clearance

Commentary: The overhead clearance is defined as the unobstructed vertical distance from the top of the rail to the bottom edge of an overhead object. The overhead clearance calculation provides the information needed for running an LRV train safely and making sure that there is enough vertical room for the installed OCS and other designated structural components.

520.6.3.1.1 Overhead clearances must follow the requirements in Set 221 Overhead Contact System.

Commentary: In semi-exclusive or mixed traffic rights-of-way, vertical clearance over intersecting roadways and restrictions on OCS gradient may increase vertical clearance requirements for structures over the roadway.

520.6.3.2 Vertical Under Clearance to Elevated Guideway

Commentary: The vertical under clearance to elevated guideway defines the minimum unobstructed vertical distance from the bottom of the elevated guideway girder to the intended finished surface of the land uses below. The clearance provides the needed space for the intended land uses, reduce intrusions, and clearance for inspection and maintenance.

520.6.3.2.1 For vertical under clearance requirements above traffic lanes and shoulders on all roadways, see Set 906 Roadways and Non-Motorized Facilities.

520.6.3.2.2 The DOR must comply with AHJ vertical clearance requirements.

Commentary: The under clearances for other designated land uses, such as for oversize haul routes, buildings and facilities, unimproved lands, lakes, rivers, streams, other railroads, navigable channels, Sound Transit's TPSS and tracks, minimum clearances for safety and accessibility, etc., are often project-oriented and specified in the design manuals of Sound Transit, WSDOT, AASHTO, and AHJs.

520.6.3.3 Overhead Utilities Clearances

520.6.3.3.1 Overhead utilities clearances must meet the requirements in Set 902 Utilities and Set 221 Overhead Contact System.

520.6.4 Track Spacing

Commentary: This section establishes the track spacing required to operate along the tracks safely. Track spacing is the distance between two adjacent centerline tracks and includes the space for OCS poles, maintenance walkway, and any obstructions.

520.6.4.1 Track Spacing Calculations

520.6.4.1.1 The DOR must prepare track spacing calculations for each tangent, curve set, and type of track.

520.6.4.1.2 Track spacing calculations must include the clearance envelope for each track, the track inspection and maintenance clear space distance, OCS poles, maintenance walkway, and any obstructions.

520.6.4.1.3 The maintenance walkway must not intrude into the Clearance Envelope.

520.6.4.2 Mainline Track Spacing

520.6.4.2.1 The minimum mainline track spacing must be 15 feet 9 inches and increased to meet the track spacing calculations.

520.6.4.3 Yard Track Spacing

520.6.4.3.1 The minimum yard track spacing must be 14 feet for run around tracks and yard tracks without service corridors.

520.6.4.3.2 The minimum yard track spacing must be 19 feet for tracks separated by a service corridor.

520.6.4.3.3 Track spacing must be increased to meet or exceed the minimum criteria for the Clearance Envelope calculations.

520.6.4.4 Track Inspection and Maintenance Clear Space

Commentary: The track inspection and maintenance clear space between two adjacent tracks is the space between the LRV clearance envelopes.

520.6.4.4.1 The minimum horizontal distance between LRV clearance envelopes, measured at 80 inches above the finished maintenance walkway surface, must be 56 inches.

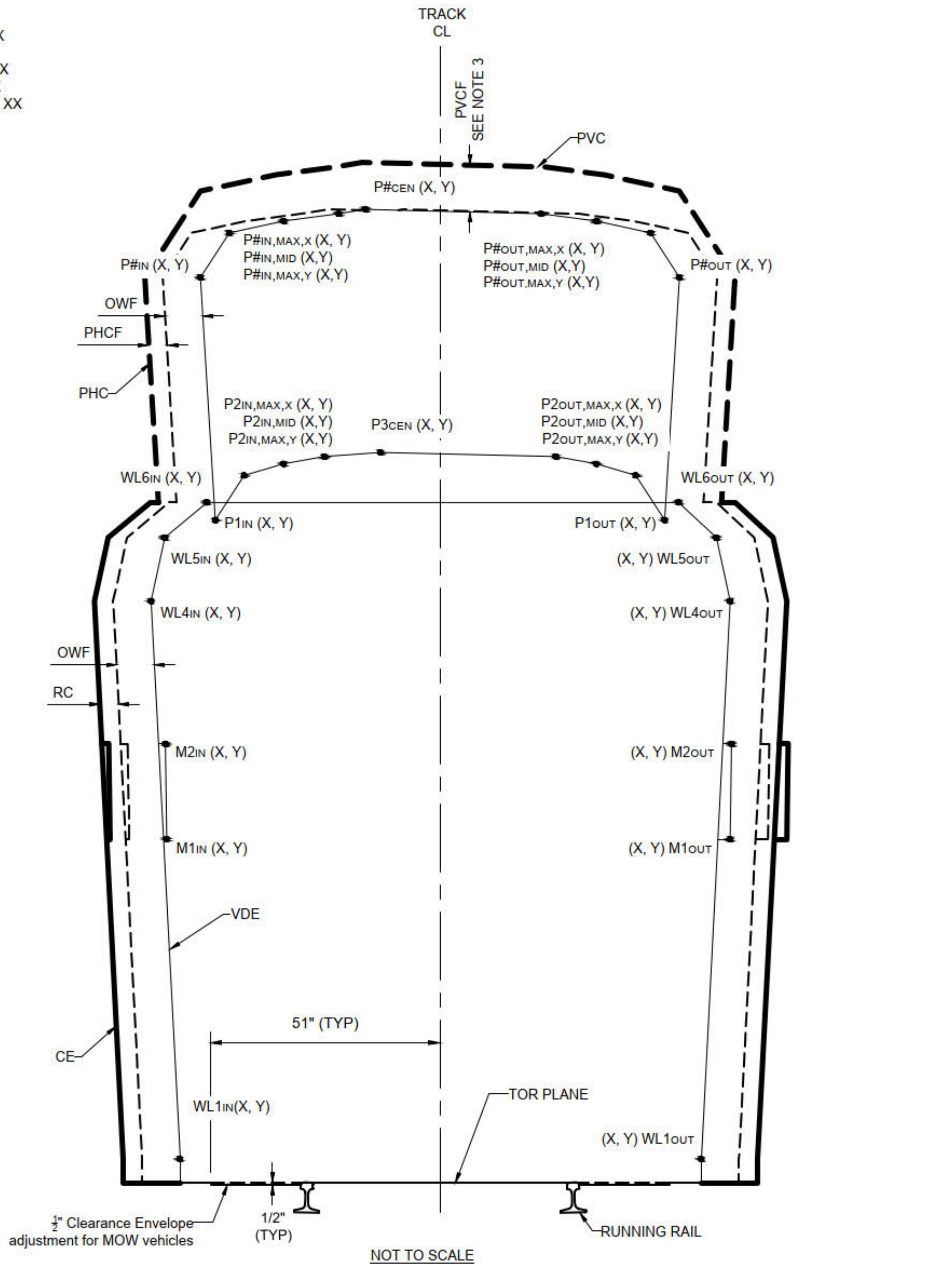
520.6.4.4.2 The finished maintenance walkway surface must be measured from the surface of ballasted track, embedded track, bridge deck surface, and the elevated surface of the maintenance walkway.

520.6.4.5 Minimum Link Light Rail Track Spacing When Paralleling Other Tracks

520.6.4.5.1 Where Link Light Rail tracks are parallel to commuter rail, AMTRAK, or freight, the minimum track centers must be the greater of the minimum track centers for the interfacing rail lines plus 30 inches.

Commentary: The additional 30 inches of track spacing is for a potential buffer barrier, such as a crash wall, to protect the Sound Transit Link Light Rail.

Figure 520-1: Light Rail Clearance Envelope Calculation Sheet



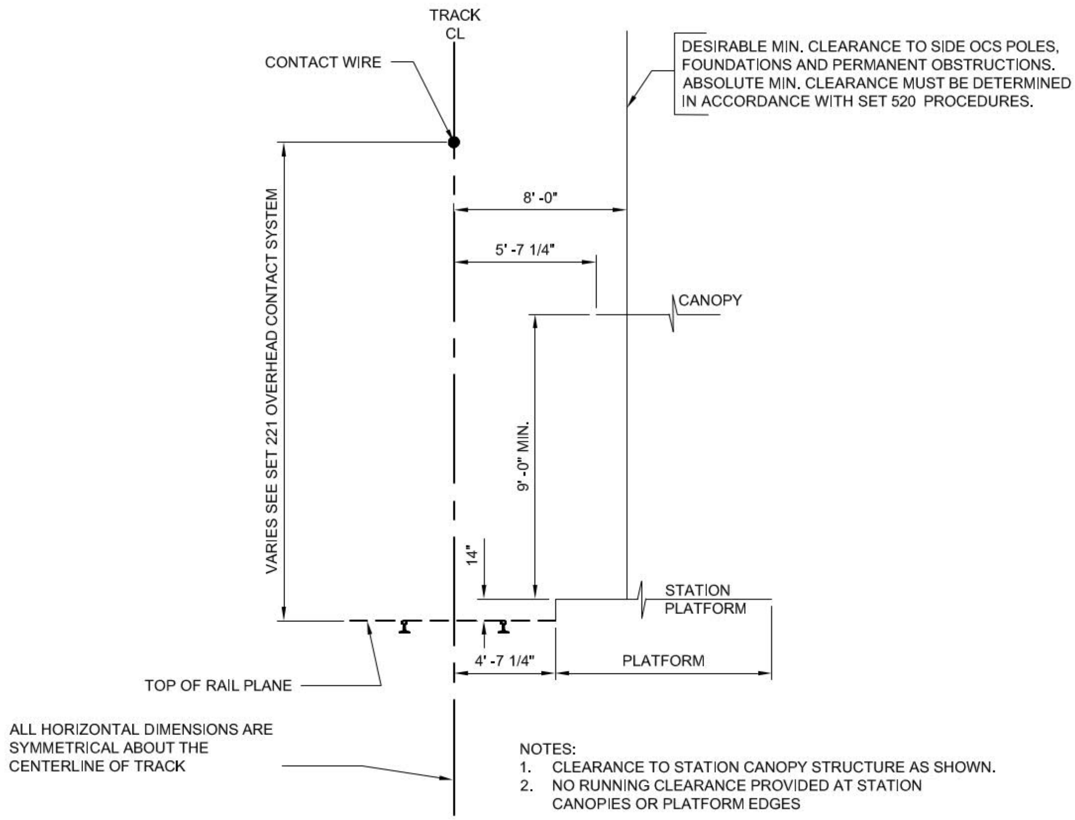
NOTES:

1. CLEARANCE CALCULATION SECTION MUST SHOW ALL OBJECTS THAT ARE WITHIN 3 FEET OF THE CLEARANCE ENVELOPE.
2. FOR PANTOGRAPH CLEARANCE FACTORS, SEE SET 221 OVERHEAD CONTACT SYSTEM.
3. ADD TCT TO PVCF WHERE APPLICABLE

LEGEND:

CE = VDE + OWF + RC
VDE = VEHICLE DYNAMIC ENVELOPE
OWF = OTHER WAYSIDE
RC = RUNNING CLEARANCE
CE = CLEARANCE ENVELOPE
TOR = TOP OF RAIL
CW = CONTACT WIRE
PVC = PANTOGRAPH VERTICAL CLEARANCE
PHC = PANTOGRAPH HORIZONTAL CLEARANCE
PHCF = PANTOGRAPH HORIZONTAL CLEARANCE FACTOR
PVCF = PANTOGRAPH VERTICAL CLEARANCE FACTOR

Figure 520-2: Light Rail Clearance Diagram



MAIN LINE - TANGENT TRACK
NTS

Figure 520-3: Additional Width for Chorded Construction - 25-foot Chord Length

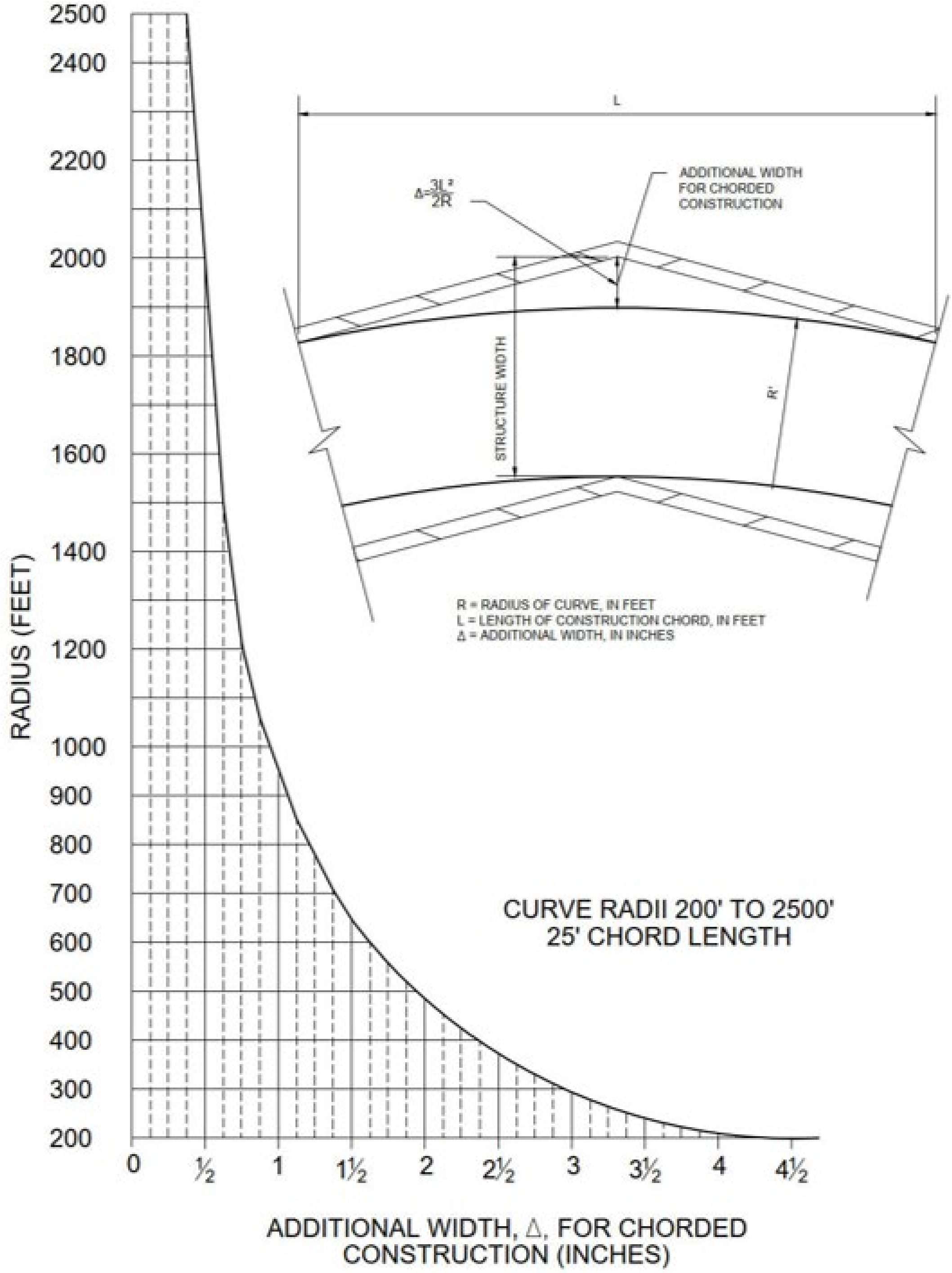


Figure 520-4: Additional Width for Chorded Construction - 50-foot Chord Length

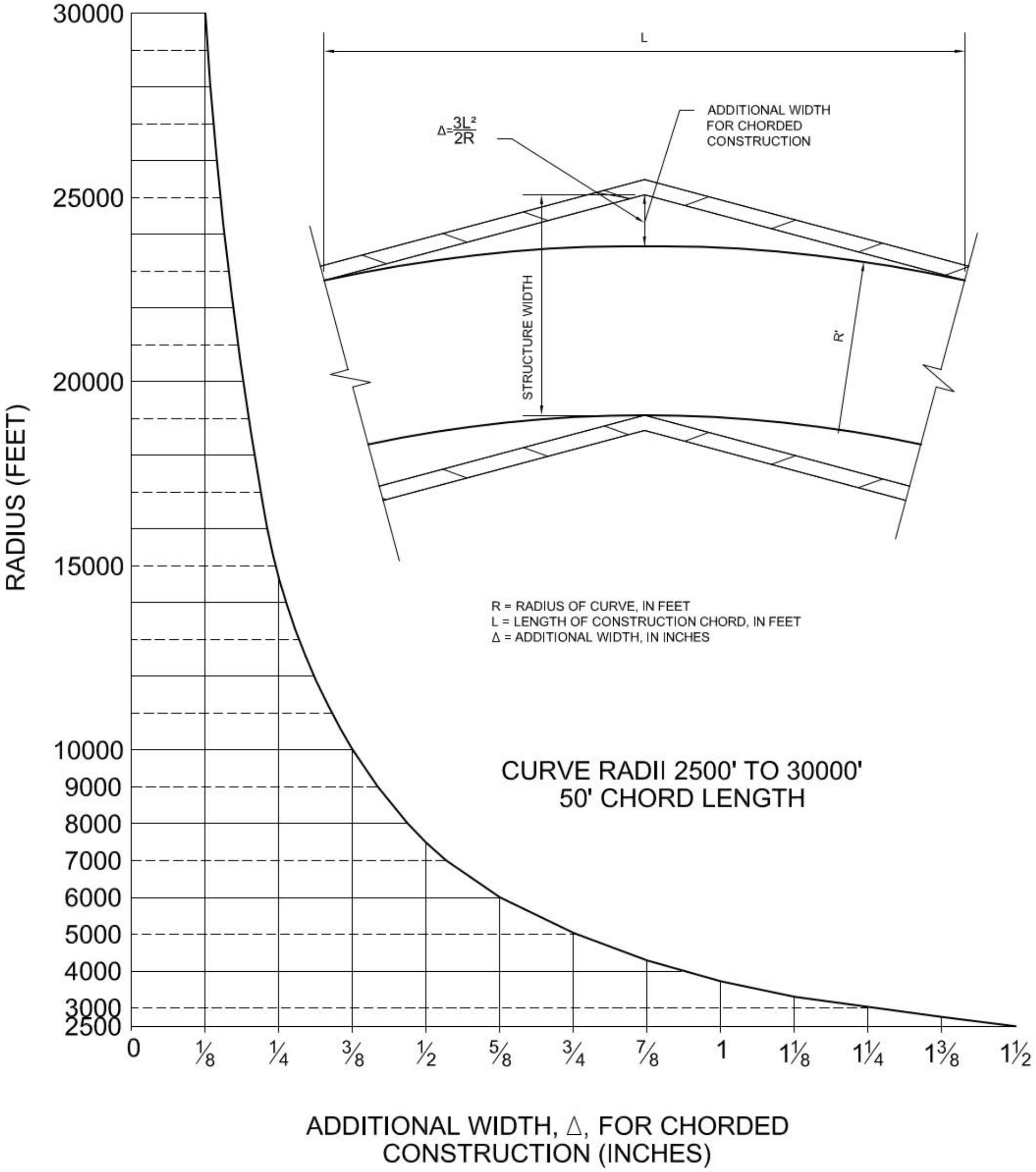
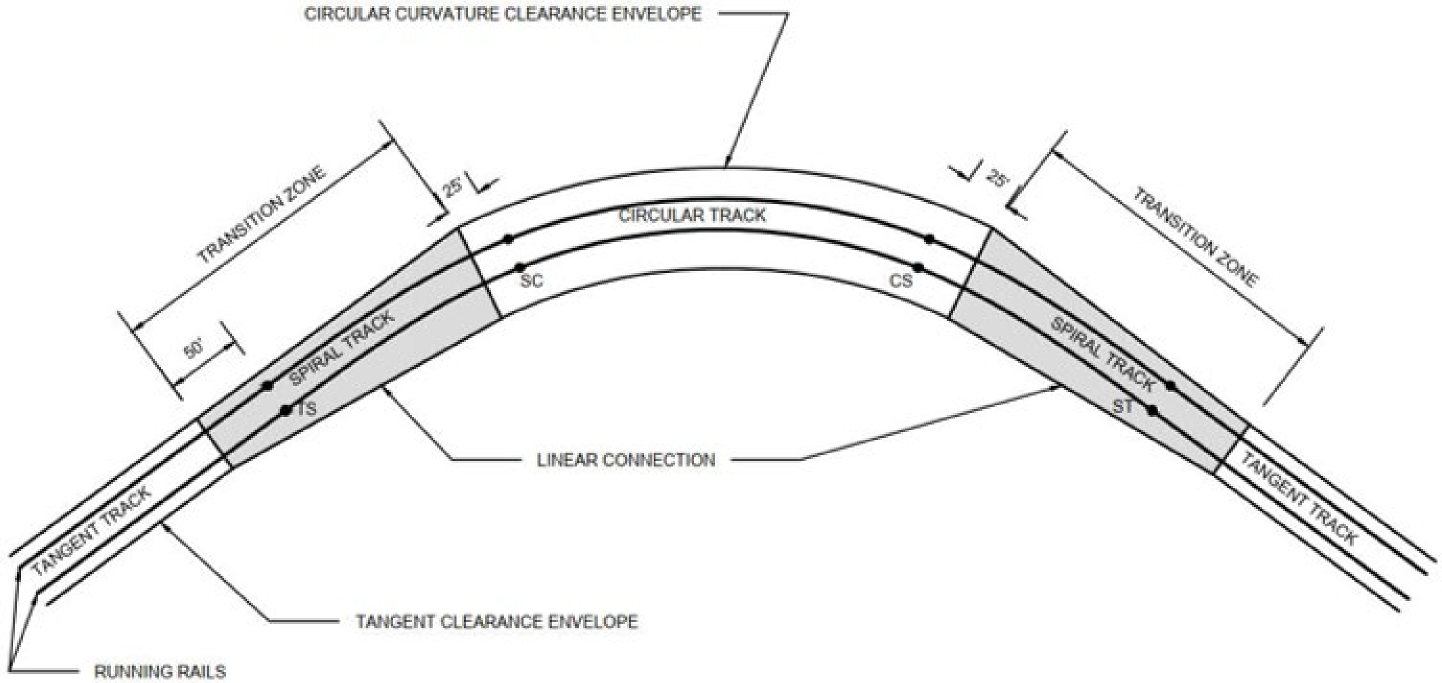
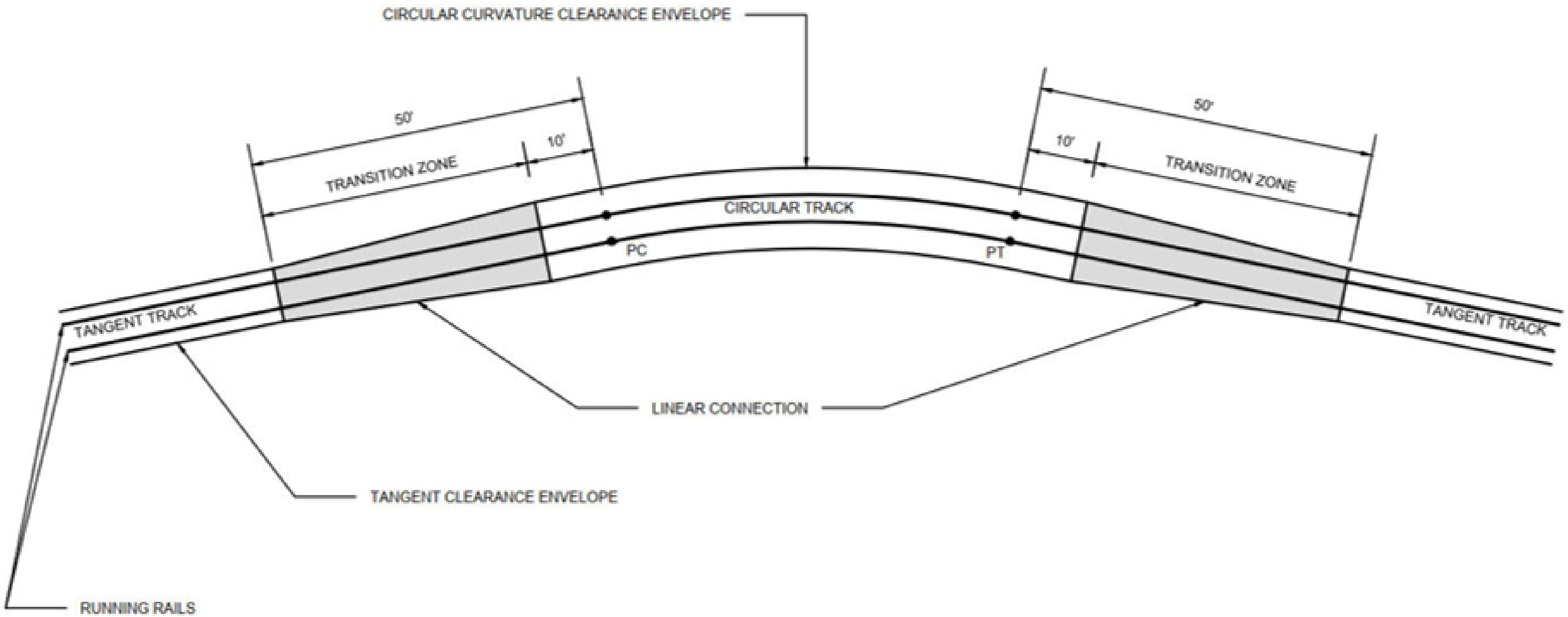


Figure 520-5: Clearance Envelope Spiral Curve Limits



NOTES: TS - POINT OF CHANGE FROM TANGENT TO SPIRAL
SC - POINT OF CHANGE FROM SPIRAL TO CIRCULAR CURVE
CS - POINT OF CHANGE FROM CIRCULAR CURVE TO SPIRAL
ST - POINT OF CHANGE FROM SPIRAL TO TANGENT

Figure 520-6: Clearance Envelope Simple Curve Limits



NOTES: PC - POINT OF CHANGE FROM TANGENT TO CIRCULAR CURVE
PT - POINT OF CHANGE FROM CIRCULAR CURVE TO TANGENT

Figure 520-7: Vehicle Static Outline

STATIC ROLL CENTER

	X	Y
	in	in
R1	0.00	15.00

STATIC PANTOGRAPH POINTS

	X	Y		X	Y
	in	in		in	in
P1OUT	37.50	150.00	P1IN	-37.50	150.00
P2OUT	30.50	159.50	P2IN	-30.50	159.50
P3CEN	0.00	162.00			
P4OUT	37.50	204.00	P4IN	-37.50	204.00
P5OUT	30.50	213.50	P5IN	-30.50	213.50
P6CEN	0.00	216.00			
P7OUT	37.50	255.72	P7IN	-37.50	255.72
P8OUT	30.50	265.22	P8IN	-30.50	265.22
P9CEN	0.00	267.72			

STATIC BODY POINTS

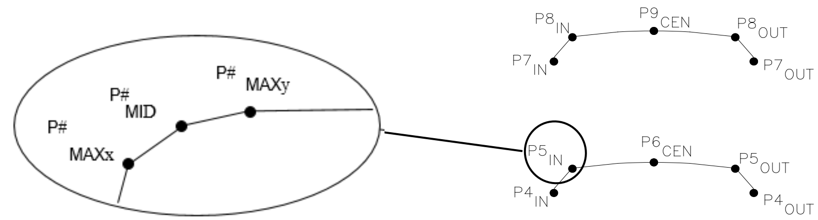
	X	Y		X	Y
	in	in		in	in
WL1OUT	52.24	8.66	WL1IN	-52.24	8.66
WL2OUT	52.24	14.00	WL2IN	-52.24	14.00
WL3OUT	0.00	0.00	WL3IN	0.00	0.00
WL4OUT	52.24	126.00	WL4IN	-52.24	126.00
WL5OUT	48.31	140.35	WL5IN	-48.31	140.35
WL6OUT	38.39	148.82	WL6IN	-38.39	148.82

STATIC CAMERA POINTS

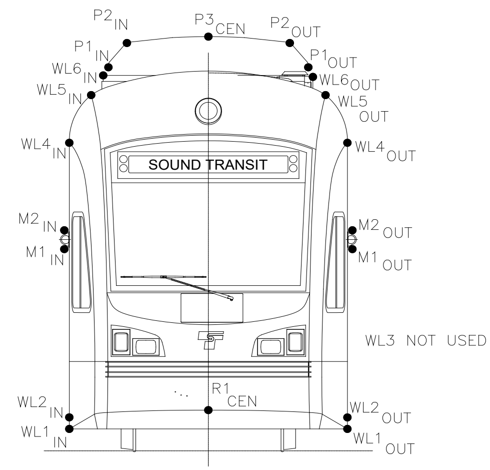
	X	Y		X	Y
	in	in		in	in
M1OUT	55.08	80.00	M1IN	-55.08	80.00
M2OUT	55.08	94.00	M2IN	-55.08	94.00

SKEW

Lateral Motion:	2.717	in
WL1 Corner Skew	3.656	in
WL1 End Skew:	4.476	in
WL2 Corner Skew:	3.656	in
WL2 End Skew:	4.476	in
WL3 Corner Skew:	2.717	in
WL3 End Skew:	2.717	in
WL4 Corner Skew:	3.656	in
WL4 End Skew:	4.476	in
WL5 Corner Skew:	3.656	in
WL5 End Skew:	4.414	in
WL6 Corner Skew:	3.933	in
WL6 End Skew:	3.933	in
Mirror Skew:	3.646	in



Points P2, P5 and P8 are each shown as three points on the VDE tables. These points are defined as P#MAXx, P#MID and P#MAXy



WL# = LRV Water Lines (layers)

M# = LRV Camera (Camera) Points

P# = LRV Pantograph Points

R# = LRV Roll Center Point

Notes applicable to all Vehicle Dynamic Envelope tables

- Coordinates shown are in standard units.
- All coordinates shown are referenced from a point located at ½ track gauge and top of rail (0,0).
- Superelevation is applied relative to top of low rail.
- Points R1CEN, P3CEN, P6CEN, and P9CEN are not specific to either Outside or Inside of curve.
- Vehicle dynamic envelope values, YMAX, for M2OUT and M2IN are increased by 9” to allow for different installation heights.

Figure 520-8: Vehicle Dynamic Envelope

Agency:	Sound Transit
Project:	

Vehicle:	Design Criteria
Conditions:	

Version / File:	values only_3rdfinal
Revision By:	K Manuele

VEHICLE PLAN DIMENSIONS

End Truck Axle Spacing:	70.87	in
Center Truck Axle Spacing:	70.87	in
L1 - Pivot Centers Length:	351.97	in
L1A - Articulation Centers:	124.02	in
WL1 Corner Length:	60.79	in
WL1 Corner Width:	104.48	in
WL1 End Length:	113.94	in
WL1 End Width:	96.06	in
WL2 Corner Length:	60.79	in
WL2 Corner Width:	104.48	in
WL2 End Length:	113.94	in
WL2 End Width:	96.06	in
WL3 Corner Length:	0.00	in
WL3 Corner Width:	0.00	in
WL3 End Length:	0.00	in
WL3 End Width:	0.00	in
WL4Corner Length:	60.79	in
WL4 Corner Width:	104.48	in
WL4 End Length:	113.94	in
WL4 End Width:	96.06	in
WL5 Corner Length:	60.79	in
WL5 Corner Width:	96.61	in
WL5 End Length:	109.94	in
WL5 End Width:	88.61	in
WL6 Corner Length:	78.74	in
WL6 Corner Width:	76.77	in
WL6 End Length:	78.74	in
WL6 End Width:	76.77	in

Camera Length:	60.19	in
Camera Width:	110.16	in

TRACK AND TRUCK

Wheel Gauge (Nominal):	56.25	in
Track Gauge (Nominal):	56.50	in
Rail Head Width:	2.72	in
Lateral flange wear (per wheel):	0.315	in
Lateral rail wear (per rail):	0.512	in
Rail gauge tolerance :	0.236	in
Wheel gauge tolerance :	0.078	in
Lateral suspension motion:	1.608	in
Nominal sideplay :	1.109	in
Lateral Motion:	2.717	in

WL HEIGHTS

WL1:	8.66	in
WL2:	14.00	in
WL3:	0.00	in
WL4:	126.00	in
WL5:	140.35	in
WL6:	[illegible]	

ROLL

Roll Center Height:	15.00	in
Roll Angle:	3.00	Degrees
Camera Roll Angle:	3.00	Degrees

PANTOGRAPH

Width over horns:	75.00	in
Width over shoulders:	61.00	in
Horn depth:	12.00	in
Pantograph height 1:	162.00	in
Pantograph height 2:	216.00	in
Pantograph height 3:	267.72	in
Pantograph Sway :	3.00	in

CAMERA HEIGHTS

Top:	85.00	in
Bottom:	80.00	in

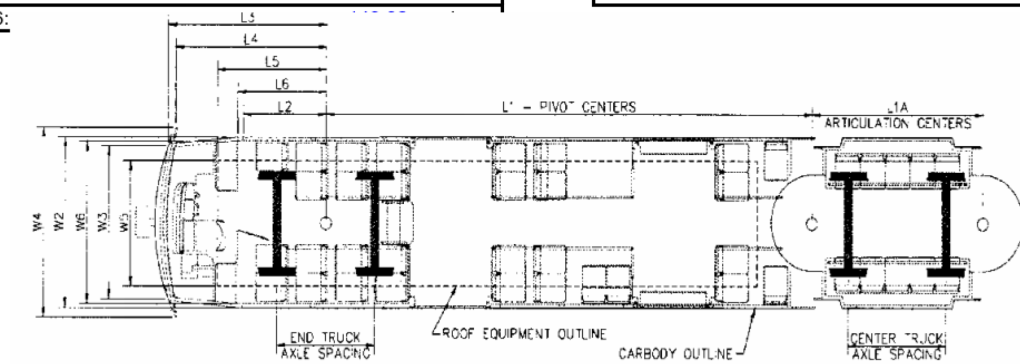


Table 520-5: Vehicle Dynamic Envelope – Outside of Curve

Condition:
Cross Level Variation = 0.5 in
Superelevation = 0.0 in

Radius:	WL1OUT		WL2OUT		WL3OUT		WL4OUT		WL5OUT		WL6OUT		M1OUT		M2OUT	
(feet)	XMAX	YMIN	XMAX	YMIN	XMAX	YMIN	XMAX	YMAX	XMAX	YMAX	XMAX	YMAX	XMAX	YMIN	XMAX	YMAX
82	76.38	5.25	76.14	10.58			82.80	129.22	78.95	143.30	65.36	151.15	72.84	76.28	73.15	97.47
100	72.48	5.25	72.25	10.58			78.90	129.22	75.20	143.30	62.89	151.15	71.23	76.28	71.54	97.47
150	66.28	5.25	66.04	10.58			72.70	129.22	69.23	143.30	58.96	151.15	68.61	76.28	68.91	97.47
200	63.05	5.25	62.81	10.58			69.47	129.22	66.13	143.30	56.92	151.15	67.22	76.28	67.52	97.47
300	59.73	5.25	59.50	10.58			66.15	129.22	62.95	143.30	54.83	151.15	65.77	76.28	66.07	97.47
400	58.60	5.25	58.37	10.58			65.02	129.22	61.97	143.30	53.77	151.15	65.02	76.28	65.33	97.47
500	58.14	5.25	57.91	10.58			64.56	129.22	61.51	143.30	53.12	151.15	64.57	76.28	64.87	97.47
600	57.83	5.25	57.60	10.58			64.25	129.22	61.20	143.30	52.69	151.15	64.26	76.28	64.57	97.47
700	57.61	5.25	57.38	10.58			64.03	129.22	60.98	143.30	52.38	151.15	64.04	76.28	64.35	97.47
800	57.44	5.25	57.21	10.58			63.86	129.22	60.81	143.30	52.15	151.15	63.88	76.28	64.18	97.47
900	57.31	5.25	57.08	10.58			63.73	129.22	60.68	143.30	51.97	151.15	63.75	76.28	64.05	97.47
1000	57.21	5.25	56.97	10.58			63.63	129.22	60.57	143.30	51.82	151.15	63.65	76.28	63.95	97.47
1200	57.05	5.25	56.81	10.58			63.47	129.22	60.41	143.30	51.60	151.15	63.49	76.28	63.79	97.47
1500	56.89	5.25	56.66	10.58			63.31	129.22	60.26	143.30	51.39	151.15	63.33	76.28	63.64	97.47
2000	56.73	5.25	56.50	10.58			63.15	129.22	60.10	143.30	51.17	151.15	63.18	76.28	63.48	97.47
5000	56.44	5.25	56.21	10.58			62.86	129.22	59.81	143.30	50.77	151.15	62.89	76.28	63.20	97.47
10000	56.35	5.25	56.11	10.58			62.77	129.22	59.71	143.30	50.64	151.15	62.80	76.28	63.10	97.47
50000	56.27	5.25	56.04	10.58			62.69	129.22	59.64	143.30	50.53	151.15	62.72	76.28	63.02	97.47
Tangent	56.25	5.25	56.02	10.58			62.67	129.22	59.62	143.30	50.51	151.15	62.70	76.28	63.01	97.47

Radius:	P1OUT		P2OUT		P4OUT		P5OUT		P7OUT		P8OUT		R1CEN		P3CEN	
(feet)	XMAX	YMIN	XMAX	YMAX	XMAX	YMIN	XMAX	YMAX	XMAX	YMIN	XMAX	YMAX	XMAX	YMAX	XMAX	YMAX
82	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
100	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
150	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
200	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
300	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
400	49.98	147.22	P2out is defined by three points, P2outMAXx, P2outMID and P2outMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		53.26	201.12	P5out is defined by three points, P5outMAXx, P5outMID and P5outMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		56.40	252.75	P8out is defined by three points, P8outMAXx, P8outMID and P8outMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-0.13	15.25	-13.28	162.24
500	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
600	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
700	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
800	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
900	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
1000	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
1200	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
1500	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
2000	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
5000	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
10000	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
50000	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24
Tangent	49.98	147.22			53.26	201.12			56.40	252.75			-0.13	15.25	-13.28	162.24

P2OUTMAXx		P2OUTMID		P2OUTMAXy		P5OUTMAXx		P5OUTMID		P5OUTMAXy		P8OUTMAXx		P8OUTMID		P8OUTMAXy	
XMAX	YMAX	XMAX	YMAX	XMAX	YMAX	XMAX	YMAX	XMAX	YMAX	XMAX	YMAX	XMAX	YMAX	XMAX	YMAX	XMAX	YMAX
43.57	157.13	34.78	159.72	25.75	161.34	46.85	211.03	34.75	213.63	22.47	215.24	49.99	262.65	34.73	265.25	19.33	266.86

Note: Vehicle dynamic envelope values, YMAX, for M2OUT and M2IN are increased by 9" to allow for different installation heights.

Table 520-6: Vehicle Dynamic Envelope – Inside of Curve

Condition:
Cross Level Variation = **0.5 in**
Superelevation = **0.0 in**

Radius:	$WL1_{IN}$		$WL2_{IN}$		$WL3_{IN}$		$WL4_{IN}$		$WL5_{IN}$		$WL6_{IN}$		$M1_{IN}$		$M2_{IN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	-70.86	5.25	-70.63	10.58			-77.29	129.22	-74.23	143.30	-64.84	151.15	-49.55	76.28	-49.86	97.47
100	-68.03	5.25	-67.80	10.58			-74.45	129.22	-71.40	143.30	-62.01	151.15	-52.14	76.28	-52.45	97.47
150	-63.77	5.25	-63.53	10.58			-70.19	129.22	-67.13	143.30	-57.75	151.15	-55.89	76.28	-56.19	97.47
200	-61.65	5.25	-61.41	10.58			-68.07	129.22	-65.01	143.30	-55.62	151.15	-57.68	76.28	-57.98	97.47
300	-59.53	5.25	-59.30	10.58			-65.95	129.22	-62.90	143.30	-53.51	151.15	-59.41	76.28	-59.71	97.47
400	-58.48	5.25	-58.24	10.58			-64.90	129.22	-61.84	143.30	-52.45	151.15	-60.25	76.28	-60.56	97.47
500	-57.84	5.25	-57.61	10.58			-64.26	129.22	-61.21	143.30	-51.82	151.15	-60.75	76.28	-61.06	97.47
600	-57.42	5.25	-57.19	10.58			-63.84	129.22	-60.79	143.30	-51.40	151.15	-61.08	76.28	-61.39	97.47
700	-57.12	5.25	-56.89	10.58			-63.54	129.22	-60.49	143.30	-51.10	151.15	-61.32	76.28	-61.62	97.47
800	-56.89	5.25	-56.66	10.58			-63.31	129.22	-60.26	143.30	-50.87	151.15	-61.49	76.28	-61.80	97.47
900	-56.72	5.25	-56.48	10.58			-63.14	129.22	-60.08	143.30	-50.70	151.15	-61.63	76.28	-61.93	97.47
1000	-56.58	5.25	-56.34	10.58			-63.00	129.22	-59.94	143.30	-50.56	151.15	-61.74	76.28	-62.04	97.47
1200	-56.37	5.25	-56.13	10.58			-62.79	129.22	-59.73	143.30	-50.34	151.15	-61.90	76.28	-62.20	97.47
1500	-56.16	5.25	-55.92	10.58			-62.58	129.22	-59.52	143.30	-50.13	151.15	-62.06	76.28	-62.37	97.47
2000	-55.95	5.25	-55.71	10.58			-62.37	129.22	-59.31	143.30	-49.92	151.15	-62.22	76.28	-62.53	97.47
5000	-56.06	5.25	-55.82	10.58			-62.48	129.22	-59.42	143.30	-50.24	151.15	-62.51	76.28	-62.81	97.47
10000	-56.15	5.25	-55.92	10.58			-62.58	129.22	-59.52	143.30	-50.37	151.15	-62.61	76.28	-62.91	97.47
50000	-56.23	5.25	-56.00	10.58			-62.65	129.22	-59.60	143.30	-50.48	151.15	-62.68	76.28	-62.99	97.47
Tangent	-56.25	5.25	-56.02	10.58			-62.67	129.22	-59.62	143.30	-50.51	151.15	-62.70	76.28	-63.01	97.47

Radius:	$P1_{IN}$		$P2_{IN}$		$P4_{IN}$		$P5_{IN}$		$P7_{IN}$		$P8_{IN}$		$P6_{CEN}$		$P9_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
100	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
150	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
200	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
300	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
400	-49.98	147.22	P2in is defined by three points, P2inMAXx, P2inMID and P2inMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		-53.26	201.12	P5in is defined by three points, P5inMAXx, P5inMID and P5inMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		-56.40	252.75	P8in is defined by three points, P8inMAXx, P8inMID and P8inMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-16.56	216.24	-19.70	267.96
500	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
600	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
700	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
800	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
900	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
1000	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
1200	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
1500	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
2000	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
5000	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
10000	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
50000	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96
Tangent	-49.98	147.22			-53.26	201.12			-56.40	252.75			-16.56	216.24	-19.70	267.96

$P2_{INMAXx}$		$P2_{INMID}$		$P2_{INMAXy}$		$P5_{INMAXx}$		$P5_{INMID}$		$P5_{INMAXy}$		$P8_{INMAXx}$		$P8_{INMID}$		$P8_{INMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
-43.57	157.13	-34.78	159.72	-25.75	161.34	-46.85	211.03	-34.75	213.63	-22.47	215.24	-49.99	262.65	-34.73	265.25	-19.33	266.86

Note: Vehicle dynamic envelope values, Y_{MAX}, for $M2_{OUT}$ and $M2_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-7: Vehicle Dynamic Envelope – Outside of Curve

Condition:
Cross Level Variation = 0.5 in
Superelevation = 1.0 in

Radius:	$WL1_{OUT}$		$WL2_{OUT}$		$WL3_{OUT}$		$WL4_{OUT}$		$WL5_{OUT}$		$WL6_{OUT}$		$M1_{OUT}$		$M2_{OUT}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	76.18	6.62	75.90	11.96			80.72	130.46	76.63	144.47	62.89	152.14	71.54	77.77	71.76	98.81
100	72.29	6.62	72.01	11.96			76.83	130.46	72.87	144.47	60.41	152.14	69.93	77.77	70.15	98.81
150	66.09	6.62	65.80	11.96			70.62	130.46	66.90	144.47	56.48	152.14	67.31	77.77	67.53	98.81
200	62.86	6.62	62.57	11.96			67.39	130.46	63.80	144.47	54.44	152.14	65.92	77.77	66.14	98.81
300	59.54	6.62	59.26	11.96			64.07	130.46	60.62	144.47	52.35	152.14	64.47	77.77	64.69	98.81
400	58.41	6.62	58.13	11.96			62.95	130.46	59.65	144.47	51.29	152.14	63.72	77.77	63.94	98.81
500	57.95	6.62	57.67	11.96			62.48	130.46	59.19	144.47	50.65	152.14	63.27	77.77	63.49	98.81
600	57.64	6.62	57.36	11.96			62.17	130.46	58.88	144.47	50.21	152.14	62.96	77.77	63.18	98.81
700	57.42	6.62	57.14	11.96			61.95	130.46	58.65	144.47	49.91	152.14	62.74	77.77	62.96	98.81
800	57.25	6.62	56.97	11.96			61.78	130.46	58.48	144.47	49.67	152.14	62.58	77.77	62.80	98.81
900	57.12	6.62	56.84	11.96			61.65	130.46	58.35	144.47	49.49	152.14	62.45	77.77	62.67	98.81
1000	57.01	6.62	56.73	11.96			61.55	130.46	58.25	144.47	49.35	152.14	62.34	77.77	62.56	98.81
1200	56.86	6.62	56.57	11.96			61.39	130.46	58.09	144.47	49.13	152.14	62.19	77.77	62.41	98.81
1500	56.70	6.62	56.42	11.96			61.23	130.46	57.93	144.47	48.91	152.14	62.03	77.77	62.25	98.81
2000	56.54	6.62	56.26	11.96			61.07	130.46	57.77	144.47	48.69	152.14	61.88	77.77	62.10	98.81
5000	56.25	6.62	55.97	11.96			60.79	130.46	57.48	144.47	48.29	152.14	61.59	77.77	61.81	98.81
10000	56.16	6.62	55.87	11.96			60.69	130.46	57.39	144.47	48.16	152.14	61.50	77.77	61.72	98.81
50000	56.08	6.62	55.80	11.96			60.61	130.46	57.31	144.47	48.06	152.14	61.42	77.77	61.64	98.81
Tangent	56.06	6.62	55.78	11.96			60.59	130.46	57.29	144.47	48.03	152.14	61.40	77.77	61.62	98.81

Radius:	$P1_{OUT}$		$P2_{OUT}$		$P4_{OUT}$		$P5_{OUT}$		$P7_{OUT}$		$P8_{OUT}$		$R1_{CEN}$		$P3_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
100	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
150	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
200	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
300	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
400	47.48	148.47	P2out is defined by three points, P2outMAXx, P2outMID and P2outMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		49.85	202.42	P5out is defined by three points, P5outMAXx, P5outMID and P5outMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		52.12	254.09	P8out is defined by three points, P8outMAXx, P8outMID and P8outMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-0.39	15.75	-16.01	162.74
500	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
600	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
700	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
800	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
900	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
1000	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
1200	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
1500	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
2000	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
5000	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
10000	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
50000	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74
Tangent	47.48	148.47			49.85	202.42			52.12	254.09			-0.39	15.75	-16.01	162.74

$P2_{OUTMAXx}$		$P2_{OUTMID}$		$P2_{OUTMAXy}$		$P5_{OUTMAXx}$		$P5_{OUTMID}$		$P5_{OUTMAXy}$		$P8_{OUTMAXx}$		$P8_{OUTMID}$		$P8_{OUTMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
40.91	158.27	32.07	160.71	23.02	162.18	43.28	212.22	31.13	214.61	18.83	216.01	52.12	254.09	37.40	256.86	22.53	258.65

Note: Vehicle dynamic envelope values, Y_{MAX}, for $M2_{OUT}$ and $M2_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-8: Vehicle Dynamic Envelope – Inside of Curve

Condition:
Cross Level Variation = 0.5 in
Superelevation = 1.0 in

Radius:	WL1$_{IN}$		WL2$_{IN}$		WL3$_{IN}$		WL4$_{IN}$		WL5$_{IN}$		WL6$_{IN}$		M1$_{IN}$		M2$_{IN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	-71.05	4.87	-70.91	10.19			-79.36	128.94	-76.55	143.10	-67.31	151.13	-50.85	75.77	-51.23	97.10
100	-68.22	4.87	-68.07	10.19			-76.52	128.94	-73.71	143.10	-64.48	151.13	-53.44	75.77	-53.82	97.10
150	-63.95	4.87	-63.81	10.19			-72.26	128.94	-69.45	143.10	-60.22	151.13	-57.18	75.77	-57.57	97.10
200	-61.83	4.87	-61.69	10.19			-70.14	128.94	-67.33	143.10	-58.10	151.13	-58.97	75.77	-59.36	97.10
300	-59.72	4.87	-59.57	10.19			-68.02	128.94	-65.21	143.10	-55.98	151.13	-60.70	75.77	-61.09	97.10
400	-58.66	4.87	-58.52	10.19			-66.97	128.94	-64.16	143.10	-54.93	151.13	-61.55	75.77	-61.93	97.10
500	-58.03	4.87	-57.89	10.19			-66.33	128.94	-63.53	143.10	-54.29	151.13	-62.05	75.77	-62.43	97.10
600	-57.61	4.87	-57.46	10.19			-65.91	128.94	-63.10	143.10	-53.87	151.13	-62.38	75.77	-62.76	97.10
700	-57.31	4.87	-57.16	10.19			-65.61	128.94	-62.80	143.10	-53.57	151.13	-62.61	75.77	-63.00	97.10
800	-57.08	4.87	-56.94	10.19			-65.39	128.94	-62.58	143.10	-53.34	151.13	-62.79	75.77	-63.17	97.10
900	-56.90	4.87	-56.76	10.19			-65.21	128.94	-62.40	143.10	-53.17	151.13	-62.92	75.77	-63.31	97.10
1000	-56.76	4.87	-56.62	10.19			-65.07	128.94	-62.26	143.10	-53.03	151.13	-63.03	75.77	-63.42	97.10
1200	-56.55	4.87	-56.41	10.19			-64.86	128.94	-62.05	143.10	-52.82	151.13	-63.19	75.77	-63.58	97.10
1500	-56.34	4.87	-56.20	10.19			-64.65	128.94	-61.84	143.10	-52.60	151.13	-63.35	75.77	-63.74	97.10
2000	-56.13	4.87	-55.99	10.19			-64.44	128.94	-61.63	143.10	-52.39	151.13	-63.51	75.77	-63.90	97.10
5000	-56.24	4.87	-56.10	10.19			-64.55	128.94	-61.74	143.10	-52.71	151.13	-63.80	75.77	-64.19	97.10
10000	-56.34	4.87	-56.20	10.19			-64.65	128.94	-61.84	143.10	-52.84	151.13	-63.90	75.77	-64.29	97.10
50000	-56.42	4.87	-56.27	10.19			-64.72	128.94	-61.91	143.10	-52.95	151.13	-63.98	75.77	-64.36	97.10
Tangent	-56.44	4.87	-56.29	10.19			-64.74	128.94	-61.93	143.10	-52.98	151.13	-63.99	75.77	-64.38	97.10

Radius:	P1$_{IN}$		P2$_{IN}$		P4$_{IN}$		P5$_{IN}$		P7$_{IN}$		P8$_{IN}$		P6$_{CEN}$		P9$_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
100	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
150	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
200	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
300	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
400	-52.47	146.93	P2in is defined by three points, P2inMAXx, P2inMID and P2inMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		-56.66	200.76	P5in is defined by three points, P5inMAXx, P5inMID and P5inMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		-60.68	252.33	P8in is defined by three points, P8inMAXx, P8inMID and P8inMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-20.21	216.74	-24.22	268.46
500	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
600	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
700	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
800	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
900	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
1000	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
1200	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
1500	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
2000	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
5000	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
10000	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
50000	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46
Tangent	-52.47	146.93			-56.66	200.76			-60.68	252.33			-20.21	216.74	-24.22	268.46

P2$_{INMAXx}$		P2$_{INMID}$		P2$_{INMAXy}$		P5$_{INMAXx}$		P5$_{INMID}$		P5$_{INMAXy}$		P8$_{INMAXx}$		P8$_{INMID}$		P8$_{INMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
-46.23	156.94	-37.47	159.68	-28.47	161.45	-50.42	210.78	-38.35	213.58	-26.10	215.40	-60.68	252.33	-46.05	255.60	-31.24	257.88

Note: Vehicle dynamic envelope values, Y_{MAX}, for M2$_{OUT}$ and M2$_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-9: Vehicle Dynamic Envelope – Outside of Curve

Condition:
Cross Level Variation = 0.5 in
Superelevation = 2.0 in

Radius:	$WL1_{OUT}$		$WL2_{OUT}$		$WL3_{OUT}$		$WL4_{OUT}$		$WL5_{OUT}$		$WL6_{OUT}$		$M1_{OUT}$		$M2_{OUT}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	75.97	7.99	75.64	13.33			78.62	131.67	74.28	145.59	60.39	153.08	70.22	79.23	70.35	100.12
100	72.08	7.99	71.75	13.33			74.72	131.67	70.53	145.59	57.92	153.08	68.61	79.23	68.74	100.12
150	65.87	7.99	65.54	13.33			68.52	131.67	64.56	145.59	53.99	153.08	65.98	79.23	66.12	100.12
200	62.64	7.99	62.31	13.33			65.29	131.67	61.45	145.59	51.95	153.08	64.59	79.23	64.73	100.12
300	59.32	7.99	59.00	13.33			61.97	131.67	58.28	145.59	49.86	153.08	63.14	79.23	63.28	100.12
400	58.20	7.99	57.87	13.33			60.84	131.67	57.30	145.59	48.79	153.08	62.40	79.23	62.53	100.12
500	57.73	7.99	57.41	13.33			60.38	131.67	56.84	145.59	48.15	153.08	61.94	79.23	62.08	100.12
600	57.42	7.99	57.10	13.33			60.07	131.67	56.53	145.59	47.72	153.08	61.64	79.23	61.77	100.12
700	57.20	7.99	56.88	13.33			59.85	131.67	56.31	145.59	47.41	153.08	61.42	79.23	61.55	100.12
800	57.03	7.99	56.71	13.33			59.68	131.67	56.14	145.59	47.18	153.08	61.25	79.23	61.39	100.12
900	56.90	7.99	56.58	13.33			59.55	131.67	56.01	145.59	47.00	153.08	61.12	79.23	61.26	100.12
1000	56.80	7.99	56.47	13.33			59.45	131.67	55.90	145.59	46.85	153.08	61.02	79.23	61.16	100.12
1200	56.64	7.99	56.31	13.33			59.29	131.67	55.74	145.59	46.63	153.08	60.86	79.23	61.00	100.12
1500	56.48	7.99	56.16	13.33			59.13	131.67	55.58	145.59	46.41	153.08	60.71	79.23	60.84	100.12
2000	56.32	7.99	56.00	13.33			58.97	131.67	55.43	145.59	46.20	153.08	60.55	79.23	60.69	100.12
5000	56.04	7.99	55.71	13.33			58.68	131.67	55.14	145.59	45.80	153.08	60.27	79.23	60.40	100.12
10000	55.94	7.99	55.61	13.33			58.59	131.67	55.04	145.59	45.67	153.08	60.17	79.23	60.31	100.12
50000	55.86	7.99	55.54	13.33			58.51	131.67	54.96	145.59	45.56	153.08	60.10	79.23	60.23	100.12
Tangent	55.84	7.99	55.52	13.33			58.49	131.67	54.95	145.59	45.54	153.08	60.08	79.23	60.21	100.12

Radius:	$P1_{OUT}$		$P2_{OUT}$		$P4_{OUT}$		$P5_{OUT}$		$P7_{OUT}$		$P8_{OUT}$		$R1_{CEN}$		$P3_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
100	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
150	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
200	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
300	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
400	44.97	149.68	P2out is defined by three points, P2outMAXx, P2outMID and P2outMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		46.43	203.66	P5out is defined by three points, P5outMAXx, P5outMID and P5outMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		47.83	255.36	P8out is defined by three points, P8outMAXx, P8outMID and P8outMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-0.66	16.24	-18.76	163.23
500	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
600	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
700	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
800	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
900	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
1000	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
1200	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
1500	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
2000	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
5000	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
10000	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
50000	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23
Tangent	44.97	149.68			46.43	203.66			47.83	255.36			-0.66	16.24	-18.76	163.23

$P2_{OUTMAXx}$		$P2_{OUTMID}$		$P2_{OUTMAXy}$		$P5_{OUTMAXx}$		$P5_{OUTMID}$		$P5_{OUTMAXy}$		$P8_{OUTMAXx}$		$P8_{OUTMID}$		$P8_{OUTMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
38.23	159.37	29.35	161.66	20.28	162.97	39.69	213.35	27.50	215.53	15.18	216.73	41.72	255.72	30.02	258.06	18.16	259.42

Note: Vehicle dynamic envelope values, Y_{MAX}, for $M2_{OUT}$ and $M2_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-10: Vehicle Dynamic Envelope – Inside of Curve

Condition:
Cross Level Variation = 0.5 in
Superelevation = 2.0 in

Radius:	$WL1_{IN}$		$WL2_{IN}$		$WL3_{IN}$		$WL4_{IN}$		$WL5_{IN}$		$WL6_{IN}$		$M1_{IN}$		$M2_{IN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	-71.23	4.49	-71.18	9.81			-81.42	128.62	-78.85	142.86	-69.78	151.05	-52.13	75.24	-52.60	96.71
100	-68.40	4.49	-68.34	9.81			-78.58	128.62	-76.02	142.86	-66.94	151.05	-54.72	75.24	-55.19	96.71
150	-64.13	4.49	-64.08	9.81			-74.32	128.62	-71.76	142.86	-62.68	151.05	-58.46	75.24	-58.94	96.71
200	-62.01	4.49	-61.96	9.81			-72.20	128.62	-69.64	142.86	-60.56	151.05	-60.25	75.24	-60.73	96.71
300	-59.90	4.49	-59.84	9.81			-70.08	128.62	-67.52	142.86	-58.45	151.05	-61.98	75.24	-62.46	96.71
400	-58.84	4.49	-58.79	9.81			-69.03	128.62	-66.47	142.86	-57.39	151.05	-62.83	75.24	-63.30	96.71
500	-58.21	4.49	-58.15	9.81			-68.39	128.62	-65.83	142.86	-56.76	151.05	-63.33	75.24	-63.80	96.71
600	-57.79	4.49	-57.73	9.81			-67.97	128.62	-65.41	142.86	-56.33	151.05	-63.66	75.24	-64.13	96.71
700	-57.49	4.49	-57.43	9.81			-67.67	128.62	-65.11	142.86	-56.03	151.05	-63.89	75.24	-64.37	96.71
800	-57.26	4.49	-57.21	9.81			-67.45	128.62	-64.88	142.86	-55.81	151.05	-64.07	75.24	-64.54	96.71
900	-57.08	4.49	-57.03	9.81			-67.27	128.62	-64.71	142.86	-55.63	151.05	-64.20	75.24	-64.68	96.71
1000	-56.94	4.49	-56.89	9.81			-67.13	128.62	-64.57	142.86	-55.49	151.05	-64.31	75.24	-64.79	96.71
1200	-56.73	4.49	-56.68	9.81			-66.92	128.62	-64.36	142.86	-55.28	151.05	-64.48	75.24	-64.95	96.71
1500	-56.52	4.49	-56.47	9.81			-66.71	128.62	-64.14	142.86	-55.07	151.05	-64.64	75.24	-65.11	96.71
2000	-56.31	4.49	-56.26	9.81			-66.50	128.62	-63.93	142.86	-54.86	151.05	-64.80	75.24	-65.27	96.71
5000	-56.42	4.49	-56.37	9.81			-66.61	128.62	-64.05	142.86	-55.18	151.05	-65.09	75.24	-65.56	96.71
10000	-56.52	4.49	-56.47	9.81			-66.71	128.62	-64.14	142.86	-55.31	151.05	-65.18	75.24	-65.65	96.71
50000	-56.60	4.49	-56.54	9.81			-66.78	128.62	-64.22	142.86	-55.41	151.05	-65.26	75.24	-65.73	96.71
Tangent	-56.62	4.49	-56.56	9.81			-66.80	128.62	-64.24	142.86	-55.44	151.05	-65.28	75.24	-65.75	96.71

Radius:	$P1_{IN}$		$P2_{IN}$		$P4_{IN}$		$P5_{IN}$		$P7_{IN}$		$P8_{IN}$		$P6_{CEN}$		$P9_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-54.96	146.59	P2in is defined by three points, P2inMAXx, P2inMID and P2inMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		-60.05	200.35	P5in is defined by three points, P5inMAXx, P5inMID and P5inMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		-64.94	251.84	P8in is defined by three points, P8inMAXx, P8inMID and P8inMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-23.85	217.23	-28.74	268.94
100	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
150	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
200	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
300	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
400	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
500	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
600	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
700	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
800	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
900	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
1000	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
1200	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
1500	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
2000	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
5000	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
10000	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
50000	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94
Tangent	-54.96	146.59			-60.05	200.35			-64.94	251.84			-23.85	217.23	-28.74	268.94

$P2_{INMAXx}$		$P2_{INMID}$		$P2_{INMAXy}$		$P5_{INMAXx}$		$P5_{INMID}$		$P5_{INMAXy}$		$P8_{INMAXx}$		$P8_{INMID}$		$P8_{INMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
-48.88	156.71	-40.17	159.60	-31.19	161.52	-53.98	210.47	-41.96	213.47	-29.73	215.50	-41.72	255.72	-38.82	257.28	-35.58	257.89

Note: Vehicle dynamic envelope values, Y_{MAX}, for $M2_{OUT}$ and $M2_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-11: Vehicle Dynamic Envelope – Outside of Curve

Condition:
Cross Level Variation = 0.5 in
Superelevation = 3.0 in

Radius:	$WL1_{OUT}$		$WL2_{OUT}$		$WL3_{OUT}$		$WL4_{OUT}$		$WL5_{OUT}$		$WL6_{OUT}$		$M1_{OUT}$		$M2_{OUT}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	75.73	9.36	75.36	14.70			76.49	132.84	71.92	146.67	57.88	153.98	68.87	80.67	68.92	101.41
100	71.84	9.36	71.47	14.70			72.60	132.84	68.16	146.67	55.40	153.98	67.26	80.67	67.31	101.41
150	65.63	9.36	65.26	14.70			66.39	132.84	62.19	146.67	51.47	153.98	64.64	80.67	64.69	101.41
200	62.40	9.36	62.03	14.70			63.16	132.84	59.09	146.67	49.43	153.98	63.24	80.67	63.29	101.41
300	59.09	9.36	58.72	14.70			59.85	132.84	55.91	146.67	47.34	153.98	61.79	80.67	61.85	101.41
400	57.96	9.36	57.59	14.70			58.72	132.84	54.94	146.67	46.28	153.98	61.05	80.67	61.10	101.41
500	57.50	9.36	57.13	14.70			58.26	132.84	54.47	146.67	45.64	153.98	60.60	80.67	60.65	101.41
600	57.19	9.36	56.82	14.70			57.95	132.84	54.16	146.67	45.21	153.98	60.29	80.67	60.34	101.41
700	56.96	9.36	56.59	14.70			57.73	132.84	53.94	146.67	44.90	153.98	60.07	80.67	60.12	101.41
800	56.80	9.36	56.43	14.70			57.56	132.84	53.77	146.67	44.67	153.98	59.91	80.67	59.96	101.41
900	56.66	9.36	56.30	14.70			57.43	132.84	53.64	146.67	44.48	153.98	59.78	80.67	59.83	101.41
1000	56.56	9.36	56.19	14.70			57.32	132.84	53.53	146.67	44.34	153.98	59.67	80.67	59.72	101.41
1200	56.40	9.36	56.03	14.70			57.16	132.84	53.38	146.67	44.12	153.98	59.52	80.67	59.57	101.41
1500	56.24	9.36	55.87	14.70			57.01	132.84	53.22	146.67	43.90	153.98	59.36	80.67	59.41	101.41
2000	56.08	9.36	55.71	14.70			56.85	132.84	53.06	146.67	43.68	153.98	59.20	80.67	59.25	101.41
5000	55.80	9.36	55.43	14.70			56.56	132.84	52.77	146.67	43.29	153.98	58.92	80.67	58.97	101.41
10000	55.70	9.36	55.33	14.70			56.46	132.84	52.67	146.67	43.15	153.98	58.82	80.67	58.88	101.41
50000	55.62	9.36	55.25	14.70			56.39	132.84	52.60	146.67	43.05	153.98	58.75	80.67	58.80	101.41
Tangent	55.60	9.36	55.23	14.70			56.37	132.84	52.58	146.67	43.02	153.98	58.73	80.67	58.78	101.41

Radius:	$P1_{OUT}$		$P2_{OUT}$		$P4_{OUT}$		$P5_{OUT}$		$P7_{OUT}$		$P8_{OUT}$		$R1_{CEN}$		$P3_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
100	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
150	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
200	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
300	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
400	42.43	150.85	P2out is defined by three points, P2outMAXx, P2outMID and P2outMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		42.98	204.84	P5out is defined by three points, P5outMAXx, P5outMID and P5outMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		43.51	256.56	P8out is defined by three points, P8outMAXx, P8outMID and P8outMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-0.94	16.73	-21.50	163.73
500	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
600	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
700	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
800	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
900	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
1000	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
1200	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
1500	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
2000	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
5000	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
10000	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
50000	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73
Tangent	42.43	150.85			42.98	204.84			43.51	256.56			-0.94	16.73	-21.50	163.73

$P2_{OUTMAXx}$		$P2_{OUTMID}$		$P2_{OUTMAXy}$		$P5_{OUTMAXx}$		$P5_{OUTMID}$		$P5_{OUTMAXy}$		$P8_{OUTMAXx}$		$P8_{OUTMID}$		$P8_{OUTMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
35.53	160.42	26.62	162.56	17.52	163.72	36.08	214.41	23.86	216.39	11.52	217.38	43.51	256.56	28.71	258.84	13.78	260.12

Note: Vehicle dynamic envelope values, YMAX, for M2OUT and M2IN are increased by 9" to allow for different installation heights.

Table 520-12: Vehicle Dynamic Envelope – Inside of Curve

Condition:
Cross Level Variation = 0.5 in
Superelevation = 3.0 in

Radius:	$WL1_{IN}$		$WL2_{IN}$		$WL3_{IN}$		$WL4_{IN}$		$WL5_{IN}$		$WL6_{IN}$		$M1_{IN}$		$M2_{IN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	-71.40	4.11	-71.44	9.42			-83.46	128.26	-81.15	142.57	-72.23	150.94	-53.40	74.69	-53.96	96.29
100	-68.57	4.11	-68.61	9.42			-80.63	128.26	-78.32	142.57	-69.40	150.94	-55.99	74.69	-56.55	96.29
150	-64.31	4.11	-64.34	9.42			-76.37	128.26	-74.05	142.57	-65.13	150.94	-59.74	74.69	-60.29	96.29
200	-62.18	4.11	-62.22	9.42			-74.25	128.26	-71.93	142.57	-63.01	150.94	-61.53	74.69	-62.08	96.29
300	-60.07	4.11	-60.11	9.42			-72.13	128.26	-69.82	142.57	-60.90	150.94	-63.26	74.69	-63.81	96.29
400	-59.01	4.11	-59.05	9.42			-71.08	128.26	-68.76	142.57	-59.84	150.94	-64.10	74.69	-64.66	96.29
500	-58.38	4.11	-58.42	9.42			-70.44	128.26	-68.13	142.57	-59.21	150.94	-64.60	74.69	-65.16	96.29
600	-57.96	4.11	-58.00	9.42			-70.02	128.26	-67.71	142.57	-58.79	150.94	-64.93	74.69	-65.49	96.29
700	-57.66	4.11	-57.69	9.42			-69.72	128.26	-67.40	142.57	-58.49	150.94	-65.17	74.69	-65.72	96.29
800	-57.43	4.11	-57.47	9.42			-69.49	128.26	-67.18	142.57	-58.26	150.94	-65.34	74.69	-65.90	96.29
900	-57.26	4.11	-57.29	9.42			-69.32	128.26	-67.00	142.57	-58.09	150.94	-65.48	74.69	-66.03	96.29
1000	-57.12	4.11	-57.15	9.42			-69.18	128.26	-66.86	142.57	-57.95	150.94	-65.59	74.69	-66.14	96.29
1200	-56.90	4.11	-56.94	9.42			-68.97	128.26	-66.65	142.57	-57.73	150.94	-65.75	74.69	-66.30	96.29
1500	-56.69	4.11	-56.73	9.42			-68.76	128.26	-66.44	142.57	-57.52	150.94	-65.91	74.69	-66.46	96.29
2000	-56.48	4.11	-56.52	9.42			-68.54	128.26	-66.23	142.57	-57.31	150.94	-66.07	74.69	-66.63	96.29
5000	-56.60	4.11	-56.63	9.42			-68.66	128.26	-66.34	142.57	-57.63	150.94	-66.36	74.69	-66.91	96.29
10000	-56.69	4.11	-56.73	9.42			-68.75	128.26	-66.44	142.57	-57.76	150.94	-66.45	74.69	-67.01	96.29
50000	-56.77	4.11	-56.81	9.42			-68.83	128.26	-66.52	142.57	-57.87	150.94	-66.53	74.69	-67.09	96.29
Tangent	-56.79	4.11	-56.82	9.42			-68.85	128.26	-66.54	142.57	-57.90	150.94	-66.55	74.69	-67.10	96.29

Radius:	$P1_{IN}$		$P2_{IN}$		$P4_{IN}$		$P5_{IN}$		$P7_{IN}$		$P8_{IN}$		$P6_{CEN}$		$P9_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
100	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
150	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
200	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
300	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
400	-57.43	146.21	P2in is defined by three points, P2inMAXx, P2inMID and P2inMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		-63.44	199.88	P5in is defined by three points, P5inMAXx, P5inMID and P5inMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		-69.19	251.28	P8in is defined by three points, P8inMAXx, P8inMID and P8inMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-27.50	217.72	-33.25	269.44
500	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
600	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
700	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
800	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
900	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
1000	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
1200	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
1500	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
2000	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
5000	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
10000	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
50000	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44
Tangent	-57.43	146.21			-63.44	199.88			-69.19	251.28			-27.50	217.72	-33.25	269.44

$P2_{INMAXx}$		$P2_{INMID}$		$P2_{INMAXy}$		$P5_{INMAXx}$		$P5_{INMID}$		$P5_{INMAXy}$		$P8_{INMAXx}$		$P8_{INMID}$		$P8_{INMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
-51.53	156.43	-42.85	159.47	-33.90	161.54	-57.54	210.10	-45.55	213.31	-33.35	215.54	-69.19	251.28	-54.66	255.04	-39.92	257.82

Note: Vehicle dynamic envelope values, Y_{MAX}, for $M2_{OUT}$ and $M2_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-13: Vehicle Dynamic Envelope – Outside of Curve

Condition:
Cross Level Variation = **0.5 in**
Superelevation = **4.0 in**

Radius:	$WL1_{OUT}$		$WL2_{OUT}$		$WL3_{OUT}$		$WL4_{OUT}$		$WL5_{OUT}$		$WL6_{OUT}$		$M1_{OUT}$		$M2_{OUT}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	75.47	10.73	75.09	16.07			74.35	133.97	69.53	147.70	55.35	154.83	67.50	82.08	67.47	102.67
100	71.57	10.73	71.20	16.07			70.46	133.97	65.77	147.70	52.87	154.83	65.89	82.08	65.86	102.67
150	65.37	10.73	65.00	16.07			64.25	133.97	59.80	147.70	48.95	154.83	63.27	82.08	63.23	102.67
200	62.14	10.73	61.76	16.07			61.02	133.97	56.70	147.70	46.91	154.83	61.87	82.08	61.84	102.67
300	58.82	10.73	58.45	16.07			57.71	133.97	53.52	147.70	44.82	154.83	60.43	82.08	60.39	102.67
400	57.69	10.73	57.32	16.07			56.58	133.97	52.55	147.70	43.75	154.83	59.68	82.08	59.65	102.67
500	57.23	10.73	56.86	16.07			56.12	133.97	52.09	147.70	43.11	154.83	59.23	82.08	59.19	102.67
600	56.92	10.73	56.55	16.07			55.81	133.97	51.78	147.70	42.68	154.83	58.92	82.08	58.89	102.67
700	56.70	10.73	56.33	16.07			55.58	133.97	51.55	147.70	42.37	154.83	58.70	82.08	58.67	102.67
800	56.53	10.73	56.16	16.07			55.41	133.97	51.39	147.70	42.14	154.83	58.54	82.08	58.50	102.67
900	56.40	10.73	56.03	16.07			55.28	133.97	51.25	147.70	41.96	154.83	58.41	82.08	58.37	102.67
1000	56.30	10.73	55.92	16.07			55.18	133.97	51.15	147.70	41.81	154.83	58.30	82.08	58.27	102.67
1200	56.14	10.73	55.76	16.07			55.02	133.97	50.99	147.70	41.59	154.83	58.15	82.08	58.11	102.67
1500	55.98	10.73	55.61	16.07			54.86	133.97	50.83	147.70	41.37	154.83	57.99	82.08	57.96	102.67
2000	55.82	10.73	55.45	16.07			54.70	133.97	50.67	147.70	41.15	154.83	57.83	82.08	57.80	102.67
5000	55.54	10.73	55.16	16.07			54.42	133.97	50.39	147.70	40.76	154.83	57.55	82.08	57.52	102.67
10000	55.44	10.73	55.06	16.07			54.32	133.97	50.29	147.70	40.63	154.83	57.45	82.08	57.42	102.67
50000	55.36	10.73	54.99	16.07			54.24	133.97	50.21	147.70	40.52	154.83	57.38	82.08	57.35	102.67
Tangent	55.34	10.73	54.97	16.07			54.22	133.97	50.19	147.70	40.49	154.83	57.36	82.08	57.33	102.67

Radius:	$P1_{OUT}$		$P2_{OUT}$		$P4_{OUT}$		$P5_{OUT}$		$P7_{OUT}$		$P8_{OUT}$		$R1_{CEN}$		$P3_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
100	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
150	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
200	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
300	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
400	39.89	151.97	P2out is defined by three points, P2outMAXx, P2outMID and P2outMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		39.53	205.96	P5out is defined by three points, P5outMAXx, P5outMID and P5outMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		39.18	257.68	P8out is defined by three points, P8outMAXx, P8outMID and P8outMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-1.22	17.22	-24.24	164.22
500	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
600	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
700	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
800	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
900	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
1000	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
1200	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
1500	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
2000	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
5000	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
10000	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
50000	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22
Tangent	39.89	151.97			39.53	205.96			39.18	257.68			-1.22	17.22	-24.24	164.22

$P2_{OUTMAXx}$		$P2_{OUTMID}$		$P2_{OUTMAXy}$		$P5_{OUTMAXx}$		$P5_{OUTMID}$		$P5_{OUTMAXy}$		$P8_{OUTMAXx}$		$P8_{OUTMID}$		$P8_{OUTMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
32.82	161.42	23.88	163.41	14.76	164.42	32.46	215.42	20.21	217.19	7.86	217.97	39.18	257.68	24.34	259.71	9.40	260.74

Note: Vehicle dynamic envelope values, Y_{MAX}, for $M2_{OUT}$ and $M2_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-14: Vehicle Dynamic Envelope – Inside of Curve

Condition:
Cross Level Variation = 0.5 in
Superelevation = 4.0 in

Radius:	$WL1_{IN}$		$WL2_{IN}$		$WL3_{IN}$		$WL4_{IN}$		$WL5_{IN}$		$WL6_{IN}$		$M1_{IN}$		$M2_{IN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	-71.57	3.73	-71.69	9.03			-85.50	127.87	-83.43	142.25	-74.68	150.78	-54.66	74.12	-55.30	95.85
100	-68.74	3.73	-68.86	9.03			-82.67	127.87	-80.60	142.25	-71.84	150.78	-57.25	74.12	-57.89	95.85
150	-64.47	3.73	-64.60	9.03			-78.40	127.87	-76.33	142.25	-67.58	150.78	-61.00	74.12	-61.64	95.85
200	-62.35	3.73	-62.48	9.03			-76.28	127.87	-74.21	142.25	-65.46	150.78	-62.79	74.12	-63.43	95.85
300	-60.24	3.73	-60.36	9.03			-74.17	127.87	-72.10	142.25	-63.34	150.78	-64.52	74.12	-65.16	95.85
400	-59.18	3.73	-59.31	9.03			-73.11	127.87	-71.04	142.25	-62.29	150.78	-65.36	74.12	-66.00	95.85
500	-58.55	3.73	-58.67	9.03			-72.48	127.87	-70.41	142.25	-61.65	150.78	-65.86	74.12	-66.50	95.85
600	-58.12	3.73	-58.25	9.03			-72.06	127.87	-69.99	142.25	-61.23	150.78	-66.19	74.12	-66.83	95.85
700	-57.82	3.73	-57.95	9.03			-71.75	127.87	-69.69	142.25	-60.93	150.78	-66.43	74.12	-67.07	95.85
800	-57.60	3.73	-57.72	9.03			-71.53	127.87	-69.46	142.25	-60.71	150.78	-66.60	74.12	-67.24	95.85
900	-57.42	3.73	-57.55	9.03			-71.35	127.87	-69.29	142.25	-60.53	150.78	-66.74	74.12	-67.38	95.85
1000	-57.28	3.73	-57.41	9.03			-71.21	127.87	-69.14	142.25	-60.39	150.78	-66.85	74.12	-67.49	95.85
1200	-57.07	3.73	-57.20	9.03			-71.00	127.87	-68.93	142.25	-60.18	150.78	-67.01	74.12	-67.65	95.85
1500	-56.86	3.73	-56.98	9.03			-70.79	127.87	-68.72	142.25	-59.97	150.78	-67.17	74.12	-67.81	95.85
2000	-56.65	3.73	-56.77	9.03			-70.58	127.87	-68.51	142.25	-59.76	150.78	-67.33	74.12	-67.97	95.85
5000	-56.76	3.73	-56.89	9.03			-70.69	127.87	-68.62	142.25	-60.07	150.78	-67.62	74.12	-68.26	95.85
10000	-56.86	3.73	-56.98	9.03			-70.79	127.87	-68.72	142.25	-60.21	150.78	-67.71	74.12	-68.35	95.85
50000	-56.94	3.73	-57.06	9.03			-70.87	127.87	-68.80	142.25	-60.31	150.78	-67.79	74.12	-68.43	95.85
Tangent	-56.95	3.73	-57.08	9.03			-70.89	127.87	-68.82	142.25	-60.34	150.78	-67.81	74.12	-68.45	95.85

Radius:	$P1_{IN}$		$P2_{IN}$		$P4_{IN}$		$P5_{IN}$		$P7_{IN}$		$P8_{IN}$		$P6_{CEN}$		$P9_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-59.90	145.80	P2in is defined by three points, P2inMAXx, P2inMID and P2inMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		-66.80	199.35	P5in is defined by three points, P5inMAXx, P5inMID and P5inMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		-73.42	250.65	P8in is defined by three points, P8inMAXx, P8inMID and P8inMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-31.15	218.22	-37.76	269.93
100	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
150	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
200	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
300	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
400	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
500	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
600	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
700	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
800	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
900	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
1000	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
1200	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
1500	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
2000	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
5000	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
10000	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
50000	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93
Tangent	-59.90	145.80			-66.80	199.35			-73.42	250.65			-31.15	218.22	-37.76	269.93

$P2_{INMAXx}$		$P2_{INMID}$		$P2_{INMAXy}$		$P5_{INMAXx}$		$P5_{INMID}$		$P5_{INMAXy}$		$P8_{INMAXx}$		$P8_{INMID}$		$P8_{INMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
-54.17	156.11	-45.54	159.29	-36.61	161.51	-61.08	209.67	-49.14	213.08	-36.97	215.51	-73.42	250.65	-58.95	254.65	-44.25	257.69

Note: Vehicle dynamic envelope values, Y_{MAX}, for $M2_{OUT}$ and $M2_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-15: Vehicle Dynamic Envelope – Outside of Curve

Condition:
Cross Level Variation = 0.5 **in**
Superelevation = 5.0 **in**

Radius:	WL1$_{OUT}$		WL2$_{OUT}$		WL3$_{OUT}$		WL4$_{OUT}$		WL5$_{OUT}$		WL6$_{OUT}$		M1$_{OUT}$		M2$_{OUT}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	75.18	12.08	74.81	17.42			72.19	135.06	67.13	148.69	52.81	155.64	66.11	83.47	65.99	103.90
100	71.29	12.08	70.92	17.42			68.29	135.06	63.37	148.69	50.33	155.64	64.50	83.47	64.38	103.90
150	65.09	12.08	64.71	17.42			62.09	135.06	57.40	148.69	46.40	155.64	61.88	83.47	61.76	103.90
200	61.86	12.08	61.48	17.42			58.86	135.06	54.30	148.69	44.36	155.64	60.48	83.47	60.37	103.90
300	58.54	12.08	58.17	17.42			55.54	135.06	51.12	148.69	42.28	155.64	59.04	83.47	58.92	103.90
400	57.41	12.08	57.04	17.42			54.41	135.06	50.15	148.69	41.21	155.64	58.29	83.47	58.17	103.90
500	56.95	12.08	56.58	17.42			53.95	135.06	49.69	148.69	40.57	155.64	57.84	83.47	57.72	103.90
600	56.64	12.08	56.27	17.42			53.64	135.06	49.38	148.69	40.14	155.64	57.53	83.47	57.41	103.90
700	56.42	12.08	56.05	17.42			53.42	135.06	49.15	148.69	39.83	155.64	57.31	83.47	57.19	103.90
800	56.25	12.08	55.88	17.42			53.25	135.06	48.98	148.69	39.60	155.64	57.15	83.47	57.03	103.90
900	56.12	12.08	55.75	17.42			53.12	135.06	48.85	148.69	39.42	155.64	57.02	83.47	56.90	103.90
1000	56.01	12.08	55.64	17.42			53.02	135.06	48.75	148.69	39.27	155.64	56.91	83.47	56.80	103.90
1200	55.86	12.08	55.48	17.42			52.86	135.06	48.59	148.69	39.05	155.64	56.76	83.47	56.64	103.90
1500	55.70	12.08	55.33	17.42			52.70	135.06	48.43	148.69	38.83	155.64	56.60	83.47	56.48	103.90
2000	55.54	12.08	55.17	17.42			52.54	135.06	48.27	148.69	38.61	155.64	56.44	83.47	56.33	103.90
5000	55.25	12.08	54.88	17.42			52.25	135.06	47.98	148.69	38.22	155.64	56.16	83.47	56.04	103.90
10000	55.16	12.08	54.78	17.42			52.16	135.06	47.89	148.69	38.09	155.64	56.07	83.47	55.95	103.90
50000	55.08	12.08	54.71	17.42			52.08	135.06	47.81	148.69	37.98	155.64	55.99	83.47	55.87	103.90
Tangent	55.06	12.08	54.69	17.42			52.06	135.06	47.79	148.69	37.95	155.64	55.97	83.47	55.85	103.90

Radius:	P1$_{OUT}$		P2$_{OUT}$		P4$_{OUT}$		P5$_{OUT}$		P7$_{OUT}$		P8$_{OUT}$		R1$_{CEN}$		P3$_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
100	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
150	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
200	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
300	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
400	37.33	153.04	P2out is defined by three points, P2outMAXx, P2outMID and P2outMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		36.06	207.03	P5out is defined by three points, P5outMAXx, P5outMID and P5outMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		34.85	258.73	P8out is defined by three points, P8outMAXx, P8outMID and P8outMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-1.52	17.70	-26.98	164.66
500	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
600	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
700	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
800	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
900	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
1000	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
1200	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
1500	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
2000	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
5000	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
10000	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
50000	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66
Tangent	37.33	153.04			36.06	207.03			34.85	258.73			-1.52	17.70	-26.98	164.66

P2$_{OUTMAXx}$		P2$_{OUTMID}$		P2$_{OUTMAXy}$		P5$_{OUTMAXx}$		P5$_{OUTMID}$		P5$_{OUTMAXy}$		P8$_{OUTMAXx}$		P8$_{OUTMID}$		P8$_{OUTMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
30.10	162.37	21.12	164.21	12.00	165.07	28.84	216.36	16.56	217.93	4.19	218.50	34.85	258.73	19.98	260.51	5.02	261.29

Note: Vehicle dynamic envelope values, YMAX, for M2OUT and M2IN are increased by 9" to allow for different installation heights.

Table 520-16: Vehicle Dynamic Envelope – Inside of Curve

Condition:
Cross Level Variation = 0.5 in
Superelevation = 5.0 in

Radius:	$WL1_{IN}$		$WL2_{IN}$		$WL3_{IN}$		$WL4_{IN}$		$WL5_{IN}$		$WL6_{IN}$		$M1_{IN}$		$M2_{IN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-71.73	3.35	-71.94	8.64			-87.52	127.44	-85.70	141.88	-77.11	150.58	-55.91	73.53	-56.63	95.39
100	-68.89	3.35	-69.11	8.64			-84.69	127.44	-82.87	141.88	-74.27	150.58	-58.50	73.53	-59.22	95.39
150	-64.63	3.35	-64.84	8.64			-80.42	127.44	-78.60	141.88	-70.01	150.58	-62.25	73.53	-62.97	95.39
200	-62.51	3.35	-62.72	8.64			-78.30	127.44	-76.48	141.88	-67.89	150.58	-64.03	73.53	-64.76	95.39
300	-60.39	3.35	-60.61	8.64			-76.19	127.44	-74.37	141.88	-65.77	150.58	-65.77	73.53	-66.49	95.39
400	-59.34	3.35	-59.55	8.64			-75.13	127.44	-73.31	141.88	-64.72	150.58	-66.61	73.53	-67.33	95.39
500	-58.71	3.35	-58.92	8.64			-74.50	127.44	-72.68	141.88	-64.09	150.58	-67.11	73.53	-67.83	95.39
600	-58.28	3.35	-58.50	8.64			-74.08	127.44	-72.26	141.88	-63.66	150.58	-67.44	73.53	-68.16	95.39
700	-57.98	3.35	-58.20	8.64			-73.77	127.44	-71.95	141.88	-63.36	150.58	-67.67	73.53	-68.40	95.39
800	-57.76	3.35	-57.97	8.64			-73.55	127.44	-71.73	141.88	-63.14	150.58	-67.85	73.53	-68.57	95.39
900	-57.58	3.35	-57.80	8.64			-73.37	127.44	-71.55	141.88	-62.96	150.58	-67.99	73.53	-68.71	95.39
1000	-57.44	3.35	-57.65	8.64			-73.23	127.44	-71.41	141.88	-62.82	150.58	-68.09	73.53	-68.82	95.39
1200	-57.23	3.35	-57.44	8.64			-73.02	127.44	-71.20	141.88	-62.61	150.58	-68.26	73.53	-68.98	95.39
1500	-57.02	3.35	-57.23	8.64			-72.81	127.44	-70.99	141.88	-62.40	150.58	-68.42	73.53	-69.14	95.39
2000	-56.81	3.35	-57.02	8.64			-72.60	127.44	-70.78	141.88	-62.19	150.58	-68.58	73.53	-69.30	95.39
5000	-56.92	3.35	-57.13	8.64			-72.71	127.44	-70.89	141.88	-62.51	150.58	-68.87	73.53	-69.59	95.39
10000	-57.02	3.35	-57.23	8.64			-72.81	127.44	-70.99	141.88	-62.64	150.58	-68.96	73.53	-69.68	95.39
50000	-57.09	3.35	-57.31	8.64			-72.89	127.44	-71.07	141.88	-62.74	150.58	-69.04	73.53	-69.76	95.39
Tangent	-57.11	3.35	-57.33	8.64			-72.90	127.44	-71.08	141.88	-62.77	150.58	-69.06	73.53	-69.78	95.39

Radius:	$P1_{IN}$		$P2_{IN}$		$P4_{IN}$		$P5_{IN}$		$P7_{IN}$		$P8_{IN}$		$P6_{CEN}$		$P9_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
100	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
150	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
200	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
300	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
400	-62.35	145.34	P2in is defined by three points, P2inMAXx, P2inMID and P2inMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		-70.15	198.77	P5in is defined by three points, P5inMAXx, P5inMID and P5inMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		-77.63	249.95	P8in is defined by three points, P8inMAXx, P8inMID and P8inMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-34.78	218.64	-42.26	270.35
500	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
600	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
700	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
800	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
900	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
1000	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
1200	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
1500	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
2000	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
5000	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
10000	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
50000	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35
Tangent	-62.35	145.34			-70.15	198.77			-77.63	249.95			-34.78	218.64	-42.26	270.35

$P2_{INMAXx}$		$P2_{INMID}$		$P2_{INMAXy}$		$P5_{INMAXx}$		$P5_{INMID}$		$P5_{INMAXy}$		$P8_{INMAXx}$		$P8_{INMID}$		$P8_{INMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
-56.80	155.75	-48.21	159.07	-39.31	161.44	-64.60	209.18	-52.71	212.79	-40.58	215.43	-77.63	249.95	-63.22	254.20	-48.56	257.47

Note: Vehicle dynamic envelope values, Y_{MAX}, for $M2_{OUT}$ and $M2_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-17: Vehicle Dynamic Envelope – Outside of Curve

Condition:
Cross Level Variation = 0.5 in
Superelevation = 6.0 in

Radius:	$WL1_{OUT}$		$WL2_{OUT}$		$WL3_{OUT}$		$WL4_{OUT}$		$WL5_{OUT}$		$WL6_{OUT}$		$M1_{OUT}$		$M2_{OUT}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	74.88	13.43	74.51	18.77			70.01	136.11	64.71	149.64	50.26	156.40	64.70	84.83	64.50	105.10
100	70.99	13.43	70.62	18.77			66.12	136.11	60.96	149.64	47.78	156.40	63.09	84.83	62.89	105.10
150	64.78	13.43	64.41	18.77			59.91	136.11	54.99	149.64	43.85	156.40	60.47	84.83	60.27	105.10
200	61.55	13.43	61.18	18.77			56.68	136.11	51.89	149.64	41.81	156.40	59.08	84.83	58.88	105.10
300	58.23	13.43	57.86	18.77			53.37	136.11	48.71	149.64	39.72	156.40	57.63	84.83	57.43	105.10
400	57.11	13.43	56.74	18.77			52.24	136.11	47.73	149.64	38.66	156.40	56.88	84.83	56.68	105.10
500	56.64	13.43	56.27	18.77			51.78	136.11	47.27	149.64	38.02	156.40	56.43	84.83	56.23	105.10
600	56.33	13.43	55.96	18.77			51.47	136.11	46.96	149.64	37.59	156.40	56.12	84.83	55.92	105.10
700	56.11	13.43	55.74	18.77			51.24	136.11	46.74	149.64	37.28	156.40	55.90	84.83	55.70	105.10
800	55.94	13.43	55.57	18.77			51.08	136.11	46.57	149.64	37.04	156.40	55.74	84.83	55.54	105.10
900	55.81	13.43	55.44	18.77			50.95	136.11	46.44	149.64	36.86	156.40	55.61	84.83	55.41	105.10
1000	55.71	13.43	55.34	18.77			50.84	136.11	46.33	149.64	36.72	156.40	55.50	84.83	55.30	105.10
1200	55.55	13.43	55.18	18.77			50.68	136.11	46.18	149.64	36.50	156.40	55.35	84.83	55.15	105.10
1500	55.39	13.43	55.02	18.77			50.52	136.11	46.02	149.64	36.28	156.40	55.19	84.83	54.99	105.10
2000	55.23	13.43	54.86	18.77			50.37	136.11	45.86	149.64	36.06	156.40	55.04	84.83	54.83	105.10
5000	54.95	13.43	54.58	18.77			50.08	136.11	45.57	149.64	35.67	156.40	54.75	84.83	54.55	105.10
10000	54.85	13.43	54.48	18.77			49.98	136.11	45.47	149.64	35.53	156.40	54.66	84.83	54.46	105.10
50000	54.77	13.43	54.40	18.77			49.90	136.11	45.40	149.64	35.43	156.40	54.58	84.83	54.38	105.10
Tangent	54.75	13.43	54.38	18.77			49.89	136.11	45.38	149.64	35.40	156.40	54.56	84.83	54.36	105.10

Radius:	$P1_{OUT}$		$P2_{OUT}$		$P4_{OUT}$		$P5_{OUT}$		$P7_{OUT}$		$P8_{OUT}$		$R1_{CEN}$		$P3_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	34.75	154.07	P2out is defined by three points, P2outMAXx, P2outMID and P2outMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		32.59	208.03	P5out is defined by three points, P5outMAXx, P5outMID and P5outMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		30.51	259.70	P8out is defined by three points, P8outMAXx, P8outMID and P8outMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-1.82	18.17	-29.71	165.05
100	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
150	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
200	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
300	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
400	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
500	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
600	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
700	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
800	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
900	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
1000	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
1200	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
1500	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
2000	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
5000	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
10000	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
50000	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05
Tangent	34.75	154.07			32.59	208.03			30.51	259.70			-1.82	18.17	-29.71	165.05

$P2_{OUTMAXx}$		$P2_{OUTMID}$		$P2_{OUTMAXy}$		$P5_{OUTMAXx}$		$P5_{OUTMID}$		$P5_{OUTMAXy}$		$P8_{OUTMAXx}$		$P8_{OUTMID}$		$P8_{OUTMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
27.38	163.28	18.37	164.97	9.23	165.67	25.21	217.24	12.91	218.61	0.53	219.00	30.51	259.70	15.61	261.24	0.64	261.78

Note: Vehicle dynamic envelope values, YMAX, for M2OUT and M2IN are increased by 9" to allow for different installation heights.

Table 520-18: Vehicle Dynamic Envelope – Inside of Curve

Condition:
Cross Level Variation = 0.5 in
Superelevation = 6.0 in

Radius:	$WL1_{IN}$		$WL2_{IN}$		$WL3_{IN}$		$WL4_{IN}$		$WL5_{IN}$		$WL6_{IN}$		$M1_{IN}$		$M2_{IN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	-71.88	2.97	-72.18	8.24			-89.52	126.98	-87.95	141.48	-79.52	150.34	-57.14	72.92	-57.95	94.90
100	-69.05	2.97	-69.35	8.24			-86.69	126.98	-85.12	141.48	-76.69	150.34	-59.73	72.92	-60.54	94.90
150	-64.78	2.97	-65.08	8.24			-82.42	126.98	-80.85	141.48	-72.43	150.34	-63.48	72.92	-64.29	94.90
200	-62.66	2.97	-62.96	8.24			-80.30	126.98	-78.73	141.48	-70.30	150.34	-65.27	72.92	-66.07	94.90
300	-60.55	2.97	-60.85	8.24			-78.19	126.98	-76.62	141.48	-68.19	150.34	-67.00	72.92	-67.80	94.90
400	-59.49	2.97	-59.79	8.24			-77.13	126.98	-75.56	141.48	-67.13	150.34	-67.84	72.92	-68.65	94.90
500	-58.86	2.97	-59.16	8.24			-76.50	126.98	-74.93	141.48	-66.50	150.34	-68.34	72.92	-69.15	94.90
600	-58.43	2.97	-58.74	8.24			-76.08	126.98	-74.51	141.48	-66.08	150.34	-68.67	72.92	-69.48	94.90
700	-58.13	2.97	-58.44	8.24			-75.78	126.98	-74.20	141.48	-65.78	150.34	-68.91	72.92	-69.71	94.90
800	-57.91	2.97	-58.21	8.24			-75.55	126.98	-73.98	141.48	-65.55	150.34	-69.08	72.92	-69.89	94.90
900	-57.73	2.97	-58.04	8.24			-75.37	126.98	-73.80	141.48	-65.38	150.34	-69.22	72.92	-70.02	94.90
1000	-57.59	2.97	-57.90	8.24			-75.23	126.98	-73.66	141.48	-65.24	150.34	-69.33	72.92	-70.13	94.90
1200	-57.38	2.97	-57.68	8.24			-75.02	126.98	-73.45	141.48	-65.02	150.34	-69.49	72.92	-70.30	94.90
1500	-57.17	2.97	-57.47	8.24			-74.81	126.98	-73.24	141.48	-64.81	150.34	-69.65	72.92	-70.46	94.90
2000	-56.96	2.97	-57.26	8.24			-74.60	126.98	-73.03	141.48	-64.60	150.34	-69.81	72.92	-70.62	94.90
5000	-57.07	2.97	-57.38	8.24			-74.71	126.98	-73.14	141.48	-64.92	150.34	-70.10	72.92	-70.91	94.90
10000	-57.17	2.97	-57.47	8.24			-74.81	126.98	-73.24	141.48	-65.05	150.34	-70.20	72.92	-71.00	94.90
50000	-57.24	2.97	-57.55	8.24			-74.89	126.98	-73.32	141.48	-65.16	150.34	-70.27	72.92	-71.08	94.90
Tangent	-57.26	2.97	-57.57	8.24			-74.91	126.98	-73.33	141.48	-65.19	150.34	-70.29	72.92	-71.10	94.90

Radius:	$P1_{IN}$		$P2_{IN}$		$P4_{IN}$		$P5_{IN}$		$P7_{IN}$		$P8_{IN}$		$P6_{CEN}$		$P9_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
100	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
150	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
200	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
300	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
400	-64.79	144.84	P2in is defined by three points, P2inMAXx, P2inMID and P2inMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		-73.48	198.14	P5in is defined by three points, P5inMAXx, P5inMID and P5inMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		-81.82	249.18	P8in is defined by three points, P8inMAXx, P8inMID and P8inMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-38.41	219.01	-46.74	270.69
500	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
600	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
700	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
800	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
900	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
1000	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
1200	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
1500	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
2000	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
5000	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
10000	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
50000	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69
Tangent	-64.79	144.84			-73.48	198.14			-81.82	249.18			-38.41	219.01	-46.74	270.69

$P2_{INMAXx}$		$P2_{INMID}$		$P2_{INMAXy}$		$P5_{INMAXx}$		$P5_{INMID}$		$P5_{INMAXy}$		$P8_{INMAXx}$		$P8_{INMID}$		$P8_{INMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
-59.41	155.34	-50.87	158.81	-42.01	161.33	-68.11	208.64	-56.27	212.44	-44.17	215.29	-81.82	249.18	-67.47	253.67	-52.86	257.19

Note: Vehicle dynamic envelope values, Y_{MAX}, for $M2_{OUT}$ and $M2_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-19: Vehicle Dynamic Envelope – Outside of Curve

Condition:
Cross Level Variation = 1.0 in
Superelevation = 0.0 in

Radius:	$WL1_{OUT}$		$WL2_{OUT}$		$WL3_{OUT}$		$WL4_{OUT}$		$WL5_{OUT}$		$WL6_{OUT}$		$M1_{OUT}$		$M2_{OUT}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	76.47	4.56	76.28	9.89			83.83	129.85	80.11	143.89	66.60	151.65	73.49	75.53	73.83	98.14
100	72.58	4.56	72.39	9.89			79.94	129.85	76.36	143.89	64.12	151.65	71.88	75.53	72.23	98.14
150	66.37	4.56	66.18	9.89			73.74	129.85	70.39	143.89	60.19	151.65	69.26	75.53	69.60	98.14
200	63.14	4.56	62.95	9.89			70.50	129.85	67.28	143.89	58.15	151.65	67.86	75.53	68.21	98.14
300	59.83	4.56	59.64	9.89			67.19	129.85	64.11	143.89	56.06	151.65	66.42	75.53	66.76	98.14
400	58.70	4.56	58.51	9.89			66.06	129.85	63.13	143.89	55.00	151.65	65.67	75.53	66.02	98.14
500	58.24	4.56	58.05	9.89			65.60	129.85	62.67	143.89	54.36	151.65	65.22	75.53	65.56	98.14
600	57.93	4.56	57.74	9.89			65.29	129.85	62.36	143.89	53.93	151.65	64.91	75.53	65.26	98.14
700	57.70	4.56	57.51	9.89			65.07	129.85	62.14	143.89	53.62	151.65	64.69	75.53	65.04	98.14
800	57.54	4.56	57.35	9.89			64.90	129.85	61.97	143.89	53.38	151.65	64.53	75.53	64.87	98.14
900	57.41	4.56	57.22	9.89			64.77	129.85	61.84	143.89	53.20	151.65	64.40	75.53	64.74	98.14
1000	57.30	4.56	57.11	9.89			64.66	129.85	61.73	143.89	53.06	151.65	64.29	75.53	64.64	98.14
1200	57.14	4.56	56.95	9.89			64.51	129.85	61.57	143.89	52.84	151.65	64.14	75.53	64.48	98.14
1500	56.98	4.56	56.79	9.89			64.35	129.85	61.41	143.89	52.62	151.65	63.98	75.53	64.33	98.14
2000	56.83	4.56	56.64	9.89			64.19	129.85	61.26	143.89	52.40	151.65	63.82	75.53	64.17	98.14
5000	56.54	4.56	56.35	9.89			63.90	129.85	60.97	143.89	52.01	151.65	63.54	75.53	63.89	98.14
10000	56.44	4.56	56.25	9.89			63.80	129.85	60.87	143.89	51.87	151.65	63.44	75.53	63.79	98.14
50000	56.36	4.56	56.17	9.89			63.73	129.85	60.79	143.89	51.77	151.65	63.37	75.53	63.71	98.14
Tangent	56.34	4.56	56.16	9.89			63.71	129.85	60.78	143.89	51.74	151.65	63.35	75.53	63.70	98.14

Radius:	$P1_{OUT}$		$P2_{OUT}$		$P4_{OUT}$		$P5_{OUT}$		$P7_{OUT}$		$P8_{OUT}$		$R1_{CEN}$		$P3_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
100	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
150	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
200	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
300	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
400	51.23	146.58	P2out is defined by three points, P2outMAXx, P2outMID and P2outMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		54.96	200.45	P5out is defined by three points, P5outMAXx, P5outMID and P5outMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		58.54	252.05	P8out is defined by three points, P8outMAXx, P8outMID and P8outMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-0.26	15.50	-14.65	162.48
500	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
600	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
700	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
800	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
900	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
1000	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
1200	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
1500	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
2000	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
5000	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
10000	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
50000	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48
Tangent	51.23	146.58			54.96	200.45			58.54	252.05			-0.26	15.50	-14.65	162.48

$P2_{OUTMAXx}$		$P2_{OUTMID}$		$P2_{OUTMAXy}$		$P5_{OUTMAXx}$		$P5_{OUTMID}$		$P5_{OUTMAXy}$		$P8_{OUTMAXx}$		$P8_{OUTMID}$		$P8_{OUTMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
44.90	156.54	34.77	159.64	24.39	161.76	48.64	210.41	34.74	213.51	20.65	215.63	58.54	252.05	41.72	255.63	24.71	258.24

Note: Vehicle dynamic envelope values, YMAX, for M2OUT and M2IN are increased by 9" to allow for different installation heights.

Table 520-20: Vehicle Dynamic Envelope – Inside of Curve

Condition:
Cross Level Variation = 1.0 in
Superelevation = 0.0 in

Radius:	$WL1_{IN}$		$WL2_{IN}$		$WL3_{IN}$		$WL4_{IN}$		$WL5_{IN}$		$WL6_{IN}$		$M1_{IN}$		$M2_{IN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	-70.96	4.56	-70.77	9.89			-78.32	129.85	-75.39	143.89	-66.08	151.65	-50.20	75.53	-50.55	98.14
100	-68.13	4.56	-67.94	9.89			-75.49	129.85	-72.56	143.89	-63.25	151.65	-52.79	75.53	-53.14	98.14
150	-63.86	4.56	-63.67	9.89			-71.22	129.85	-68.29	143.89	-58.98	151.65	-56.54	75.53	-56.88	98.14
200	-61.74	4.56	-61.55	9.89			-69.10	129.85	-66.17	143.89	-56.86	151.65	-58.33	75.53	-58.67	98.14
300	-59.63	4.56	-59.44	9.89			-66.99	129.85	-64.06	143.89	-54.75	151.65	-60.06	75.53	-60.40	98.14
400	-58.57	4.56	-58.38	9.89			-65.93	129.85	-63.00	143.89	-53.69	151.65	-60.90	75.53	-61.25	98.14
500	-57.94	4.56	-57.75	9.89			-65.30	129.85	-62.37	143.89	-53.06	151.65	-61.40	75.53	-61.75	98.14
600	-57.52	4.56	-57.33	9.89			-64.88	129.85	-61.95	143.89	-52.64	151.65	-61.73	75.53	-62.08	98.14
700	-57.21	4.56	-57.02	9.89			-64.58	129.85	-61.64	143.89	-52.33	151.65	-61.97	75.53	-62.31	98.14
800	-56.99	4.56	-56.80	9.89			-64.35	129.85	-61.42	143.89	-52.11	151.65	-62.14	75.53	-62.49	98.14
900	-56.81	4.56	-56.62	9.89			-64.18	129.85	-61.24	143.89	-51.93	151.65	-62.28	75.53	-62.62	98.14
1000	-56.67	4.56	-56.48	9.89			-64.03	129.85	-61.10	143.89	-51.79	151.65	-62.39	75.53	-62.73	98.14
1200	-56.46	4.56	-56.27	9.89			-63.82	129.85	-60.89	143.89	-51.58	151.65	-62.55	75.53	-62.89	98.14
1500	-56.25	4.56	-56.06	9.89			-63.61	129.85	-60.68	143.89	-51.37	151.65	-62.71	75.53	-63.05	98.14
2000	-56.04	4.56	-55.85	9.89			-63.40	129.85	-60.47	143.89	-51.16	151.65	-62.87	75.53	-63.22	98.14
5000	-56.15	4.56	-55.96	9.89			-63.51	129.85	-60.58	143.89	-51.48	151.65	-63.16	75.53	-63.50	98.14
10000	-56.25	4.56	-56.06	9.89			-63.61	129.85	-60.68	143.89	-51.61	151.65	-63.25	75.53	-63.60	98.14
50000	-56.33	4.56	-56.14	9.89			-63.69	129.85	-60.76	143.89	-51.72	151.65	-63.33	75.53	-63.68	98.14
Tangent	-56.34	4.56	-56.16	9.89			-63.71	129.85	-60.78	143.89	-51.74	151.65	-63.35	75.53	-63.70	98.14

Radius:	$P1_{IN}$		$P2_{IN}$		$P4_{IN}$		$P5_{IN}$		$P7_{IN}$		$P8_{IN}$		$P6_{CEN}$		$P9_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
100	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
150	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
200	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
300	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
400	-51.23	146.58	P2in is defined by three points, P2inMAXx, P2inMID and P2inMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		-54.96	200.45	P5in is defined by three points, P5inMAXx, P5inMID and P5inMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		-58.54	252.05	P8in is defined by three points, P8inMAXx, P8inMID and P8inMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-18.38	216.47	-21.96	268.18
500	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
600	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
700	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
800	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
900	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
1000	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
1200	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
1500	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
2000	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
5000	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
10000	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
50000	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18
Tangent	-51.23	146.58			-54.96	200.45			-58.54	252.05			-18.38	216.47	-21.96	268.18

$P2_{INMAXx}$		$P2_{INMID}$		$P2_{INMAXy}$		$P5_{INMAXx}$		$P5_{INMID}$		$P5_{INMAXy}$		$P8_{INMAXx}$		$P8_{INMID}$		$P8_{INMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
-44.90	156.54	-34.77	159.64	-24.39	161.76	-48.64	210.41	-34.74	213.51	-20.65	215.63	-58.54	252.05	-41.72	255.63	-24.71	258.24

Note: Vehicle dynamic envelope values, Y_{MAX}, for $M2_{OUT}$ and $M2_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-21: Vehicle Dynamic Envelope – Outside of Curve

Condition:
Cross Level Variation = 1.0 in
Superelevation = 1.0 in

Radius:	$WL1_{OUT}$		$WL2_{OUT}$		$WL3_{OUT}$		$WL4_{OUT}$		$WL5_{OUT}$		$WL6_{OUT}$		$M1_{OUT}$		$M2_{OUT}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	76.29	5.93	76.03	11.27			81.77	131.07	77.80	145.03	64.13	152.62	72.20	77.03	72.46	99.47
100	72.40	5.93	72.14	11.27			77.87	131.07	74.04	145.03	61.66	152.62	70.59	77.03	70.85	99.47
150	66.19	5.93	65.93	11.27			71.67	131.07	68.07	145.03	57.73	152.62	67.97	77.03	68.23	99.47
200	62.96	5.93	62.70	11.27			68.44	131.07	64.97	145.03	55.69	152.62	66.58	77.03	66.84	99.47
300	59.65	5.93	59.39	11.27			65.12	131.07	61.79	145.03	53.60	152.62	65.13	77.03	65.39	99.47
400	58.52	5.93	58.26	11.27			63.99	131.07	60.82	145.03	52.54	152.62	64.38	77.03	64.64	99.47
500	58.06	5.93	57.80	11.27			63.53	131.07	60.36	145.03	51.89	152.62	63.93	77.03	64.19	99.47
600	57.75	5.93	57.49	11.27			63.22	131.07	60.05	145.03	51.46	152.62	63.62	77.03	63.88	99.47
700	57.52	5.93	57.26	11.27			63.00	131.07	59.82	145.03	51.15	152.62	63.40	77.03	63.66	99.47
800	57.36	5.93	57.10	11.27			62.83	131.07	59.66	145.03	50.92	152.62	63.24	77.03	63.50	99.47
900	57.22	5.93	56.96	11.27			62.70	131.07	59.52	145.03	50.74	152.62	63.11	77.03	63.37	99.47
1000	57.12	5.93	56.86	11.27			62.60	131.07	59.42	145.03	50.59	152.62	63.00	77.03	63.27	99.47
1200	56.96	5.93	56.70	11.27			62.44	131.07	59.26	145.03	50.38	152.62	62.85	77.03	63.11	99.47
1500	56.80	5.93	56.54	11.27			62.28	131.07	59.10	145.03	50.16	152.62	62.69	77.03	62.95	99.47
2000	56.64	5.93	56.38	11.27			62.12	131.07	58.94	145.03	49.94	152.62	62.54	77.03	62.80	99.47
5000	56.36	5.93	56.10	11.27			61.83	131.07	58.66	145.03	49.54	152.62	62.25	77.03	62.51	99.47
10000	56.26	5.93	56.00	11.27			61.74	131.07	58.56	145.03	49.41	152.62	62.16	77.03	62.42	99.47
50000	56.18	5.93	55.92	11.27			61.66	131.07	58.48	145.03	49.30	152.62	62.08	77.03	62.34	99.47
Tangent	56.16	5.93	55.90	11.27			61.64	131.07	58.46	145.03	49.28	152.62	62.06	77.03	62.32	99.47

Radius:	$P1_{OUT}$		$P2_{OUT}$		$P4_{OUT}$		$P5_{OUT}$		$P7_{OUT}$		$P8_{OUT}$		$R1_{CEN}$		$P3_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
100	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
150	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
200	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
300	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
400	48.74	147.85	P2out is defined by three points, P2outMAXx, P2outMID and P2outMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		51.57	201.78	P5out is defined by three points, P5outMAXx, P5outMID and P5outMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		54.27	253.43	P8out is defined by three points, P8outMAXx, P8outMID and P8outMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-0.52	16.00	-17.39	163.00
500	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
600	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
700	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
800	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
900	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
1000	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
1200	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
1500	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
2000	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
5000	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
10000	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
50000	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00
Tangent	48.74	147.85			51.57	201.78			54.27	253.43			-0.52	16.00	-17.39	163.00

$P2_{OUTMAXx}$		$P2_{OUTMID}$		$P2_{OUTMAXy}$		$P5_{OUTMAXx}$		$P5_{OUTMID}$		$P5_{OUTMAXy}$		$P8_{OUTMAXx}$		$P8_{OUTMID}$		$P8_{OUTMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
42.25	157.71	32.06	160.63	21.65	162.58	45.07	211.63	31.12	214.50	17.01	216.38	54.27	253.43	37.39	256.73	20.35	259.04

Note: Vehicle dynamic envelope values, YMAX, for M2OUT and M2IN are increased by 9" to allow for different installation heights.

Table 520-22: Vehicle Dynamic Envelope – Inside of Curve

Condition:
Cross Level Variation = 1.0 in
Superelevation = 1.0 in

Radius:	$WL1_{IN}$		$WL2_{IN}$		$WL3_{IN}$		$WL4_{IN}$		$WL5_{IN}$		$WL6_{IN}$		$M1_{IN}$		$M2_{IN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	-71.14	4.18	-71.04	9.50			-80.39	129.58	-77.70	143.71	-68.55	151.65	-51.49	75.01	-51.92	97.79
100	-68.31	4.18	-68.21	9.50			-77.55	129.58	-74.87	143.71	-65.71	151.65	-54.08	75.01	-54.51	97.79
150	-64.04	4.18	-63.94	9.50			-73.29	129.58	-70.60	143.71	-61.45	151.65	-57.83	75.01	-58.26	97.79
200	-61.92	4.18	-61.82	9.50			-71.17	129.58	-68.48	143.71	-59.33	151.65	-59.61	75.01	-60.04	97.79
300	-59.81	4.18	-59.71	9.50			-69.06	129.58	-66.37	143.71	-57.21	151.65	-61.34	75.01	-61.77	97.79
400	-58.75	4.18	-58.65	9.50			-68.00	129.58	-65.31	143.71	-56.16	151.65	-62.19	75.01	-62.62	97.79
500	-58.12	4.18	-58.02	9.50			-67.37	129.58	-64.68	143.71	-55.53	151.65	-62.69	75.01	-63.12	97.79
600	-57.70	4.18	-57.60	9.50			-66.94	129.58	-64.26	143.71	-55.10	151.65	-63.02	75.01	-63.45	97.79
700	-57.40	4.18	-57.30	9.50			-66.64	129.58	-63.96	143.71	-54.80	151.65	-63.25	75.01	-63.68	97.79
800	-57.17	4.18	-57.07	9.50			-66.42	129.58	-63.73	143.71	-54.58	151.65	-63.43	75.01	-63.86	97.79
900	-57.00	4.18	-56.90	9.50			-66.24	129.58	-63.56	143.71	-54.40	151.65	-63.56	75.01	-63.99	97.79
1000	-56.85	4.18	-56.76	9.50			-66.10	129.58	-63.41	143.71	-54.26	151.65	-63.67	75.01	-64.10	97.79
1200	-56.64	4.18	-56.54	9.50			-65.89	129.58	-63.20	143.71	-54.05	151.65	-63.84	75.01	-64.27	97.79
1500	-56.43	4.18	-56.33	9.50			-65.68	129.58	-62.99	143.71	-53.84	151.65	-64.00	75.01	-64.43	97.79
2000	-56.22	4.18	-56.12	9.50			-65.47	129.58	-62.78	143.71	-53.63	151.65	-64.16	75.01	-64.59	97.79
5000	-56.33	4.18	-56.23	9.50			-65.58	129.58	-62.89	143.71	-53.94	151.65	-64.45	75.01	-64.88	97.79
10000	-56.43	4.18	-56.33	9.50			-65.68	129.58	-62.99	143.71	-54.08	151.65	-64.54	75.01	-64.97	97.79
50000	-56.51	4.18	-56.41	9.50			-65.75	129.58	-63.07	143.71	-54.18	151.65	-64.62	75.01	-65.05	97.79
Tangent	-56.53	4.18	-56.43	9.50			-65.77	129.58	-63.09	143.71	-54.21	151.65	-64.64	75.01	-65.07	97.79

Radius:	$P1_{IN}$		$P2_{IN}$		$P4_{IN}$		$P5_{IN}$		$P7_{IN}$		$P8_{IN}$		$P6_{CEN}$		$P9_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
100	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
150	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
200	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
300	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
400	-53.71	146.27	P2in is defined by three points, P2inMAXx, P2inMID and P2inMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		-58.36	200.06	P5in is defined by three points, P5inMAXx, P5inMID and P5inMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		-62.81	251.59	P8in is defined by three points, P8inMAXx, P8inMID and P8inMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-22.03	217.00	-26.48	268.72
500	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
600	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
700	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
800	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
900	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
1000	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
1200	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
1500	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
2000	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
5000	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
10000	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
50000	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72
Tangent	-53.71	146.27			-58.36	200.06			-62.81	251.59			-22.03	217.00	-26.48	268.72

$P2_{INMAXx}$		$P2_{INMID}$		$P2_{INMAXy}$		$P5_{INMAXx}$		$P5_{INMID}$		$P5_{INMAXy}$		$P8_{INMAXx}$		$P8_{INMID}$		$P8_{INMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
-47.56	156.33	-37.46	159.60	-27.10	161.90	-52.20	210.13	-38.34	213.47	-24.28	215.82	-62.81	251.59	-46.03	255.46	-29.06	258.35

Note: Vehicle dynamic envelope values, Y_{MAX}, for $M2_{OUT}$ and $M2_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-23: Vehicle Dynamic Envelope – Outside of Curve

Condition:
Cross Level Variation = 1.0 in
Superelevation = 2.0 in

Radius:	$WL1_{OUT}$		$WL2_{OUT}$		$WL3_{OUT}$		$WL4_{OUT}$		$WL5_{OUT}$		$WL6_{OUT}$		$M1_{OUT}$		$M2_{OUT}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	76.09	7.31	75.78	12.64			79.68	132.26	75.47	146.13	61.65	153.54	70.89	78.50	71.07	100.77
100	72.19	7.31	71.89	12.64			75.78	132.26	71.71	146.13	59.17	153.54	69.28	78.50	69.46	100.77
150	65.99	7.31	65.68	12.64			69.58	132.26	65.74	146.13	55.24	153.54	66.66	78.50	66.83	100.77
200	62.76	7.31	62.45	12.64			66.35	132.26	62.64	146.13	53.20	153.54	65.26	78.50	65.44	100.77
300	59.44	7.31	59.14	12.64			63.03	132.26	59.46	146.13	51.11	153.54	63.81	78.50	63.99	100.77
400	58.31	7.31	58.01	12.64			61.90	132.26	58.49	146.13	50.05	153.54	63.07	78.50	63.25	100.77
500	57.85	7.31	57.55	12.64			61.44	132.26	58.02	146.13	49.41	153.54	62.62	78.50	62.79	100.77
600	57.54	7.31	57.24	12.64			61.13	132.26	57.71	146.13	48.98	153.54	62.31	78.50	62.49	100.77
700	57.32	7.31	57.02	12.64			60.91	132.26	57.49	146.13	48.67	153.54	62.09	78.50	62.27	100.77
800	57.15	7.31	56.85	12.64			60.74	132.26	57.32	146.13	48.44	153.54	61.92	78.50	62.10	100.77
900	57.02	7.31	56.72	12.64			60.61	132.26	57.19	146.13	48.25	153.54	61.80	78.50	61.97	100.77
1000	56.92	7.31	56.61	12.64			60.51	132.26	57.08	146.13	48.11	153.54	61.69	78.50	61.87	100.77
1200	56.76	7.31	56.45	12.64			60.35	132.26	56.93	146.13	47.89	153.54	61.54	78.50	61.71	100.77
1500	56.60	7.31	56.30	12.64			60.19	132.26	56.77	146.13	47.67	153.54	61.38	78.50	61.56	100.77
2000	56.44	7.31	56.14	12.64			60.03	132.26	56.61	146.13	47.45	153.54	61.22	78.50	61.40	100.77
5000	56.15	7.31	55.85	12.64			59.74	132.26	56.32	146.13	47.06	153.54	60.94	78.50	61.12	100.77
10000	56.06	7.31	55.75	12.64			59.65	132.26	56.22	146.13	46.92	153.54	60.84	78.50	61.02	100.77
50000	55.98	7.31	55.68	12.64			59.57	132.26	56.15	146.13	46.82	153.54	60.77	78.50	60.95	100.77
Tangent	55.96	7.31	55.66	12.64			59.55	132.26	56.13	146.13	46.79	153.54	60.75	78.50	60.93	100.77

Radius:	$P1_{OUT}$		$P2_{OUT}$		$P4_{OUT}$		$P5_{OUT}$		$P7_{OUT}$		$P8_{OUT}$		$R1_{CEN}$		$P3_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
100	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
150	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
200	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
300	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
400	46.23	149.08	P2out is defined by three points, P2outMAXx, P2outMID and P2outMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		48.15	203.05	P5out is defined by three points, P5outMAXx, P5outMID and P5outMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		49.98	254.74	P8out is defined by three points, P8outMAXx, P8outMID and P8outMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-0.80	16.50	-20.13	163.48
500	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
600	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
700	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
800	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
900	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
1000	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
1200	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
1500	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
2000	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
5000	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
10000	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
50000	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48
Tangent	46.23	149.08			48.15	203.05			49.98	254.74			-0.80	16.50	-20.13	163.48

$P2_{OUTMAXx}$		$P2_{OUTMID}$		$P2_{OUTMAXy}$		$P5_{OUTMAXx}$		$P5_{OUTMID}$		$P5_{OUTMAXy}$		$P8_{OUTMAXx}$		$P8_{OUTMID}$		$P8_{OUTMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
39.58	158.82	29.34	161.58	18.90	163.35	41.49	212.79	27.49	215.42	13.35	217.06	49.98	254.74	33.05	257.75	15.97	259.78

Note: Vehicle dynamic envelope values, YMAX, for M2OUT and M2IN are increased by 9" to allow for different installation heights.

Table 520-24: Vehicle Dynamic Envelope – Inside of Curve

Condition:
Cross Level Variation = 1.0 in
Superelevation = 2.0 in

Radius:	$WL1_{IN}$		$WL2_{IN}$		$WL3_{IN}$		$WL4_{IN}$		$WL5_{IN}$		$WL6_{IN}$		$M1_{IN}$		$M2_{IN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	-71.32	3.80	-71.31	9.11			-82.44	129.28	-80.00	143.48	-71.01	151.59	-52.77	74.47	-53.28	97.41
100	-68.48	3.80	-68.48	9.11			-79.61	129.28	-77.17	143.48	-68.18	151.59	-55.36	74.47	-55.87	97.41
150	-64.22	3.80	-64.21	9.11			-75.35	129.28	-72.91	143.48	-63.91	151.59	-59.10	74.47	-59.62	97.41
200	-62.10	3.80	-62.09	9.11			-73.23	129.28	-70.79	143.48	-61.79	151.59	-60.89	74.47	-61.41	97.41
300	-59.99	3.80	-59.98	9.11			-71.11	129.28	-68.67	143.48	-59.68	151.59	-62.62	74.47	-63.14	97.41
400	-58.93	3.80	-58.92	9.11			-70.05	129.28	-67.62	143.48	-58.62	151.59	-63.47	74.47	-63.98	97.41
500	-58.30	3.80	-58.29	9.11			-69.42	129.28	-66.98	143.48	-57.99	151.59	-63.97	74.47	-64.48	97.41
600	-57.87	3.80	-57.86	9.11			-69.00	129.28	-66.56	143.48	-57.56	151.59	-64.30	74.47	-64.81	97.41
700	-57.57	3.80	-57.56	9.11			-68.70	129.28	-66.26	143.48	-57.26	151.59	-64.53	74.47	-65.05	97.41
800	-57.35	3.80	-57.34	9.11			-68.47	129.28	-66.03	143.48	-57.04	151.59	-64.71	74.47	-65.22	97.41
900	-57.17	3.80	-57.16	9.11			-68.30	129.28	-65.86	143.48	-56.86	151.59	-64.84	74.47	-65.36	97.41
1000	-57.03	3.80	-57.02	9.11			-68.16	129.28	-65.72	143.48	-56.72	151.59	-64.95	74.47	-65.47	97.41
1200	-56.82	3.80	-56.81	9.11			-67.95	129.28	-65.51	143.48	-56.51	151.59	-65.11	74.47	-65.63	97.41
1500	-56.61	3.80	-56.60	9.11			-67.73	129.28	-65.30	143.48	-56.30	151.59	-65.27	74.47	-65.79	97.41
2000	-56.40	3.80	-56.39	9.11			-67.52	129.28	-65.08	143.48	-56.09	151.59	-65.44	74.47	-65.95	97.41
5000	-56.51	3.80	-56.50	9.11			-67.64	129.28	-65.20	143.48	-56.41	151.59	-65.72	74.47	-66.24	97.41
10000	-56.61	3.80	-56.60	9.11			-67.73	129.28	-65.29	143.48	-56.54	151.59	-65.82	74.47	-66.33	97.41
50000	-56.68	3.80	-56.68	9.11			-67.81	129.28	-65.37	143.48	-56.64	151.59	-65.90	74.47	-66.41	97.41
Tangent	-56.70	3.80	-56.69	9.11			-67.83	129.28	-65.39	143.48	-56.67	151.59	-65.92	74.47	-66.43	97.41

Radius:	$P1_{IN}$		$P2_{IN}$		$P4_{IN}$		$P5_{IN}$		$P7_{IN}$		$P8_{IN}$		$P6_{CEN}$		$P9_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
100	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
150	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
200	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
300	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
400	-56.20	145.91	P2in is defined by three points, P2inMAXx, P2inMID and P2inMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		-61.75	199.62	P5in is defined by three points, P5inMAXx, P5inMID and P5inMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		-67.07	251.07	P8in is defined by three points, P8inMAXx, P8inMID and P8inMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-25.68	217.48	-31.00	269.20
500	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
600	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
700	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
800	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
900	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
1000	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
1200	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
1500	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
2000	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
5000	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
10000	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
50000	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20
Tangent	-56.20	145.91			-61.75	199.62			-67.07	251.07			-25.68	217.48	-31.00	269.20

$P2_{INMAXx}$		$P2_{INMID}$		$P2_{INMAXy}$		$P5_{INMAXx}$		$P5_{INMID}$		$P5_{INMAXy}$		$P8_{INMAXx}$		$P8_{INMID}$		$P8_{INMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
-50.21	156.08	-40.15	159.51	-29.82	161.99	-55.76	209.79	-41.94	213.36	-27.90	215.95	-67.07	251.07	-50.34	255.22	-33.40	258.40

Note: Vehicle dynamic envelope values, Y_{MAX}, for $M2_{OUT}$ and $M2_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-25: Vehicle Dynamic Envelope – Outside of Curve

Condition:
Cross Level Variation = 1.0 in
Superelevation = 3.0 in

Radius:	$WL1_{OUT}$		$WL2_{OUT}$		$WL3_{OUT}$		$WL4_{OUT}$		$WL5_{OUT}$		$WL6_{OUT}$		$M1_{OUT}$		$M2_{OUT}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	75.86	8.68	75.51	14.02			77.57	133.41	73.11	147.19	59.15	154.41	69.55	79.95	69.65	102.05
100	71.97	8.68	71.62	14.02			73.67	133.41	69.35	147.19	56.67	154.41	67.94	79.95	68.04	102.05
150	65.76	8.68	65.41	14.02			67.47	133.41	63.38	147.19	52.74	154.41	65.32	79.95	65.41	102.05
200	62.53	8.68	62.18	14.02			64.24	133.41	60.28	147.19	50.70	154.41	63.93	79.95	64.02	102.05
300	59.21	8.68	58.87	14.02			60.92	133.41	57.10	147.19	48.61	154.41	62.48	79.95	62.57	102.05
400	58.09	8.68	57.74	14.02			59.79	133.41	56.13	147.19	47.55	154.41	61.73	79.95	61.83	102.05
500	57.62	8.68	57.28	14.02			59.33	133.41	55.67	147.19	46.91	154.41	61.28	79.95	61.37	102.05
600	57.31	8.68	56.97	14.02			59.02	133.41	55.36	147.19	46.47	154.41	60.97	79.95	61.07	102.05
700	57.09	8.68	56.74	14.02			58.80	133.41	55.13	147.19	46.16	154.41	60.75	79.95	60.85	102.05
800	56.92	8.68	56.58	14.02			58.63	133.41	54.97	147.19	45.93	154.41	60.59	79.95	60.68	102.05
900	56.79	8.68	56.45	14.02			58.50	133.41	54.83	147.19	45.75	154.41	60.46	79.95	60.55	102.05
1000	56.69	8.68	56.34	14.02			58.40	133.41	54.73	147.19	45.61	154.41	60.36	79.95	60.45	102.05
1200	56.53	8.68	56.18	14.02			58.24	133.41	54.57	147.19	45.39	154.41	60.20	79.95	60.29	102.05
1500	56.37	8.68	56.02	14.02			58.08	133.41	54.41	147.19	45.17	154.41	60.04	79.95	60.14	102.05
2000	56.21	8.68	55.87	14.02			57.92	133.41	54.25	147.19	44.95	154.41	59.89	79.95	59.98	102.05
5000	55.93	8.68	55.58	14.02			57.63	133.41	53.97	147.19	44.55	154.41	59.60	79.95	59.70	102.05
10000	55.83	8.68	55.48	14.02			57.54	133.41	53.87	147.19	44.42	154.41	59.51	79.95	59.60	102.05
50000	55.75	8.68	55.40	14.02			57.46	133.41	53.79	147.19	44.32	154.41	59.43	79.95	59.53	102.05
Tangent	55.73	8.68	55.39	14.02			57.44	133.41	53.77	147.19	44.29	154.41	59.41	79.95	59.51	102.05

Radius:	$P1_{OUT}$		$P2_{OUT}$		$P4_{OUT}$		$P5_{OUT}$		$P7_{OUT}$		$P8_{OUT}$		$R1_{CEN}$		$P3_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
100	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
150	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
200	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
300	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
400	43.71	150.27	P2out is defined by three points, P2outMAXx, P2outMID and P2outMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		44.72	204.26	P5out is defined by three points, P5outMAXx, P5outMID and P5outMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		45.68	255.97	P8out is defined by three points, P8outMAXx, P8outMID and P8outMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-1.08	16.99	-22.87	163.96
500	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
600	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
700	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
800	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
900	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
1000	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
1200	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
1500	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
2000	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
5000	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
10000	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
50000	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96
Tangent	43.71	150.27			44.72	204.26			45.68	255.97			-1.08	16.99	-22.87	163.96

$P2_{OUTMAXx}$		$P2_{OUTMID}$		$P2_{OUTMAXy}$		$P5_{OUTMAXx}$		$P5_{OUTMID}$		$P5_{OUTMAXy}$		$P8_{OUTMAXx}$		$P8_{OUTMID}$		$P8_{OUTMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
36.89	159.90	26.61	162.48	16.14	164.07	37.90	213.89	23.86	216.28	9.68	217.69	45.68	255.97	28.70	258.70	11.59	260.44

Note: Vehicle dynamic envelope values, YMAX, for M2OUT and M2IN are increased by 9" to allow for different installation heights.

Table 520-26: Vehicle Dynamic Envelope – Inside of Curve

Condition:
Cross Level Variation = 1.0 in
Superelevation = 3.0 in

Radius:	WL1$_{IN}$		WL2$_{IN}$		WL3$_{IN}$		WL4$_{IN}$		WL5$_{IN}$		WL6$_{IN}$		M1$_{IN}$		M2$_{IN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	-71.49	3.42	-71.57	8.72			-84.49	128.94	-82.30	143.22	-73.46	151.50	-54.03	73.91	-54.63	97.00
100	-68.65	3.42	-68.73	8.72			-81.65	128.94	-79.46	143.22	-70.63	151.50	-56.62	73.91	-57.22	97.00
150	-64.39	3.42	-64.47	8.72			-77.39	128.94	-75.20	143.22	-66.36	151.50	-60.37	73.91	-60.97	97.00
200	-62.27	3.42	-62.35	8.72			-75.27	128.94	-73.08	143.22	-64.24	151.50	-62.16	73.91	-62.76	97.00
300	-60.15	3.42	-60.23	8.72			-73.15	128.94	-70.96	143.22	-62.13	151.50	-63.89	73.91	-64.49	97.00
400	-59.10	3.42	-59.18	8.72			-72.10	128.94	-69.91	143.22	-61.07	151.50	-64.73	73.91	-65.33	97.00
500	-58.47	3.42	-58.55	8.72			-71.46	128.94	-69.27	143.22	-60.44	151.50	-65.23	73.91	-65.83	97.00
600	-58.04	3.42	-58.12	8.72			-71.04	128.94	-68.85	143.22	-60.02	151.50	-65.56	73.91	-66.16	97.00
700	-57.74	3.42	-57.82	8.72			-70.74	128.94	-68.55	143.22	-59.71	151.50	-65.80	73.91	-66.40	97.00
800	-57.52	3.42	-57.60	8.72			-70.52	128.94	-68.32	143.22	-59.49	151.50	-65.97	73.91	-66.57	97.00
900	-57.34	3.42	-57.42	8.72			-70.34	128.94	-68.15	143.22	-59.31	151.50	-66.11	73.91	-66.71	97.00
1000	-57.20	3.42	-57.28	8.72			-70.20	128.94	-68.01	143.22	-59.17	151.50	-66.22	73.91	-66.82	97.00
1200	-56.99	3.42	-57.07	8.72			-69.99	128.94	-67.80	143.22	-58.96	151.50	-66.38	73.91	-66.98	97.00
1500	-56.78	3.42	-56.86	8.72			-69.78	128.94	-67.59	143.22	-58.75	151.50	-66.54	73.91	-67.14	97.00
2000	-56.57	3.42	-56.65	8.72			-69.57	128.94	-67.38	143.22	-58.54	151.50	-66.70	73.91	-67.30	97.00
5000	-56.68	3.42	-56.76	8.72			-69.68	128.94	-67.49	143.22	-58.86	151.50	-66.99	73.91	-67.59	97.00
10000	-56.78	3.42	-56.86	8.72			-69.78	128.94	-67.58	143.22	-58.99	151.50	-67.09	73.91	-67.68	97.00
50000	-56.85	3.42	-56.93	8.72			-69.85	128.94	-67.66	143.22	-59.10	151.50	-67.16	73.91	-67.76	97.00
Tangent	-56.87	3.42	-56.95	8.72			-69.87	128.94	-67.68	143.22	-59.12	151.50	-67.18	73.91	-67.78	97.00

Radius:	P1$_{IN}$		P2$_{IN}$		P4$_{IN}$		P5$_{IN}$		P7$_{IN}$		P8$_{IN}$		P6$_{CEN}$		P9$_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
100	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
150	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
200	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
300	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
400	-58.67	145.51	P2in is defined by three points, P2inMAXx, P2inMID and P2inMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		-65.13	199.12	P5in is defined by three points, P5inMAXx, P5inMID and P5inMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		-71.31	250.47	P8in is defined by three points, P8inMAXx, P8inMID and P8inMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-29.33	217.96	-35.51	269.67
500	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
600	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
700	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
800	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
900	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
1000	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
1200	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
1500	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
2000	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
5000	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
10000	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
50000	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67
Tangent	-58.67	145.51			-65.13	199.12			-71.31	250.47			-29.33	217.96	-35.51	269.67

P2$_{INMAXx}$		P2$_{INMID}$		P2$_{INMAXy}$		P5$_{INMAXx}$		P5$_{INMID}$		P5$_{INMAXy}$		P8$_{INMAXx}$		P8$_{INMID}$		P8$_{INMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
-52.86	155.78	-42.84	159.38	-32.53	162.03	-59.31	209.39	-45.54	213.19	-31.53	216.02	-71.31	250.47	-54.64	254.91	-37.74	258.37

Note: Vehicle dynamic envelope values, Y_{MAX}, for M2$_{OUT}$ and M2$_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-27: Vehicle Dynamic Envelope – Outside of Curve

Condition:
Cross Level Variation = **1.0 in**
Superelevation = **4.0 in**

Radius: (feet)	$WL1_{OUT}$ X_{MAX}	$WL1_{OUT}$ Y_{MIN}	$WL2_{OUT}$ X_{MAX}	$WL2_{OUT}$ Y_{MIN}	$WL3_{OUT}$ X_{MAX}	$WL3_{OUT}$ Y_{MIN}	$WL4_{OUT}$ X_{MAX}	$WL4_{OUT}$ Y_{MAX}	$WL5_{OUT}$ X_{MAX}	$WL5_{OUT}$ Y_{MAX}	$WL6_{OUT}$ X_{MAX}	$WL6_{OUT}$ Y_{MAX}	$M1_{OUT}$ X_{MAX}	$M1_{OUT}$ Y_{MIN}	$M2_{OUT}$ X_{MAX}	$M2_{OUT}$ Y_{MAX}
82	75.61	10.04	75.23	15.38			75.43	134.52	70.74	148.20	56.63	155.24	68.20	81.38	68.20	103.29
100	71.72	10.04	71.34	15.38			71.54	134.52	66.98	148.20	54.15	155.24	66.59	81.38	66.60	103.29
150	65.51	10.04	65.13	15.38			65.34	134.52	61.01	148.20	50.22	155.24	63.96	81.38	63.97	103.29
200	62.28	10.04	61.90	15.38			62.10	134.52	57.91	148.20	48.18	155.24	62.57	81.38	62.58	103.29
300	58.96	10.04	58.59	15.38			58.79	134.52	54.73	148.20	46.09	155.24	61.12	81.38	61.13	103.29
400	57.84	10.04	57.46	15.38			57.66	134.52	53.76	148.20	45.03	155.24	60.38	81.38	60.39	103.29
500	57.37	10.04	57.00	15.38			57.20	134.52	53.29	148.20	44.39	155.24	59.92	81.38	59.93	103.29
600	57.06	10.04	56.69	15.38			56.89	134.52	52.98	148.20	43.96	155.24	59.62	81.38	59.63	103.29
700	56.84	10.04	56.47	15.38			56.67	134.52	52.76	148.20	43.65	155.24	59.40	81.38	59.41	103.29
800	56.67	10.04	56.30	15.38			56.50	134.52	52.59	148.20	43.41	155.24	59.23	81.38	59.24	103.29
900	56.54	10.04	56.17	15.38			56.37	134.52	52.46	148.20	43.23	155.24	59.10	81.38	59.11	103.29
1000	56.44	10.04	56.06	15.38			56.26	134.52	52.36	148.20	43.09	155.24	59.00	81.38	59.01	103.29
1200	56.28	10.04	55.90	15.38			56.11	134.52	52.20	148.20	42.87	155.24	58.84	81.38	58.85	103.29
1500	56.12	10.04	55.75	15.38			55.95	134.52	52.04	148.20	42.65	155.24	58.69	81.38	58.70	103.29
2000	55.96	10.04	55.59	15.38			55.79	134.52	51.88	148.20	42.43	155.24	58.53	81.38	58.54	103.29
5000	55.68	10.04	55.30	15.38			55.50	134.52	51.59	148.20	42.04	155.24	58.25	81.38	58.26	103.29
10000	55.58	10.04	55.20	15.38			55.40	134.52	51.50	148.20	41.90	155.24	58.15	81.38	58.16	103.29
50000	55.50	10.04	55.13	15.38			55.33	134.52	51.42	148.20	41.80	155.24	58.07	81.38	58.08	103.29
Tangent	55.48	10.04	55.11	15.38			55.31	134.52	51.40	148.20	41.77	155.24	58.06	81.38	58.06	103.29

Radius: (feet)	$P1_{OUT}$ X_{MAX}	$P1_{OUT}$ Y_{MIN}	$P2_{OUT}$ X_{MAX}	$P2_{OUT}$ Y_{MAX}	$P4_{OUT}$ X_{MAX}	$P4_{OUT}$ Y_{MIN}	$P5_{OUT}$ X_{MAX}	$P5_{OUT}$ Y_{MAX}	$P7_{OUT}$ X_{MAX}	$P7_{OUT}$ Y_{MIN}	$P8_{OUT}$ X_{MAX}	$P8_{OUT}$ Y_{MAX}	$R1_{CEN}$ X_{MAX}	$R1_{CEN}$ Y_{MAX}	$P3_{CEN}$ X_{MAX}	$P3_{CEN}$ Y_{MAX}
82	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
100	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
150	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
200	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
300	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
400	41.17	151.41	P2out is defined by three points, P2outMAXx, P2outMID and P2outMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		41.27	205.41	P5out is defined by three points, P5outMAXx, P5outMID and P5outMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		41.36	257.13	P8out is defined by three points, P8outMAXx, P8outMID and P8outMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-1.37	17.48	-25.62	164.48
500	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
600	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
700	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
800	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
900	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
1000	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
1200	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
1500	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
2000	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
5000	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
10000	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
50000	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48
Tangent	41.17	151.41			41.27	205.41			41.36	257.13			-1.37	17.48	-25.62	164.48

$P2_{OUTMAXx}$ X_{MAX}	$P2_{OUTMAXx}$ Y_{MAX}	$P2_{OUTMID}$ X_{MAX}	$P2_{OUTMID}$ Y_{MAX}	$P2_{OUTMAXy}$ X_{MAX}	$P2_{OUTMAXy}$ Y_{MAX}	$P5_{OUTMAXx}$ X_{MAX}	$P5_{OUTMAXx}$ Y_{MAX}	$P5_{OUTMID}$ X_{MAX}	$P5_{OUTMID}$ Y_{MAX}	$P5_{OUTMAXy}$ X_{MAX}	$P5_{OUTMAXy}$ Y_{MAX}	$P8_{OUTMAXx}$ X_{MAX}	$P8_{OUTMAXx}$ Y_{MAX}	$P8_{OUTMID}$ X_{MAX}	$P8_{OUTMID}$ Y_{MAX}	$P8_{OUTMAXy}$ X_{MAX}	$P8_{OUTMAXy}$ Y_{MAX}
34.19	160.92	23.87	163.33	13.37	164.75	34.29	214.92	20.21	217.08	6.02	218.25	34.29	214.92	20.21	217.08	6.02	218.25

Note: Vehicle dynamic envelope values, YMAX, for M2OUT and M2IN are increased by 9" to allow for different installation heights.

Table 520-28: Vehicle Dynamic Envelope – Inside of Curve

Condition:
Cross Level Variation = 1.0 in
Superelevation = 4.0 in

Radius:	$WL1_{IN}$		$WL2_{IN}$		$WL3_{IN}$		$WL4_{IN}$		$WL5_{IN}$		$WL6_{IN}$		$M1_{IN}$		$M2_{IN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	-71.65	3.04	-71.82	8.33			-86.52	128.57	-84.57	142.91	-75.90	151.37	-55.29	73.33	-55.97	96.58
100	-68.82	3.04	-68.99	8.33			-83.68	128.57	-81.74	142.91	-73.07	151.37	-57.88	73.33	-58.56	96.58
150	-64.55	3.04	-64.72	8.33			-79.42	128.57	-77.48	142.91	-68.80	151.37	-61.63	73.33	-62.31	96.58
200	-62.43	3.04	-62.60	8.33			-77.30	128.57	-75.35	142.91	-66.68	151.37	-63.41	73.33	-64.10	96.58
300	-60.32	3.04	-60.49	8.33			-75.18	128.57	-73.24	142.91	-64.57	151.37	-65.15	73.33	-65.83	96.58
400	-59.26	3.04	-59.43	8.33			-74.13	128.57	-72.18	142.91	-63.51	151.37	-65.99	73.33	-66.67	96.58
500	-58.63	3.04	-58.80	8.33			-73.49	128.57	-71.55	142.91	-62.88	151.37	-66.49	73.33	-67.17	96.58
600	-58.21	3.04	-58.38	8.33			-73.07	128.57	-71.13	142.91	-62.46	151.37	-66.82	73.33	-67.50	96.58
700	-57.90	3.04	-58.07	8.33			-72.77	128.57	-70.83	142.91	-62.15	151.37	-67.06	73.33	-67.74	96.58
800	-57.68	3.04	-57.85	8.33			-72.55	128.57	-70.60	142.91	-61.93	151.37	-67.23	73.33	-67.91	96.58
900	-57.50	3.04	-57.67	8.33			-72.37	128.57	-70.43	142.91	-61.75	151.37	-67.37	73.33	-68.05	96.58
1000	-57.36	3.04	-57.53	8.33			-72.23	128.57	-70.29	142.91	-61.61	151.37	-67.47	73.33	-68.16	96.58
1200	-57.15	3.04	-57.32	8.33			-72.02	128.57	-70.07	142.91	-61.40	151.37	-67.64	73.33	-68.32	96.58
1500	-56.94	3.04	-57.11	8.33			-71.81	128.57	-69.86	142.91	-61.19	151.37	-67.80	73.33	-68.48	96.58
2000	-56.73	3.04	-56.90	8.33			-71.60	128.57	-69.65	142.91	-60.98	151.37	-67.96	73.33	-68.64	96.58
5000	-56.84	3.04	-57.01	8.33			-71.71	128.57	-69.77	142.91	-61.30	151.37	-68.25	73.33	-68.93	96.58
10000	-56.94	3.04	-57.11	8.33			-71.81	128.57	-69.86	142.91	-61.43	151.37	-68.34	73.33	-69.02	96.58
50000	-57.02	3.04	-57.19	8.33			-71.88	128.57	-69.94	142.91	-61.54	151.37	-68.42	73.33	-69.10	96.58
Tangent	-57.03	3.04	-57.21	8.33			-71.90	128.57	-69.96	142.91	-61.56	151.37	-68.44	73.33	-69.12	96.58

Radius:	$P1_{IN}$		$P2_{IN}$		$P4_{IN}$		$P5_{IN}$		$P7_{IN}$		$P8_{IN}$		$P6_{CEN}$		$P9_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
100	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
150	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
200	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
300	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
400	-61.13	145.07	P2in is defined by three points, P2inMAXx, P2inMID and P2inMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		-68.49	198.57	P5in is defined by three points, P5inMAXx, P5inMID and P5inMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		-75.54	249.81	P8in is defined by three points, P8inMAXx, P8inMID and P8inMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-32.97	218.48	-40.02	270.20
500	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
600	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
700	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
800	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
900	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
1000	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
1200	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
1500	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
2000	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
5000	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
10000	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
50000	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20
Tangent	-61.13	145.07			-68.49	198.57			-75.54	249.81			-32.97	218.48	-40.02	270.20

$P2_{INMAXx}$		$P2_{INMID}$		$P2_{INMAXy}$		$P5_{INMAXx}$		$P5_{INMID}$		$P5_{INMAXy}$		$P8_{INMAXx}$		$P8_{INMID}$		$P8_{INMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
-55.49	155.44	-45.52	159.21	-35.24	162.03	-62.85	208.93	-49.12	212.97	-35.15	216.03	-62.85	208.93	-49.12	212.97	-35.15	216.03

Note: Vehicle dynamic envelope values, Y_{MAX}, for $M2_{OUT}$ and $M2_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-29: Vehicle Dynamic Envelope – Outside of Curve

Condition:
Cross Level Variation = 1.0 in
Superelevation = 5.0 in

Radius:	$WL1_{OUT}$		$WL2_{OUT}$		$WL3_{OUT}$		$WL4_{OUT}$		$WL5_{OUT}$		$WL6_{OUT}$		$M1_{OUT}$		$M2_{OUT}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	75.34	11.40	74.96	16.74			73.28	135.59	68.35	149.17	54.10	156.03	66.82	82.78	66.74	104.51
100	71.44	11.40	71.07	16.74			69.39	135.59	64.59	149.17	51.62	156.03	65.21	82.78	65.13	104.51
150	65.24	11.40	64.86	16.74			63.19	135.59	58.62	149.17	47.69	156.03	62.59	82.78	62.51	104.51
200	62.01	11.40	61.63	16.74			59.95	135.59	55.52	149.17	45.65	156.03	61.19	82.78	61.12	104.51
300	58.69	11.40	58.32	16.74			56.64	135.59	52.34	149.17	43.56	156.03	59.74	82.78	59.67	104.51
400	57.56	11.40	57.19	16.74			55.51	135.59	51.37	149.17	42.50	156.03	59.00	82.78	58.92	104.51
500	57.10	11.40	56.73	16.74			55.05	135.59	50.90	149.17	41.86	156.03	58.54	82.78	58.47	104.51
600	56.79	11.40	56.42	16.74			54.74	135.59	50.59	149.17	41.42	156.03	58.24	82.78	58.16	104.51
700	56.57	11.40	56.20	16.74			54.52	135.59	50.37	149.17	41.12	156.03	58.02	82.78	57.94	104.51
800	56.40	11.40	56.03	16.74			54.35	135.59	50.20	149.17	40.88	156.03	57.85	82.78	57.78	104.51
900	56.27	11.40	55.90	16.74			54.22	135.59	50.07	149.17	40.70	156.03	57.72	82.78	57.65	104.51
1000	56.17	11.40	55.79	16.74			54.11	135.59	49.96	149.17	40.56	156.03	57.62	82.78	57.55	104.51
1200	56.01	11.40	55.63	16.74			53.96	135.59	49.81	149.17	40.34	156.03	57.47	82.78	57.39	104.51
1500	55.85	11.40	55.48	16.74			53.80	135.59	49.65	149.17	40.12	156.03	57.31	82.78	57.23	104.51
2000	55.69	11.40	55.32	16.74			53.64	135.59	49.49	149.17	39.90	156.03	57.15	82.78	57.08	104.51
5000	55.40	11.40	55.03	16.74			53.35	135.59	49.20	149.17	39.50	156.03	56.87	82.78	56.79	104.51
10000	55.31	11.40	54.93	16.74			53.25	135.59	49.10	149.17	39.37	156.03	56.77	82.78	56.70	104.51
50000	55.23	11.40	54.86	16.74			53.18	135.59	49.03	149.17	39.27	156.03	56.70	82.78	56.62	104.51
Tangent	55.21	11.40	54.84	16.74			53.16	135.59	49.01	149.17	39.24	156.03	56.68	82.78	56.60	104.51

Radius:	$P1_{OUT}$		$P2_{OUT}$		$P4_{OUT}$		$P5_{OUT}$		$P7_{OUT}$		$P8_{OUT}$		$R1_{CEN}$		$P3_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
100	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
150	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
200	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
300	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
400	38.62	152.51	P2out is defined by three points, P2outMAXx, P2outMID and P2outMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		37.81	206.50	P5out is defined by three points, P5outMAXx, P5outMID and P5outMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		37.04	258.21	P8out is defined by three points, P8outMAXx, P8outMID and P8outMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-1.67	17.96	-28.35	164.94
500	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
600	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
700	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
800	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
900	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
1000	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
1200	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
1500	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
2000	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
5000	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
10000	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
50000	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94
Tangent	38.62	152.51			37.81	206.50			37.04	258.21			-1.67	17.96	-28.35	164.94

$P2_{OUTMAXx}$		$P2_{OUTMID}$		$P2_{OUTMAXy}$		$P5_{OUTMAXx}$		$P5_{OUTMID}$		$P5_{OUTMAXy}$		$P8_{OUTMAXx}$		$P8_{OUTMID}$		$P8_{OUTMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
31.48	161.90	21.12	164.13	10.60	165.38	30.67	215.89	16.56	217.82	2.35	218.74	37.04	258.21	19.97	260.37	2.81	261.54

Note: Vehicle dynamic envelope values, YMAX, for M2OUT and M2IN are increased by 9" to allow for different installation heights.

Table 520-30: Vehicle Dynamic Envelope – Inside of Curve

Condition:
Cross Level Variation = 1.0 in
Superelevation = 5.0 in

Radius:	$WL1_{IN}$		$WL2_{IN}$		$WL3_{IN}$		$WL4_{IN}$		$WL5_{IN}$		$WL6_{IN}$		$M1_{IN}$		$M2_{IN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	-71.80	2.66	-72.06	7.94			-88.53	128.16	-86.83	142.57	-78.33	151.19	-56.53	72.73	-57.30	96.13
100	-68.97	2.66	-69.23	7.94			-85.70	128.16	-84.00	142.57	-75.49	151.19	-59.12	72.73	-59.89	96.13
150	-64.71	2.66	-64.97	7.94			-81.43	128.16	-79.74	142.57	-71.23	151.19	-62.87	72.73	-63.63	96.13
200	-62.59	2.66	-62.85	7.94			-79.31	128.16	-77.62	142.57	-69.11	151.19	-64.66	72.73	-65.42	96.13
300	-60.47	2.66	-60.73	7.94			-77.20	128.16	-75.50	142.57	-66.99	151.19	-66.39	72.73	-67.15	96.13
400	-59.42	2.66	-59.68	7.94			-76.14	128.16	-74.45	142.57	-65.94	151.19	-67.23	72.73	-68.00	96.13
500	-58.78	2.66	-59.04	7.94			-75.51	128.16	-73.81	142.57	-65.30	151.19	-67.73	72.73	-68.50	96.13
600	-58.36	2.66	-58.62	7.94			-75.09	128.16	-73.39	142.57	-64.88	151.19	-68.06	72.73	-68.83	96.13
700	-58.06	2.66	-58.32	7.94			-74.79	128.16	-73.09	142.57	-64.58	151.19	-68.30	72.73	-69.06	96.13
800	-57.83	2.66	-58.09	7.94			-74.56	128.16	-72.86	142.57	-64.36	151.19	-68.47	72.73	-69.24	96.13
900	-57.66	2.66	-57.92	7.94			-74.38	128.16	-72.69	142.57	-64.18	151.19	-68.61	72.73	-69.37	96.13
1000	-57.52	2.66	-57.78	7.94			-74.24	128.16	-72.55	142.57	-64.04	151.19	-68.72	72.73	-69.48	96.13
1200	-57.31	2.66	-57.57	7.94			-74.03	128.16	-72.34	142.57	-63.83	151.19	-68.88	72.73	-69.64	96.13
1500	-57.09	2.66	-57.36	7.94			-73.82	128.16	-72.13	142.57	-63.62	151.19	-69.04	72.73	-69.81	96.13
2000	-56.88	2.66	-57.14	7.94			-73.61	128.16	-71.91	142.57	-63.41	151.19	-69.20	72.73	-69.97	96.13
5000	-57.00	2.66	-57.26	7.94			-73.72	128.16	-72.03	142.57	-63.72	151.19	-69.49	72.73	-70.25	96.13
10000	-57.09	2.66	-57.35	7.94			-73.82	128.16	-72.12	142.57	-63.86	151.19	-69.59	72.73	-70.35	96.13
50000	-57.17	2.66	-57.43	7.94			-73.90	128.16	-72.20	142.57	-63.96	151.19	-69.66	72.73	-70.43	96.13
Tangent	-57.19	2.66	-57.45	7.94			-73.92	128.16	-72.22	142.57	-63.99	151.19	-69.68	72.73	-70.45	96.13

Radius:	$P1_{IN}$		$P2_{IN}$		$P4_{IN}$		$P5_{IN}$		$P7_{IN}$		$P8_{IN}$		$P6_{CEN}$		$P9_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
100	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
150	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
200	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
300	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
400	-63.58	144.59	P2in is defined by three points, P2inMAXx, P2inMID and P2inMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		-71.83	197.96	P5in is defined by three points, P5inMAXx, P5inMID and P5inMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		-79.74	249.07	P8in is defined by three points, P8inMAXx, P8inMID and P8inMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-36.61	218.94	-44.52	270.65
500	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
600	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
700	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
800	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
900	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
1000	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
1200	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
1500	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
2000	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
5000	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
10000	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
50000	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65
Tangent	-63.58	144.59			-71.83	197.96			-79.74	249.07			-36.61	218.94	-44.52	270.65

$P2_{INMAXx}$		$P2_{INMID}$		$P2_{INMAXy}$		$P5_{INMAXx}$		$P5_{INMID}$		$P5_{INMAXy}$		$P8_{INMAXx}$		$P8_{INMID}$		$P8_{INMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
-58.11	155.05	-48.19	158.99	-37.95	161.99	-66.37	208.42	-52.69	212.68	-38.76	215.98	-79.74	249.07	-63.20	254.06	-46.39	258.09

Note: Vehicle dynamic envelope values, Y_{MAX}, for $M2_{OUT}$ and $M2_{IN}$ are increased by 9" to allow for different installation heights.

Table 520-31: Vehicle Dynamic Envelope – Outside of Curve

Condition:
Cross Level Variation = 1.0 in
Superelevation = 6.0 in

Radius:	$WL1_{OUT}$		$WL2_{OUT}$		$WL3_{OUT}$		$WL4_{OUT}$		$WL5_{OUT}$		$WL6_{OUT}$		$M1_{OUT}$		$M2_{OUT}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	75.04	12.75	74.67	18.09			71.12	136.62	65.94	150.10	51.55	156.77	65.42	84.15	65.26	105.70
100	71.15	12.75	70.78	18.09			67.22	136.62	62.19	150.10	49.08	156.77	63.81	84.15	63.65	105.70
150	64.94	12.75	64.57	18.09			61.02	136.62	56.22	150.10	45.15	156.77	61.19	84.15	61.03	105.70
200	61.71	12.75	61.34	18.09			57.79	136.62	53.11	150.10	43.11	156.77	59.80	84.15	59.64	105.70
300	58.40	12.75	58.03	18.09			54.47	136.62	49.94	150.10	41.02	156.77	58.35	84.15	58.19	105.70
400	57.27	12.75	56.90	18.09			53.34	136.62	48.96	150.10	39.96	156.77	57.60	84.15	57.44	105.70
500	56.81	12.75	56.44	18.09			52.88	136.62	48.50	150.10	39.31	156.77	57.15	84.15	56.99	105.70
600	56.50	12.75	56.13	18.09			52.57	136.62	48.19	150.10	38.88	156.77	56.84	84.15	56.68	105.70
700	56.28	12.75	55.90	18.09			52.35	136.62	47.96	150.10	38.57	156.77	56.62	84.15	56.46	105.70
800	56.11	12.75	55.74	18.09			52.18	136.62	47.80	150.10	38.34	156.77	56.46	84.15	56.30	105.70
900	55.98	12.75	55.61	18.09			52.05	136.62	47.67	150.10	38.16	156.77	56.33	84.15	56.17	105.70
1000	55.87	12.75	55.50	18.09			51.95	136.62	47.56	150.10	38.01	156.77	56.22	84.15	56.07	105.70
1200	55.71	12.75	55.34	18.09			51.79	136.62	47.40	150.10	37.80	156.77	56.07	84.15	55.91	105.70
1500	55.56	12.75	55.18	18.09			51.63	136.62	47.24	150.10	37.58	156.77	55.91	84.15	55.75	105.70
2000	55.40	12.75	55.03	18.09			51.47	136.62	47.08	150.10	37.36	156.77	55.75	84.15	55.60	105.70
5000	55.11	12.75	54.74	18.09			51.18	136.62	46.80	150.10	36.96	156.77	55.47	84.15	55.31	105.70
10000	55.01	12.75	54.64	18.09			51.09	136.62	46.70	150.10	36.83	156.77	55.38	84.15	55.22	105.70
50000	54.94	12.75	54.56	18.09			51.01	136.62	46.62	150.10	36.72	156.77	55.30	84.15	55.14	105.70
Tangent	54.92	12.75	54.54	18.09			50.99	136.62	46.60	150.10	36.70	156.77	55.28	84.15	55.12	105.70

Radius:	$P1_{OUT}$		$P2_{OUT}$		$P4_{OUT}$		$P5_{OUT}$		$P7_{OUT}$		$P8_{OUT}$		$R1_{CEN}$		$P3_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
100	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
150	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
200	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
300	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
400	36.06	153.56	P2out is defined by three points, P2outMAXx, P2outMID and P2outMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		34.35	207.53	P5out is defined by three points, P5outMAXx, P5outMID and P5outMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		32.71	259.22	P8out is defined by three points, P8outMAXx, P8outMID and P8outMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-1.97	18.43	-31.09	165.36
500	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
600	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
700	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
800	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
900	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
1000	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
1200	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
1500	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
2000	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
5000	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
10000	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
50000	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36
Tangent	36.06	153.56			34.35	207.53			32.71	259.22			-1.97	18.43	-31.09	165.36

$P2_{OUTMAXx}$		$P2_{OUTMID}$		$P2_{OUTMAXy}$		$P5_{OUTMAXx}$		$P5_{OUTMID}$		$P5_{OUTMAXy}$		$P8_{OUTMAXx}$		$P8_{OUTMID}$		$P8_{OUTMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
28.76	162.83	18.37	164.89	7.83	165.96	27.05	216.80	12.91	218.52	-1.32	219.24	32.71	259.22	15.61	261.12	-1.57	262.02

Note: Vehicle dynamic envelope values, YMAX, for M2OUT and M2IN are increased by 9" to allow for different installation heights.

Table 520-32: Vehicle Dynamic Envelope – Inside of Curve

Condition:
Cross Level Variation = 1.0 in
Superelevation = 6.0 in

Radius:	WL1$_{IN}$		WL2$_{IN}$		WL3$_{IN}$		WL4$_{IN}$		WL5$_{IN}$		WL6$_{IN}$		M1$_{IN}$		M2$_{IN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}
82	-71.95	2.28	-72.30	7.54			-90.53	127.72	-89.08	142.19	-80.74	150.97	-57.76	72.11	-58.61	95.65
100	-69.12	2.28	-69.47	7.54			-87.69	127.72	-86.25	142.19	-77.90	150.97	-60.35	72.11	-61.20	95.65
150	-64.85	2.28	-65.20	7.54			-83.43	127.72	-81.98	142.19	-73.64	150.97	-64.10	72.11	-64.95	95.65
200	-62.73	2.28	-63.08	7.54			-81.31	127.72	-79.86	142.19	-71.52	150.97	-65.89	72.11	-66.73	95.65
300	-60.62	2.28	-60.97	7.54			-79.19	127.72	-77.75	142.19	-69.40	150.97	-67.62	72.11	-68.46	95.65
400	-59.56	2.28	-59.91	7.54			-78.14	127.72	-76.69	142.19	-68.35	150.97	-68.46	72.11	-69.31	95.65
500	-58.93	2.28	-59.28	7.54			-77.51	127.72	-76.06	142.19	-67.72	150.97	-68.96	72.11	-69.81	95.65
600	-58.51	2.28	-58.86	7.54			-77.08	127.72	-75.64	142.19	-67.29	150.97	-69.29	72.11	-70.14	95.65
700	-58.21	2.28	-58.56	7.54			-76.78	127.72	-75.33	142.19	-66.99	150.97	-69.53	72.11	-70.37	95.65
800	-57.98	2.28	-58.33	7.54			-76.56	127.72	-75.11	142.19	-66.77	150.97	-69.70	72.11	-70.55	95.65
900	-57.81	2.28	-58.15	7.54			-76.38	127.72	-74.93	142.19	-66.59	150.97	-69.84	72.11	-70.68	95.65
1000	-57.66	2.28	-58.01	7.54			-76.24	127.72	-74.79	142.19	-66.45	150.97	-69.95	72.11	-70.79	95.65
1200	-57.45	2.28	-57.80	7.54			-76.03	127.72	-74.58	142.19	-66.24	150.97	-70.11	72.11	-70.96	95.65
1500	-57.24	2.28	-57.59	7.54			-75.82	127.72	-74.37	142.19	-66.03	150.97	-70.27	72.11	-71.12	95.65
2000	-57.03	2.28	-57.38	7.54			-75.61	127.72	-74.16	142.19	-65.82	150.97	-70.43	72.11	-71.28	95.65
5000	-57.14	2.28	-57.49	7.54			-75.72	127.72	-74.27	142.19	-66.14	150.97	-70.72	72.11	-71.57	95.65
10000	-57.24	2.28	-57.59	7.54			-75.82	127.72	-74.37	142.19	-66.27	150.97	-70.81	72.11	-71.66	95.65
50000	-57.32	2.28	-57.67	7.54			-75.89	127.72	-74.45	142.19	-66.37	150.97	-70.89	72.11	-71.74	95.65
Tangent	-57.34	2.28	-57.69	7.54			-75.91	127.72	-74.47	142.19	-66.40	150.97	-70.91	72.11	-71.76	95.65

Radius:	P1$_{IN}$		P2$_{IN}$		P4$_{IN}$		P5$_{IN}$		P7$_{IN}$		P8$_{IN}$		P6$_{CEN}$		P9$_{CEN}$	
(feet)	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MIN}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
82	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
100	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
150	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
200	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
300	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
400	-66.01	144.07	P2in is defined by three points, P2inMAXx, P2inMID and P2inMAXy. See values at bottom of the table to define these three points. P2 points have the same X and Y value for all radius calculations.		-75.16	197.29	P5in is defined by three points, P5inMAXx, P5inMID and P5inMAXy. See values at bottom of the table to define these three points. P5 points have the same X and Y value for all radius calculations.		-83.92	248.27	P8in is defined by three points, P8inMAXx, P8inMID and P8inMAXy. See values at bottom of the table to define these three points. P8 points have the same X and Y value for all radius calculations.		-40.23	219.33	-49.00	271.03
500	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
600	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
700	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
800	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
900	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
1000	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
1200	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
1500	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
2000	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
5000	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
10000	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
50000	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03
Tangent	-66.01	144.07			-75.16	197.29			-83.92	248.27			-40.23	219.33	-49.00	271.03

P2$_{INMAXx}$		P2$_{INMID}$		P2$_{INMAXy}$		P5$_{INMAXx}$		P5$_{INMID}$		P5$_{INMAXy}$		P8$_{INMAXx}$		P8$_{INMID}$		P8$_{INMAXy}$	
X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}	X_{MAX}	Y_{MAX}
-60.72	154.62	-50.85	158.73	-40.64	161.89	-69.87	207.84	-56.25	212.33	-42.35	215.87	-83.92	248.27	-67.44	253.54	-50.69	257.84

Note: Vehicle dynamic envelope values, Y_{MAX}, for M2$_{OUT}$ and M2$_{IN}$ are increased by 9" to allow for different installation heights.

520.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

520.7.1 Interface and Integration Management

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520.7.3 Manufacturing and Construction Management

520.7.4 Installation Management

520.7.5 Inspection and Testing Management

520.7.6 Training, Pre-Revenue Operations

520.7.7 Certification Management

520.8 APPENDICES (NOT USED)

END SET - 520

521 TRACK GEOMETRY

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SET - 521 TRACK GEOMETRY

521.1 INTRODUCTION

521.1.1 Document Scope

521.1.1.1 This set establishes the minimum standards and criteria for track alignment geometry to be used in the design of Sound Transit Link and commuter rail projects including track stationing, types of alignments, speed, curvature, and alignments through special trackwork.

521.1.1.2 Commentaries provide further explanation of the corresponding requirements. In case there are conflicts from the DOR's perspective between the commentary and the requirement, the DOR must follow the requirements in the main text and bring them to the attention of Sound Transit.

521.1.1.3 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 521 owner to determine the technical source for the design criteria.

521.1.2 Regulations, Codes, Standards, and Guidelines

521.1.2.1 International Regulations, Codes, Standards, and Guidelines (Not Used)

521.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines (Not Used)

521.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines (Not Used)

521.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

521.1.2.4.1 AREMA Manual for Railway Engineering.

521.1.2.4.2 AREMA Portfolio of Trackwork Plans.

521.1.2.5 Other Jurisdictions

521.1.2.5.1 AMTRAK Spec 63.

521.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines (Not Used)

521.1.3 Abbreviations and Acronyms

521.1.3.1 A–algebraic difference in gradients

521.1.3.2 AHJ–authority having jurisdiction

521.1.3.3 AREMA–American Railway Engineering and Maintenance-of-Way Association

521.1.3.4 AMTRAK –American Track (National Railroad Passenger Corporation)

521.1.3.5 D–degree of curvature; absolute value of the difference in rates of grades

521.1.3.6 DOR–designer of record

521.1.3.7 Ea–actual superelevation

521.1.3.8 EB–eastbound

521.1.3.9 Eq–equilateral equilibrium

521.1.3.10 EQL–equilateral

521.1.3.11 Eu–unbalanced superelevation

521.1.3.12 FRA –Federal Railroad Administration

521.1.3.13 G–percent grade

521.1.3.14 K–conversion factor

521.1.3.15 L–length of circular curve; length of vertical curve

521.1.3.16 LRT–light rail transit

521.1.3.17 LRV–light rail vehicle

521.1.3.18 Ls–length of spiral curve

521.1.3.19 LVC–length of vertical curve

521.1.3.20 MOW–maintenance of way

521.1.3.21 MP–milepost

521.1.3.22 NB–northbound

521.1.3.23 OCS–overhead contact system

521.1.3.24 PI–point of intersection

521.1.3.25 PVI–point of vertical curve intersection

521.1.3.26 R–radius; radius of curvature; radius of curve

521.1.3.27 RCW–Revised Code of Washington

521.1.3.28 SB–southbound

521.1.3.29 V–design speed, design speed through the curve

521.1.3.30 WB–westbound

521.1.4 Definitions and Classifications

521.1.4.1 Angle point: point where two tangents on the alignment intersect each other as opposed to becoming co-linear.

521.1.4.2 At-grade: see Set 001.

521.1.4.3 Ballast car: a freight car for carrying ballast.

521.1.4.4 Ballast regulator: a piece of rail transport MOW equipment used to distribute aggregate around the track.

521.1.4.5 Broken back curve: two closely spaced horizontal curves, of the same or different radii, with deflections in the same direction and a short tangent between the curves.

521.1.4.6 Cant deficiency: A vehicle's speed on a curve is greater than the balance speed and produces a net lateral force to the outside of the curve.

521.1.4.7 Compound curve: the combination of two or more circular curves of different radii joined tangentially and curving in the same direction.

521.1.4.8 Control track: see Set 001.

521.1.4.9 Design speed: maximum speed set by determining the maximum rate of lateral acceleration that passengers can comfortably endure.

521.1.4.10 Elevated guideway: see Set 001.

521.1.4.11 Frog: see Set 001.

521.1.4.12 Industry track: see Set 001.

521.1.4.13 Layover track: see Set 001.

521.1.4.14 Lead track: see Set 001.

521.1.4.15 Locomotive: a powered rail vehicle used for pulling trains.

521.1.4.16 Mainline track: see Set 001.

521.1.4.17 Maintenance of Way: see Set 001.

521.1.4.18 Non control track: the track adjacent to control track.

521.1.4.19 Operating speed: the light rail transit speed considering passenger comfort and safety coordinated with the car design.

521.1.4.20 Pocket track: see Set 001.

521.1.4.21 Point of switch: point of movable rails which guide the wheels towards either the straight or the diverging track.

521.1.4.22 Reverse curve: two circular curves with deflections in opposite directions joined at a common point or by a relatively short tangent.

521.1.4.23 Rolling stock: railway vehicles, including both powered and unpowered vehicles.

521.1.4.24 Sag: see Set 001.

521.1.4.25 Secondary track: see Set 001.

521.1.4.26 Shop track: see Set 001.

521.1.4.27 Siding: see Set 001.

521.1.4.28 Simple curve: A circular curve joining two tangents.

521.1.4.29 Special trackwork: see Set 001.

521.1.4.30 Spiral: see Set 001.

521.1.4.31 Subway: an underground electric tunnel for light rail vehicles.

521.1.4.32 Summit: see Set 001.

521.1.4.33 Superelevation, actual: see Set 001.

521.1.4.34 Superelevation, equilibrium: see Set 001.

521.1.4.35 Superelevation, unbalanced: see Set 001.

521.1.4.36 Tamper: A rail-mounted machine used to pack the track ballast under railway tracks to make the tracks and roadbed more durable and level.

521.1.4.37 Tunnel: see Set 722.

521.1.4.38 Turnback curve: see Set 001.

521.1.4.39 Wheel flange: projecting edge or rim on the circumference of a steel wheel that is designed to keep the wheel on a rail.

521.1.4.40 Yard track: see Set 001.

521.1.5 References

521.1.5.1 Thomas F. Hickerson, Route Location Design, 5th ed. (New York: McGraw-Hill, 1964), pp 168-171, 374-375.

521.2 STAKEHOLDER NEEDS (NOT USED)

521.2.1 Passenger Experience

521.2.2 Operational Needs

521.2.3 Maintenance Needs

521.2.4 Safety Needs

521.2.5 Security Needs

521.2.6 Reliability, Availability and Maintainability Needs

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521.4.2.3.6.2 Control Track

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521.5 SYSTEM INTERFACE REQUIREMENTS

Table 521-1 lists requirement sets that are typically coordinated and may have dependencies with this set.

The description of the interfaces below are provided to highlight only the major interface elements between Track and the other discipline sets. The list is not intended to capture all interface elements. The DOR must review and coordinate all interface requirements between Track and the other disciplines at each phase of the design and/or construction.

Table 521-1: Interface between Track and Other Disciplines

SET SERIES	SET NAMES	SET 521 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	X
500	Track	X
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	
1100	Technology	
1200	Security	

521.5.1 Train Control and Signals

521.5.1.1 Verify LRV operating speed with signal system design.

521.5.1.2 Verify track civil speeds does not conflict with signals overspeed calculations at each phase of design.

521.5.2 Traction Electrification

521.5.2.1 Coordinate vertical curve lengths and the rate of convergence or separation with OCS design requirements.

521.5.3 Vehicle

521.5.3.1 Coordinate minimum horizontal tangent lengths meet the vehicle truck and articulation length designs.

521.5.3.2 Coordinate minimum horizontal tangent length with vehicle design at platforms.

521.5.3.3 Coordinate minimum horizontal tangent length with vehicle design at Special Trackwork.

521.5.3.4 Coordinate minimum vertical tangent length with vehicle design at Special Trackwork.

521.5.3.5 Coordinate LRV civil/operating speed with the train performance simulation program speed-distance profile.

521.5.3.6 Coordinate LRV vehicle operating parameters on steep grades.

521.5.3.7 Coordinate minimum vertical tangent length with vehicle design at platforms.

521.5.3.8 Coordinate minimum curve length with vehicle design.

521.5.4 Track

521.5.5 Fire/Life Safety

521.5.6 Structures

521.5.6.1 Coordinate rail-structure interaction on curved elevated guideway.

521.5.7 Architecture

521.5.7.1 Coordinate vehicle horizontal clearances (length, outswing, inswing) at platforms.

521.5.7.2 Coordinate vertical grade limitations with platform design elements.

521.5.8 Civil

521.5.8.1 Coordinate utility or roadway limitations on steep grades.

521.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

521.6.1 General

Commentary: The criteria for track alignment geometry establishes the provisions of safe, economical, comfortable, and efficient transportation of passengers while maintaining factors of safety for the overall operation, maintenance, inspection, and vehicle stability.

Commentary: The following requirements apply to all sites and locations unless otherwise noted.

521.6.2 Track Stationing

Commentary: Track stationing provides visual cues to help designers locate the track alignment position when working with alignments, profiles, and sections. Stationing markers are not the same and uniform and can be different for each project.

521.6.2.1 All tracks must include track stationing.

521.6.2.2 Stationing must be continuous.

521.6.2.3 Stationing protocol must remain independent of any mile-posting system.

521.6.2.4 Link rail: Stationing must progress from the Downtown Seattle Transit Tunnel, increasing in an outbound direction.

521.6.2.5 Link rail: When viewing the alignment looking ahead station (outbound), the track on the viewer's right must be designated as the control track.

521.6.2.6 Commuter rail: When viewing the alignment looking ahead station (southbound), the track on the viewer's right must be designated as the control track.

521.6.2.7 Stationing along the control track must be the basis of control for locating all other system facilities along the route.

521.6.2.8 Non-control tracks must equate their stationing to the control track at the end of the curve or the spiral to tangent point of whichever track has the spiral that extends the farthest ahead station.

521.6.2.9 Independent stationing must be required for all other tracks.

521.6.2.10 Link rail: All centerline stationing must bear a prefix indicating the normal direction of LRV travel, i.e., NB, SB, EB, and WB.

521.6.2.11 Link rail: Parallel corridors indicating the normal direction of LRV travel must be incremented on the added corridor with a number prefix, i.e., NB1, NB2, SB1, SB2, EB1, EB2, WB1, and WB2.

521.6.2.12 Link rail: Track stationing must be labeled on all OCS poles and at every 100 feet on the open track and inside the tunnel.

521.6.2.13 Link rail: Track stationing label and signage must comply with the Sound Transit Signage Manual.

521.6.3 Track Milepost

Commentary: Mileposts are track footage measurements in miles along the mainline track's centerline. Mileposts allow train crews and maintainers to determine the exact location along the alignment rather than using track stationing, which can vary between projects. Milepost markers are continuous throughout the alignment starting from one zero location.

521.6.3.1 Link rail: All tracks must include track milepost.

521.6.3.2 Link rail: Milepost for track traversing northbound and southbound must originate from the Operations and Maintenance Facility Central.

521.6.3.3 Link rail: Milepost for track traversing eastbound and westbound must originate from the Downtown Seattle Transit Tunnel.

521.6.3.4 Link rail: Track milepost must be labeled every 528 feet (0.1 mile) on the open track.

521.6.3.5 Commuter rail: Track milepost must be labeled every 5,280 feet (1 mile) on the open track.

Commentary: Table 521-2: Commuter rail: Track Milepost lists the labeled milepost on the existing commuter rail tracks and the originating point.

Table 521-2: Commuter Rail: Track Milepost

<table>
<tr><td rowspan="20">SOUTHBOUND ↓</td><th>Mile Post</th><th>Lakewood Subdivision
MAIN LINE
STATIONS</th><th>Miles to next station</th><td rowspan="20">↑ NORTHBOUND</td></tr>
<tr><td colspan="3">Adjoining RR: BNSF, Seattle Sub
Subdivision Boundary: Lakewood MP 0.7 / Seattle MP 38.3X Information for TR Jct is found in the BNSF Seattle Sub timetable.</td></tr>
<tr><td>0.7</td><td>TR JCTTR
Adj RR: BNSF, MP 0.7</td><td>0.4</td></tr>
<tr><td>1.1</td><td>PORTLAND AVE</td><td>0.3</td></tr>
<tr><td>1.4</td><td>L STREET</td><td>0.5</td></tr>
<tr><td>1.9</td><td>TACOMA DOME</td><td>0.1</td></tr>
<tr><td>2.0</td><td>CP TACOMA DOME</td><td>2.0</td></tr>
<tr><td>4.0</td><td>CP 40</td><td>2.3</td></tr>
<tr><td>6.3</td><td>CP 63</td><td>0.1</td></tr>
<tr><td>6.4</td><td>SOUTH TACOMA</td><td>0.1</td></tr>
<tr><td>6.5</td><td>CP 65</td><td>0.4</td></tr>
<tr><td>6.9</td><td>MANITOU</td><td>2.1</td></tr>
<tr><td>9.0</td><td>CENTURY</td><td>0.4</td></tr>
<tr><td>9.4</td><td>PRAIRIE JCT</td><td>0.5</td></tr>
<tr><td>9.9</td><td>CP 99
(MT2)</td><td>0.2</td></tr>
<tr><td>10.1</td><td>LAKEWOOD</td><td>0.1</td></tr>
<tr><td>10.2</td><td>CP LAKEWOOD
(MT2)</td><td>0.5</td></tr>
<tr><td>10.7</td><td>RILL</td><td>8.1</td></tr>
<tr><td>18.8</td><td>CP 188</td><td>20.6</td></tr>
<tr><td colspan="3">Adjoining RR: BNSF, Seattle Sub
Subdivision Boundary: Lakewood MP 21.4 / Seattle MP 24.5 Information for Nisqually is found in the BNSF Seattle Sub timetable.</td></tr>
</table>

521.6.3.6 Link rail: Track milepost must be labeled every 0.020 miles inside the tunnel.

521.6.3.7 Link rail: Non-control tracks must equate their milepost to the control track at every milepost.

521.6.4 Horizontal Geometry

521.6.4.1 General

Commentary: The horizontal alignment consists of a series of tangents and circular curves, connected with transition spirals as required. The nomenclature used to describe horizontal alignments must be consistent with that illustrated in Figure 521-1.

Commentary: The track alignment design should be optimized to provide maximum speed, passenger comfort, and minimize track maintenance. Generally, the straighter the route, the less maintenance it will require. The design of the horizontal alignment must minimize the number of curves, especially sharp curves, and maximize tangent lengths between curves.

521.6.4.1.1 Link rail: All requirements from this set, including all applicable geometric criteria of the authority having jurisdiction and grade crossing requirements in Set 522 Track Construction, must be met at track grade crossings where LRVs will operate in mixed traffic with rubber-tired vehicles.

521.6.4.1.2 All tracks must have independent horizontal and vertical geometry.

521.6.4.1.3 Commuter rail: The track design must comply with all parts of the Federal Railroad Administration (FRA) Track Safety Standards Part 213.

521.6.4.1.4 Commuter rail: Contact the Sound Transit track engineer for the locomotive and vehicle dimensions used as the basis for the track geometry requirements.

521.6.4.2 Tangent Length

Commentary: The development of this section considers the requirements of AREMA Manual for Railway Engineer, Chapter 5, which specifies that the minimum length of tangent between curves is equal to the longest car that will traverse the system. The tangent length requirements consider vehicle operation and passenger ride comfort.

521.6.4.2.1 Tangent Length Between Curves

Commentary: The desirable minimum tangent length is 200 feet where possible in the design.

Mainline:

521.6.4.2.1.1 The tangent length between curved sections of track on mainline must be a minimum of 100 feet, or 3V, whichever is greater. V equals the maximum speed of LRV, freight or passenger train in miles per hour, whichever is greater.

Yard:

521.6.4.2.1.2 Link rail: The tangent length between curved sections of track in the yard must be a minimum of 45 feet.

521.6.4.2.1.3 Commuter rail: The tangent length between curved sections of track in the yard must be a minimum of 75 feet.

Secondary:

521.6.4.2.1.4 The tangent length in the secondary track must be a minimum of 45 feet if the design speed is less than or equal to 20 miles per hour.

521.6.4.2.1.5 The tangent length in the secondary track must comply with the tangent length of mainline track requirement if the design speed is greater than 20 miles per hour.

521.6.4.2.2 Tangent Length between Reverse Curves

521.6.4.2.2.1 Commuter Rail: The minimum tangent length between reverse curves must satisfy the requirements in Table 521-3.

Table 521-3: Commuter Rail: Minimum Tangent Length between Reverse Curves

Condition	Tangent Length
60 miles per hour to 80 miles per hour	240 feet
40 miles per hour to 59 miles per hour	180 feet
25 miles per hour to 39 miles per hour	150 feet
25 miles per hour and less	100 feet

521.6.4.2.3 Tangent Length between Broken Back Curves

Commentary: Broken back curves occur when two curves deflecting in the same direction are joined by a short tangent less than 100 feet in length. Broken back curves do not affect safety or operating speeds but does create substandard ride quality.

521.6.4.2.3.1 Broken back curves must not be used.

521.6.4.2.4 Tangent Length at Station Platforms

521.6.4.2.4.1 At station platforms, the horizontal alignment must be tangent throughout the entire length of the platform.

521.6.4.2.4.2 Link rail: The tangent must extend 50 feet minimum beyond both ends of the platform.

521.6.4.2.4.3 Commuter rail: The tangent must extend 100 feet minimum beyond both ends of the platform.

521.6.4.2.5 Tangent Length in Special Trackwork

521.6.4.2.5.1 Special trackwork must be on horizontal and vertical tangent track.

Mainline:

521.6.4.2.5.2 Link rail: The horizontal tangent must extend a minimum of 45 feet before the point of switch and 45 feet beyond heel of frog through the straight movement.

521.6.4.2.5.3 Commuter rail: The horizontal tangent must extend a minimum of 200 feet before the point of switch and 200 feet beyond heel of frog through the straight movement.

Non-mainline:

521.6.4.2.5.4 Link rail: In the yard, the horizontal tangent must extend a minimum of 10 feet before the point of switch and 10 feet beyond heel of frog through the straight movement.

521.6.4.2.5.5 Link rail: For special trackwork in the yard, see Set 522 Track Construction.

521.6.4.2.5.6 Commuter rail: In the yard, the horizontal tangent must extend a minimum of 75 feet before the point of switch and 75 feet beyond the heel of frog through the straight movement.

521.6.4.3 Curved Alignment

Commentary: Intersections of horizontal alignment tangents are connected by circular curves. The curves may be spiraled curves or simple curves, depending on the curve location, curve radius, and required superelevation. Spiraled curves are preferable to improve ride quality and minimize impacts to rolling stock.

521.6.4.3.1 Commuter Rail: Horizontal alignment must be designed firstly for passenger operation and secondly be checked for freight speed.

521.6.4.3.2 Degree of Curvature

521.6.4.3.2.1 Link Rail: Circular curves must be specified by their radius or degree of curvature defined by the arc definition as follows:

$$D = 5729.578 / R$$

Where,

D = degree of curvature, in degrees (arc definition)

R = radius of curvature, in feet

521.6.4.3.2.2 Commuter Rail: The curvature of a circular curve, D, is defined by FRA chord definition as follows:

$$D = 2 \sin^{-1} (50/R)$$

Where,

D = degree of curvature, in degrees (chord definition)

R = radius of curvature, in feet

521.6.4.3.3 Curve Radius

Commentary: The minimum radius for the track is determined by the physical characteristics of the vehicle. On-track MOW equipment must also be considered in the selection of minimum curve radius criteria. Depending on the maintenance plan for the system, this could include a wide variety of MOW trucks, tampers, ballast regulators, ballast cars, catenary maintenance vehicles, and even small locomotives. The minimum radius requirement for the track is there to minimize or eliminate wheel flanging and wheel squeal noise.

Commentary: For elevated structures, the minimum radius is set to conform to the thermal forces on the rail to limit structure impact and avoid the employment of more expensive track forms. For at-grade and embedded track, the minimum radius allows conformance with the existing street grid. For subway section, it allows for different types of subway or tunnel construction. For Yard and Secondary track, the requirements in this section allow safe movement of the LRV.

521.6.4.3.3.1 Link rail: Circular curves are defined by curve radius or degree of curve by arc definition. The geometric properties of a circular curve are summarized in Figure 521-1.

521.6.4.3.3.2 The minimum radii for tracks must be as follows:

Table 521-4: Link Rail: Minimum Radii for Tracks

Location	Ballasted Track (feet)	Direct Fixation Track (feet)	Embedded Track (feet)
Elevated Structure	650	650	650
At-grade	300	300	300
Subway/Tunnel	250	250	250
Yard	100	-	100
Secondary Tracks, Elevated (Lead)	300	300	-

Table 521-5: Commuter Rail: Minimum Radii for Tracks

Location	Minimum Radius
Mainline Track	500 feet
Non-mainline track	459 feet

521.6.4.3.3.3 Turnback curves on the divergent side of a turnout may be built without a spiral where site constraints do not provide the minimum length to meet the spiral curve requirements. Turnback curves without a spiral must comply with the minimum radius in Table 521-6 and 521-7.

Table 521-6: Link rail: Turnback Curve Minimum Radius

Turnout No.	Min Radius of Turnback Curves (feet)
5	100
6	300
8	550
10	550
15	1200
20	2150
5 EQL	200

Commentary: Link rail: Turnback curves on the divergent side of a turnout is based upon using maximum Eu = 3 inches.

521.6.4.3.3.4 Link rail: Turnback curves on the divergent side of a turnout must not be superelevated.

Table 521-7: Commuter Rail: Turnback Curve Minimum Radius

Turnout Data	Min Radius of Turnback Curves (feet)				
	With 0 inches Superelevation	With 0.5 inches Superelevation	With 1 inch Superelevation	With 1.5 inches Superelevation	With 2 inches Superelevation
7(yard)	500	500	500	500	500
9(yard)	800	650	550	500	500
11	1250	1000	850	750	650
15	2450	2000	1650	1400	1250
20	3200	2550	2150	1100	1600
24	5000	4000	3300	2850	2500

521.6.4.3.4 Curve Length

Commentary: The minimum circular curve length is dictated by ride comfort.

521.6.4.3.4.1 The minimum circular curve length must be determined as follows:

$$L = 3V$$

Where,

L = minimum length of circular curve, in feet

V = design speed through the curve, in miles per hour

Commentary: Link Rail: Curves in Link Rail that include no actual circular curve segment (e.g., double-spiraled curves) can be permitted only in areas of extremely restricted geometry provided no actual superelevation (Ea) is used, and with a maximum speed of 30 miles per hour.

521.6.4.3.4.1.1 For spiraled circular curves, the length in feet of the circular curve calculated from the requirement above added to the sum of one-half the lengths of both spirals is an acceptable method of determining compliance with the minimum length criteria.

521.6.4.3.4.1.2 The circular curve length must be a minimum of 45 feet when including spiral lengths for compliance with Equation 521-3.

521.6.4.3.4.2 Link rail: Turnback curves on the divergent side of a turnout built without a spiral on the mainline must meet the minimum curve length requirements in Table 521-8.

Table 521-8: Link rail: Turnback Curve Minimum Length

Turnout Data	Turnback Curve Min Length (feet)
5	40
6	50
8	70
10	55
15	80
20	110
5 EQL	40

521.6.4.3.4.3 Link rail: Turnback curves on the divergent side of a turnout built without a spiral in the yard must be minimum 20 feet long.

521.6.4.3.5 Angle Point

521.6.4.3.5.1 Link rail: At tie-in locations to existing track, the maximum angle point allowance must be 2 minutes 30 seconds.

521.6.4.3.5.2 Commuter rail: Maximum angle point allowance must be based upon Class 5 speed as defined by AMTRAK Spec 63.

521.6.4.3.5.3 Commuter rail: All angle points greater than 5 minutes 30 seconds must be connected by a circular curve and meet the spiral curve requirements.

521.6.4.3.6 Track Grade Crossings

521.6.4.3.6.1 For track geometry requirements in grade crossings, refer to Set 522 Track Construction.

521.6.4.4 Speed

Commentary: Link rail: The track alignment is to be designed to accommodate the maximum design speed of 55 miles per hour except for areas where Link light rail operates within or adjacent to surface streets. Physical constraints along various portions of the system, together with other design limitations, may preclude achievement of this objective.

521.6.4.4.1 Design and Operating Speed

521.6.4.4.1.1 Design speed is as specified in the project documents.

521.6.4.4.1.2 Commuter rail: Where project specific future speeds are defined, spiral length, and superelevation design must meet the future speed requirements.

521.6.4.4.1.3 Link rail: The civil design speed for a given horizontal curvature must be based on its radius, length of spiral transition, and actual and unbalanced superelevation through the curve.

521.6.4.4.1.4 Link rail: The civil design speed must be coordinated with the normal operating speeds as provided on the train performance simulation program speed-distance profiles.

521.6.4.4.1.5 Link rail: The operational speed must be coordinated and checked with the signal system at the end of design and at end of construction.

521.6.4.4.1.6 Commuter rail: Operating speed changes are governed by RCW 81.48.040.

521.6.4.4.1.7 The signal system and operating speed must not exceed the civil design speed.

Mainline:

521.6.4.4.1.8 The design speed for the new mainline track must meet or exceed the existing mainline or parallel mainline civil and operating speeds.

Table 521-9: Commuter Rail: Existing Mainline Operating Speed Limits

Main Track	High-speed Passive Tilt Technology Train (mph)	Passenger (mph)	Freight (mph)
MP 0.7 to MP 10.7	79	60	40
MP 10.7 to MP 21.4	79	79	40

Note: MP=milepost; MPH=miles per hour

Non-mainline:

521.6.4.4.1.9 Link rail: Yard tracks must be designed for 10 miles per hour.

521.6.4.4.1.10 Link rail: Yard lead tracks greater or equal to 2,000 feet long must be designed for 20 miles per hour minimum.

521.6.4.4.1.11 Commuter rail: Yard and layover tracks must be designed for 10 miles per hour.

521.6.4.4.1.12 Commuter rail: The maximum operating speed for industry and secondary tracks is 10 miles per hour.

521.6.4.4.2 Overspeed Calculations

521.6.4.4.2.1 Link rail: Superelevation calculations must include a separate over speed calculation. Over speed is determined by the design speed plus 4 miles per hour. The unbalanced superelevation for the over speed calculation must not exceed 4.5 inches.

521.6.4.4.2.2 Commuter rail: Superelevation calculations must include a separate over speed calculation. Over speed is determined by the design speed plus 5 miles per hour. The unbalanced superelevation for the over speed calculation must not exceed 6 inches.

521.6.4.5 Superelevation

Commentary: The design speed at which a rail vehicle can negotiate a curve is increased proportionally by increasing the elevation of the outside rail of the track, creating a banking effect called superelevation. Superelevation must be used to maximize running speeds where it does not interfere with pavement grades in areas of mixed traffic operation.

Commentary: Commuter Rail: Many factors influence the design of curve superelevation on mixed-service commuter railway lines where different types of trains operate at different speeds. For a given degree of curve and actual superelevation, maximum civil speed is dictated by the allowable cant deficiency of the train type. To maximize speeds for the design of high speed, passenger, and freight trains operating on the joint use rail corridor, the design must minimize superelevation by using a larger radius curve and longer spirals rather than smaller radius curves.

521.6.4.5.1 Equilibrium Superelevation

521.6.4.5.1.1 The following equation is used to compute the equilibrium superelevation, Eq, for curves given the degree of curvature and maximum allowable train design speed:

$$Eq = Ea + Eu = 3.96\left(\frac{V^2}{R}\right) = 0.00069V^2D$$

Where,

Eq = equilibrium superelevation, in inches

Ea = actual superelevation, in inches

Eu = unbalanced superelevation, in inches

V = design speed through the curve, in miles per hour

R = radius of curve, in feet

D = degree of curve, in degrees (arc definition)

521.6.4.5.2 Actual Superelevation (Ea)

Commentary: Link rail: The actual superelevation installed in the track is typically somewhat less than the required for equilibrium. Large values of Ea are seldom used, in part because the passengers on any train that might stop on such curve would be extremely uncomfortable.

521.6.4.5.2.1 Actual superelevation (Ea) must be attained and removed linearly throughout the full length of the spiral transition curve by raising the outside rail while maintaining the inside rail at the profile grade.

521.6.4.5.2.2 When superelevation is added to a simple curve, the transition must be applied on tangent track.

521.6.4.5.2.3 The calculated values for actual superelevation must be rounded to the nearest 1/4 inch.

521.6.4.5.2.4 The design value of actual superelevation can be adjusted up to 1/4 inch.

521.6.4.5.2.5 Link Rail: The actual superelevation (Ea) to be applied must be determined by the following formula:

$$Ea = 2.64\left(\frac{V^2}{R}\right) - 0.66 = 2Eu - 2$$

Where,

Ea = actual superelevation to be constructed, in inches

Eu = unbalanced superelevation, in inches

V = design speed through the curve, in miles per hour

R = radius of curve, in feet

521.6.4.5.2.6 Link rail: The track actual superelevation (Ea) must be revised based upon the design speed.

521.6.4.5.2.7 Link rail: Ea must be set so that trains will have a positive Eu on curves where speed is likely to vary.

521.6.4.5.2.8 Link rail: For an equilibrium superelevation of 1 inch or less, no actual superelevation (Ea) is applied.

521.6.4.5.2.9 Link rail: In specific cases where physical constraints limit the amount of Ea that can be introduced, a maximum of 1-1/2 inches of Eu is permitted without introduction of Ea.

521.6.4.5.2.10 Commuter rail: All curves must have at least 1/2-inch superelevation with the following exceptions:

i. Curves that are no sharper than 0 degrees-15 feet may have a minimum of 1/4-inch superelevation if the resulting underbalance is not less than 0.
ii. Curves that have less than 1/4 inch of total equilibrium superelevation (Eq) must have no actual superelevation.
iii. Curves that connect the diverging sides of turnouts with tracks that are parallel to the normal side of the turnout may have no superelevation.
iv. Curved yard track designed at 10 miles per hour or less does not require superelevation.

Non-mainline:

521.6.4.5.2.11 There must be no actual superelevation in Yard tracks.

521.6.4.5.2.12 There must be no actual superelevation in pocket tracks.

521.6.4.5.2.13 Commuter rail: There must be no actual superelevation in layover tracks.

Station Platforms:

521.6.4.5.2.14 There must be no actual superelevation at station platforms.

Special Trackwork:

521.6.4.5.2.15 There must be no actual superelevation in Special Trackwork.

521.6.4.5.3 Maximum Ea

521.6.4.5.3.1 Link Rail: Maximum Ea = 4.5 inches

521.6.4.5.3.2 Commuter rail: High-speed passive tilt technology train Maximum Ea = 5 inches

521.6.4.5.3.3 Commuter rail: Conventional Passenger Train Maximum Ea = 5 inches

521.6.4.5.3.4 Commuter rail: Freight Train Maximum Ea = 5 inches

521.6.4.5.4 Maximum Eu

521.6.4.5.4.1 Link Rail: Maximum Eu = 3.5 inches

521.6.4.5.4.2 Commuter rail: High-speed passive tilt technology train Maximum Eu = 5 inches

521.6.4.5.4.3 Commuter rail: Conventional Passenger Train Maximum Eu = 3 inches

521.6.4.5.4.4 Commuter rail: Freight Train Maximum Eu = 2 inches

Commentary: Commuter rail: On curves where the traffic is mixed with passenger and freight trains, the designed superelevation is based on the passenger train operating speed. The designed superelevation based on the passenger operating speed needs to be checked with freight train operating speed to limit the surplus unbalanced superelevation within 2 inches.

521.6.4.6 Spirals

Commentary: Spiral curves provide the transition for introducing superelevation into the outside rail of the curve, and transition between compound circular curves. Spiral curves are necessary to ease into the curve to provide passenger comfort and reduce jerk rate.

521.6.4.6.1 Spiral transition curves must be clothoid spirals as depicted in Figure 521-1 and as defined by Hickerson.

521.6.4.6.2 Link rail: Spirals must be provided at the ends of all simple curves with a radius less than 10,000 feet.

521.6.4.6.3 Commuter rail: Spirals must be provided at the ends of all simple curves with a radius less than 25,000 feet.

521.6.4.6.4 Spirals must be provided between segments of compound curves.

521.6.4.6.5 Spirals are not required for the divergent track turnback curve on a turnout.

521.6.4.6.6 Superelevation runoff must be at a uniform rate and extend the full length of the spiral.

Mainline:

521.6.4.6.7 Link Rail: The minimum length of spiral must be the greater of the lengths determined from the following equations (rounded up to the next largest 10 feet), but not less than 60 feet:

$Ls = 31\ Ea$

$Ls = 0.82\ Ea\ V$

$Ls = 1.10\ Eu\ V$

Where,

L_s = minimum length of spiral curve, in feet

E_a = actual superelevation, in inches

E_u = unbalanced superelevation, in inches

V = design speed, in miles per hour

Commentary: Commuter rail: Where practicable, the minimum desirable spiral length for commuter rail calculation length should include Ls= 1.63EuV for both high-speed passenger and freight to allow for more flexibility in the future to adjust speed.

521.6.4.6.8 Commuter rail: The minimum length of spiral must be the greater of the lengths determined from the following equations (rounded up to the next nearest 10 feet), but not less than 80 feet:

Passenger Train, High-speed Non-passive Tilt Technology Trains and Freight:

$L_s = 1.22*E_u*V$

$L_s = 62*E_a$

High-speed Passive Tilt Technology Trains Only:

$L_s = 0.83*E_u*V$

$L_s = 62*E_a$

Where,

L_s = length of spiral curve, in feet

E_a = actual superelevation, in inches

E_u = unbalanced superelevation, in inches

V = design speed, in miles per hour

Non-mainline:

Commentary: Commuter rail: A spiral is preferred, but not required for yard and secondary tracks where design speeds are less than 10 miles per hour.

521.6.4.6.9 Yard and Secondary tracks, which have design speeds greater than 10 miles per hour, must have spirals.

521.6.4.7 Compound Circular Curve

Commentary: Compound circular curves are made up of two or more circular arcs of successively larger or smaller radii curving in the same direction. For adjacent curves oriented in the same direction, a single simple curve with spiral transitions should be used. If adjacent curves in the same direction, which are close to one another cannot be replaced by a single simple curve due to geometric constraints, a series of compound curves joined by means of spiral transition curves should be the preferred arrangement.

521.6.4.7.1 Where compound curves are used, the first and second curves must be designed for uniform speed.

521.6.4.7.2 Where compound curves are used, the first and second curve segments must be designed for uniform Eu.

521.6.4.7.3 Unbalanced superelevation in compound curves must be within 1/4 inch and must meet all the requirements in this set.

521.6.4.7.4 Link Rail: The minimum spiral length used to connect the first and second curves must be the greater of the lengths determined by the following equations (rounded up to the next nearest 10 feet), but not less than 40 feet:

Ls = 31 (Ea2 - Ea1)

Ls = 0.82 (Ea2 – Ea1) V

Ls = 1.10 (Eu2 – Eu1) V

521.6.4.7.5 Commuter rail: The minimum spiral length used to connect the first and second curve must be the greater of the lengths determined from the following equations (rounded up to the next nearest 10 feet), but not less than 80 feet:

Passenger Train, High-speed Non-passive Tilt Technology and Freight:

$L_s = 1.22*(E_{u,2} – E_{u,1})*V$

$L_s = 62*(E_{a,2} – E_{a,1})$

High-speed Passive Tilt Technology Trains Only:

$L_s = 62*(E_{a,2} – E_{a,1})$

$L_s =0.83*(E_{a,2} – E_{a,1})*V$

Where,

L_s = minimum length of spiral curve, in feet

$E_{a,1}$ = actual superelevation of the first circular curve, in inches

$E_{a,2}$ = actual superelevation of the second circular curve, in inches

$E_{u,1}$ = unbalanced superelevation of the first circular curve, in inches

$E_{u,2}$ = unbalanced superelevation of the second circular curve, in inches

V = design speed, in miles per hour

521.6.4.8 Reverse Curve

Commentary: Link rail: Reverse curve is formed by the combination of two circular curves with opposite direction curvatures.

Commentary: Link rail: If extremely restrictive horizontal geometrics make it impossible to provide sufficient tangent length between reversed superelevated curves, the curves may meet at a point of reverse spiral upon approval from Sound Transit. In approved cases, a reverse curve can be used at the point of extreme restrictive geometry, at station approaches, or at track alignments that have a design speed of 30 miles per hour or less. The reverse curve spirals must be designed so that the length of the spiral (in inches) leaving the first curve multiplied by the actual superelevation of the second circular curve is equal to the length of the spiral entering the second curve multiplied by the actual superelevation of the first circular curve (Ls_1 x Ea_2 = Ls_2 x Ea_1). A maximum tangent length of 3 feet between spirals is acceptable in lieu of meeting at a point. At the point of reverse spirals, the Ea must be 0 inches. The superelevation transition between reversed spirals must be accomplished by sloping both rails of the track throughout the entire transition spiral as shown in Figure 521-2. Note that through the entire transition, both rails will be at an elevation above the theoretical profile grade line.

521.6.4.8.1 Link rail: Reverse curves must not be used.

521.6.5 Vertical Geometry

521.6.5.1 General

Commentary: Vertical curves must be designed as long as physically and economically possible. The vehicle's performance, dimensions, and tolerance to vertical bending stress dictate requirements for vertical alignments.

521.6.5.1.1 The vertical alignment must be composed of constant grade tangent segments connected at their intersection by parabolic curves having a constant rate of change in grade.

521.6.5.1.2 The nomenclature used to describe vertical alignments must be consistent with that illustrated in Figure 521-3.

521.6.5.1.3 Profile Grade Control Line

521.6.5.1.3.1 The profile grade line in tangent track must be along the centerline of track between the two running rails and in the plane defined by the top of the two rails.

521.6.5.1.3.2 In curved track, the profile grade line represents the elevation of the top of the low rail.

521.6.5.1.3.3 In areas of horizontal curvature where the profile is given for the right track only (control track), the top of rail elevation of the left track must be adjusted uniformly throughout the curve to compensate for the difference in horizontal curve lengths.

521.6.5.1.3.4 Commuter rail: All main line tracks and sidings must be designed to the same vertical profile of the control line.

521.6.5.1.3.5 Commuter rail: New track profiles must match the existing parallel track but not be more than 12 inches above the existing track profile.

521.6.5.1.3.6 Commuter Rail: For multiple tracks, when top of rail profile is given for one reference track only, the top of rail elevations of the other tracks must be projected radially and perpendicularly to the reference profile track.

521.6.5.2 Vertical Grades

Commentary: Maximum grades in track are controlled by vehicle braking and tractive efforts and are constrained by the limits of adhesion between the wheels and the rails. Adhesion between the wheels and the rails can vary depending on the environmental condition. The maximum grade can be affected by the presence of not only water, snow, and ice, but also vegetation, particularly wet and oily fallen leaves.

521.6.5.2.1 Grade Limitations

521.6.5.2.1.1 The following profile grade limitations must apply:

Mainline:

Table 521-10: Link Rail: Grade Limitation – Mainline and Lead Tracks

Mainline Tracks	Grade
Maximum (sustained grade unlimited length)	4.00%
Maximum (sustained grade with up to 2,500 feet between PVIs of vertical curves)	6.00%
Maximum (short, sustained grade with no more than 500 feet between PVIs of vertical curves)	7.00%
Minimum (for drainage on direct fixation track)	0.50%

Table 521-11: Commuter Rail: Grade Limitation – Mainline Tracks

Mainline Tracks	Grade
Maximum (sustained grade unlimited length)	≤ 2.00%
Sawyer Street to C Street	2.85%

Non-mainline and Special Trackwork

521.6.5.2.1.2 All tracks entering the yard must be pitched downward away from the mainline to prevent any vehicle from rolling onto the mainline tracks.

521.6.5.2.1.3 Link rail: Tracks located within maintenance shop buildings must be 0 percent grade.

Table 521-12: Link rail: Grade Limitations – Yard Track, Pocket Tracks, Secondary, Special Trackwork, and Turnouts

Yard Track, Pocket Tracks, Secondary, Special Trackwork, and Turnouts	Grade
Desirable - Yard Only	0.00%
Maximum	2.00%

Table 521-13: Commuter rail: Maximum Grades in Non-mainline and Special Trackwork

Track Segment Type	Maximum Grade
Industry Line	≤2%
Freight Yard Leads	≤0.3%
Yard Track	≤0.2%
Stations	≤0.5%
Shop Track	0.0%
Special Trackwork	≤2%

521.6.5.2.2 Vertical Grades in Station Platforms

Commentary: Flatter station platforms can better accommodate construction of architectural elements such as plumbness of canopies and ADA. The preferred vertical grade in station platforms is 0.5 percent when the upstream and downstream ends of the guideway do not result in higher construction costs due to the vertical alignment making up or chasing slopes with significantly taller columns and longer drainage lines.

Table 521-14: Link Rail: Grade Limitations – Stations

Stations	Grade
Minimum	0.50%
Maximum	1.00%

521.6.5.2.3 Vertical Grades in Tunnels

Commentary: Link rail: For tunnel profile design, and accounting for cross passage grade in tunnel, refer to Set 722 Tunnel Structures for cross-passage criteria slope in tunnel break-outs.

521.6.5.3 Vertical Tangent Length

Commentary: Vertical tangents are the tangents connecting between vertical curves. Vertical tangent requirements are developed to avoid abrupt changes in vertical grades that could result in both passenger discomfort and excessive vehicle suspension system wear.

521.6.5.3.1 Tangent Length Between Curves

521.6.5.3.1.1 The minimum length of constant profile grade between vertical curves must be 100 feet or 3V, whichever is greater, where V equals the design speed in miles per hour.

521.6.5.3.2 Tangent Length at Station Platforms

521.6.5.3.2.1 Stations must be on a vertical tangent.

521.6.5.3.2.2 Link rail: Vertical tangent at stations must extend 40 feet beyond each end of the platform.

521.6.5.3.2.3 Commuter rail: Vertical tangent must extend at least 100 feet beyond each end of the platform.

521.6.5.3.3 Tangent Length in Special Trackwork

521.6.5.3.3.1 Special trackwork must be located on vertical tangents.

521.6.5.3.3.2 Link rail: Vertical tangents must extend a minimum of 45 feet before the point of switch and 45 feet beyond the heel of frog.

521.6.5.3.3.3 Commuter rail: Vertical tangents must extend a minimum of 75 feet before the point of switch and 75 feet beyond the heel of frog.

521.6.5.4 Vertical Curve

Commentary: All grade changes are connected by vertical curves. Vertical curves are defined by parabolas having a constant rate of change in grades. A vertical curve provides a transition between two vertical tangents, allowing a vehicle to negotiate the elevation rate change at a gradual rate rather than a sharp cut. The design of the curve is dependent on the intended design speed, drainage, slope, and acceptable rate of change and friction. All vertical curve designs are to accommodate the maximum design speed of 55 miles per hour to lower the impacts of vertical forces on the track structure.

521.6.5.4.1 Vertical Curve Length

Commentary: The minimum length of vertical curve in the requirement is controlled by designed speed, stopping distance, passenger comfort, and change in grade. The desirable minimum vertical curve length is LVC = 200A. The vertical curve lengths from this requirement section are minimums.

Commentary: Both sag and summit vertical curves should have the maximum possible length, especially if approach and departure tangents are long. Short vertical curve lengths increase the impact forces on the track structure and must be avoided. Vertical broken back curves and short horizontal curves at sags and summits of vertical curves must not be used.

Commentary: Link Rail: Minimum vertical curve length and design speed may be governed by the OCS design due to the maximum permissible rate of separation or convergence between the track grade and the contact wire grade.

521.6.5.4.1.1 Link rail: Track DOR must coordinate any vertical curves that the OCS designer identifies as conflicting with the rate of separation or convergence requirement in the OCS design.

Commentary: Link rail: The minimum curve tables have been informed using TCRP 155 and use V + 5 miles per hour over speed to provide additional passenger comfort within the equations.

521.6.5.4.1.2 Link rail: The minimum length of vertical curve must be determined as follows:

Table 521-15: Link rail: Length of Vertical Curve

Condition	Length
Sag and Summit Curve for V ≤ 20 MPH	LVC = 50A
Sag and Summit Curve for 20 MPH < V ≤ 35 MPH	LVC = 80A
Sag Curve for V > 35 MPH	LVC = 100A
Summit Curve for V > 35 MPH	LVC = 150A
Notes: ***If the calculated vertical curve length is less than 100 feet, use 100 feet.**	

Where,

LVC = length of vertical curve, in feet

A = (G2 - G1) = algebraic difference in gradients connected by the vertical curve, in percent

G1 = percent grade of approaching tangent

G2 = percent grade of departing tangent
V = design speed, in miles per hour

521.6.5.4.1.3 Commuter Rail: The vertical curve length must satisfy the requirements in the latest AREMA Manual.

Commentary: Commuter rail: In some restrictive situations, the K factor may be reduced to satisfy passenger comfort criteria. When using the passenger comfort equation, use V + 5 miles per hour to address over speed conditions and being able to maintain the track alignment perturbations.

521.6.5.4.1.4 Commuter rail: The minimum length of vertical curve must be designed as follows and not less than 100 feet:

$$LVC = \frac{DV^2(K)}{A}$$

Where,

A = vertical acceleration in ft/sec² (0.60 for passenger rail, 0.10 for freight)

D = absolute value of the difference in rates of grades expressed as a decimal

K = 2.15 conversion factor to give LVC in feet

LVC = minimum length of vertical curve (rounded up to nearest 10), in feet

V = design speed of train, in miles per hour.

521.6.5.4.1.5 Commuter Rail: The rate of change for vertical curves must be less than 0.02

$$\text{Rate of change} = \frac{(100 * D)}{LVC}$$

Where,

D = absolute value of the difference in rates of grades expressed as a decimal

LVC = length of vertical curve, in feet

521.6.5.4.2 Vertical Curve Grade Changes

521.6.5.4.2.1 Commuter rail: Vertical curves are not required for grade intersections where the algebraic difference in grade is less than or equal to 0.1 percent.

Commentary: Commuter rail: Complex vertical curves are a series of consecutive summit and sag curves with less than 700 feet between the point of intersection (PI) and grade changes more than 1.5 percent.

521.6.5.4.2.2 Commuter rail: Complex vertical alignment must be avoided.

521.6.5.4.2.3 Commuter rail: Vertical curves with grade changes more than 1.5 percent must have a point of intersection spacing greater than 700 feet, when connecting to another grade change in opposite direction of 1.5 percent or more.

521.6.5.5 Link Rail: Compound Vertical Curve

521.6.5.5.1 Compound vertical curves must not be used.

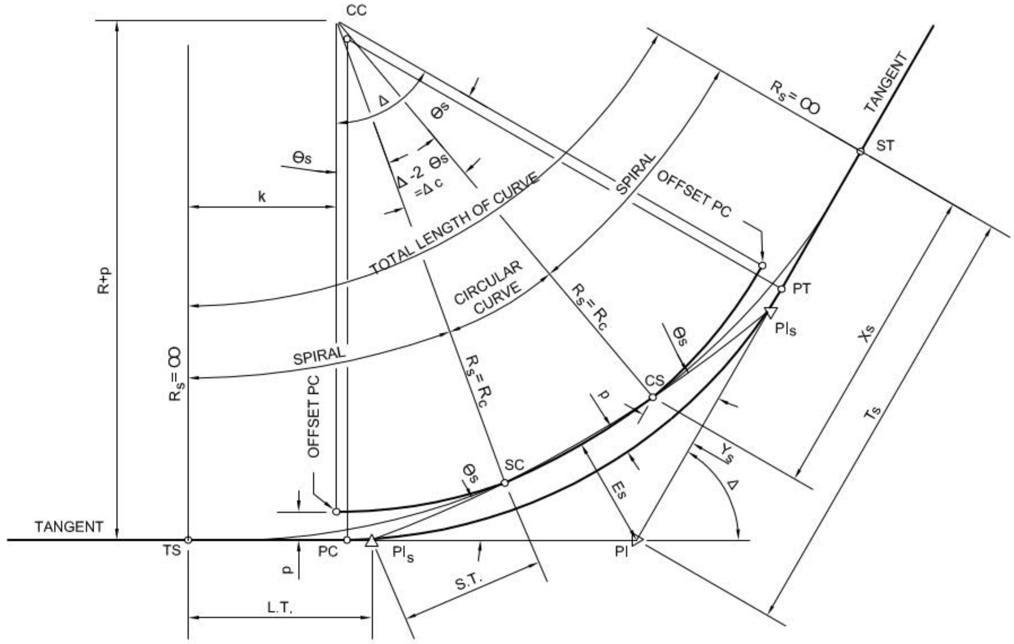
521.6.6 Combined Vertical and Horizontal Curve

Commentary: Combined vertical and horizontal curves should be avoided. Where areas of combined vertical and horizontal curvature cannot be avoided, superposition of a vertical curve over a horizontal spiral curve should be avoided.

Commentary: Link rail: Where areas of combined vertical and horizontal curvature cannot be avoided, the geometrics must not be more restrictive than a 100-foot radius horizontal curve combined with an 820-foot equivalent radius vertical summit curve and 1,150-foot equivalent radius for sag curve. These values are given as an absolute minimum radius for horizontal and vertical summit curve while still providing passenger comfort and safe operation of the train. These parameters must conform to the vehicle design specifications.

521.6.6.1 Coordination of horizontal and vertical alignment must avoid a combination of minimum radius, maximum grade, and maximum unbalanced superelevation.

Figure 521-1: Horizontal Curve and Spiral Nomenclature



NOTATIONS

CC	=	CENTER OF CIRCULAR CURVE
CS	=	POINT OF CHANGE FROM CIRCULAR CURVE TO SPIRAL
D_c	=	DEGREE OF CIRCULAR CURVE, ARC DEFINITION
E_s	=	TOTAL EXTERNAL DISTANCE OF A SPIRALIZED CURVE
k	=	TANGENT DISTANCE FROM TS OR ST TO PC OR PT OF THE SHIFTED CIRCULAR CURVE
L_c	=	TOTAL LENGTH OF CIRCULAR CURVE ARC
L_s	=	TOTAL LENGTH OF SPIRAL
L.T.	=	LONG TANGENT OF SPIRAL
p	=	OFFSET FROM THE MAIN TANGENT TO THE PC OR PT OF THE SHIFTED CIRCULAR CURVE
PC	=	POINT OF CHANGE FROM TANGENT TO CIRCULAR CURVE
PI	=	POINT OF INTERSECTION OF MAIN TANGENTS
PI_s	=	POINT OF INTERSECTION OF MAIN TANGENT WITH TANGENT THROUGH SC OR CS POINT
PT	=	POINT OF CHANGE FROM CIRCULAR CURVE TO TANGENT
R	=	RADIUS OF CIRCULAR CURVE
SC	=	POINT OF CHANGE FROM SPIRAL TO CIRCULAR CURVE
ST	=	POINT OF CHANGE FROM SPIRAL TO TANGENT
S.T.	=	SHORT TANGENT OF SPIRAL
T_s	=	TOTAL TANGENT DISTANCE FROM TS OR ST TO PI
TS	=	POINT OF CHANGE FROM TANGENT TO SPIRAL
X_s	=	TANGENT DISTANCE FROM TS TO SC OR ST TO CS
Y_s	=	TANGENT OFFSET AT SC OR CS
Δ	=	TOTAL CENTRAL ANGLE OF SPIRAL AND CIRCULAR CURVES
Δc	=	CENTRAL ANGLE OF THE CIRCULAR CURVE
Θ_s	=	CENTRAL ANGLE OF SPIRAL

CURVE FORMULAS

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

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

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

$$L_c = \frac{\Delta c}{D_c} \times 100 = \frac{\Delta - 2f_s}{D_c} \times 100$$

SPIRAL FORMULAS

Θ_s IN RADIANS

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

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

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

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

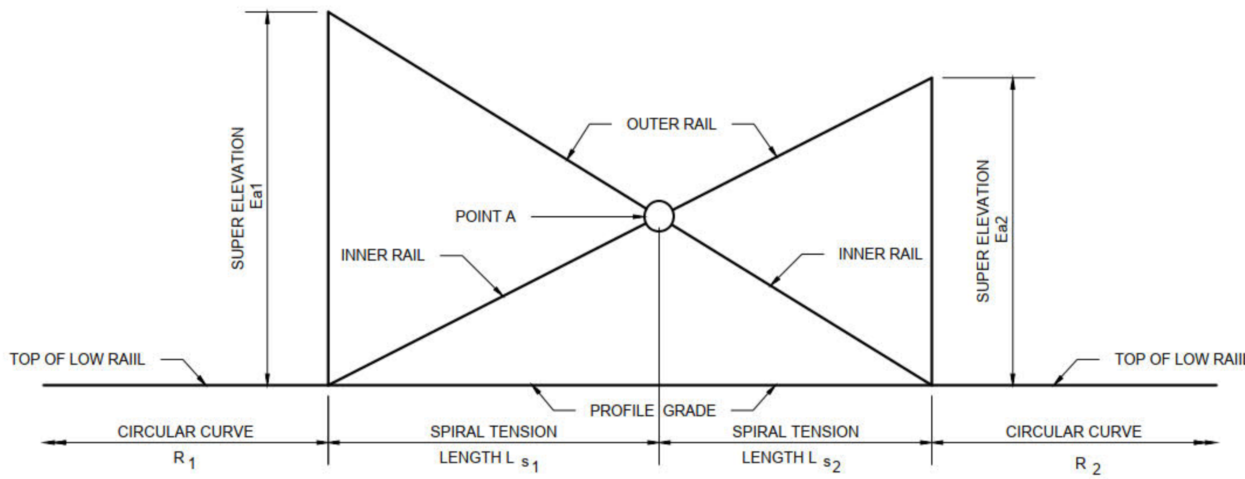
$$L_s = 2R\,\Theta_s$$

$$\Theta f_s = \frac{1}{2}\frac{L_s}{R}$$

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

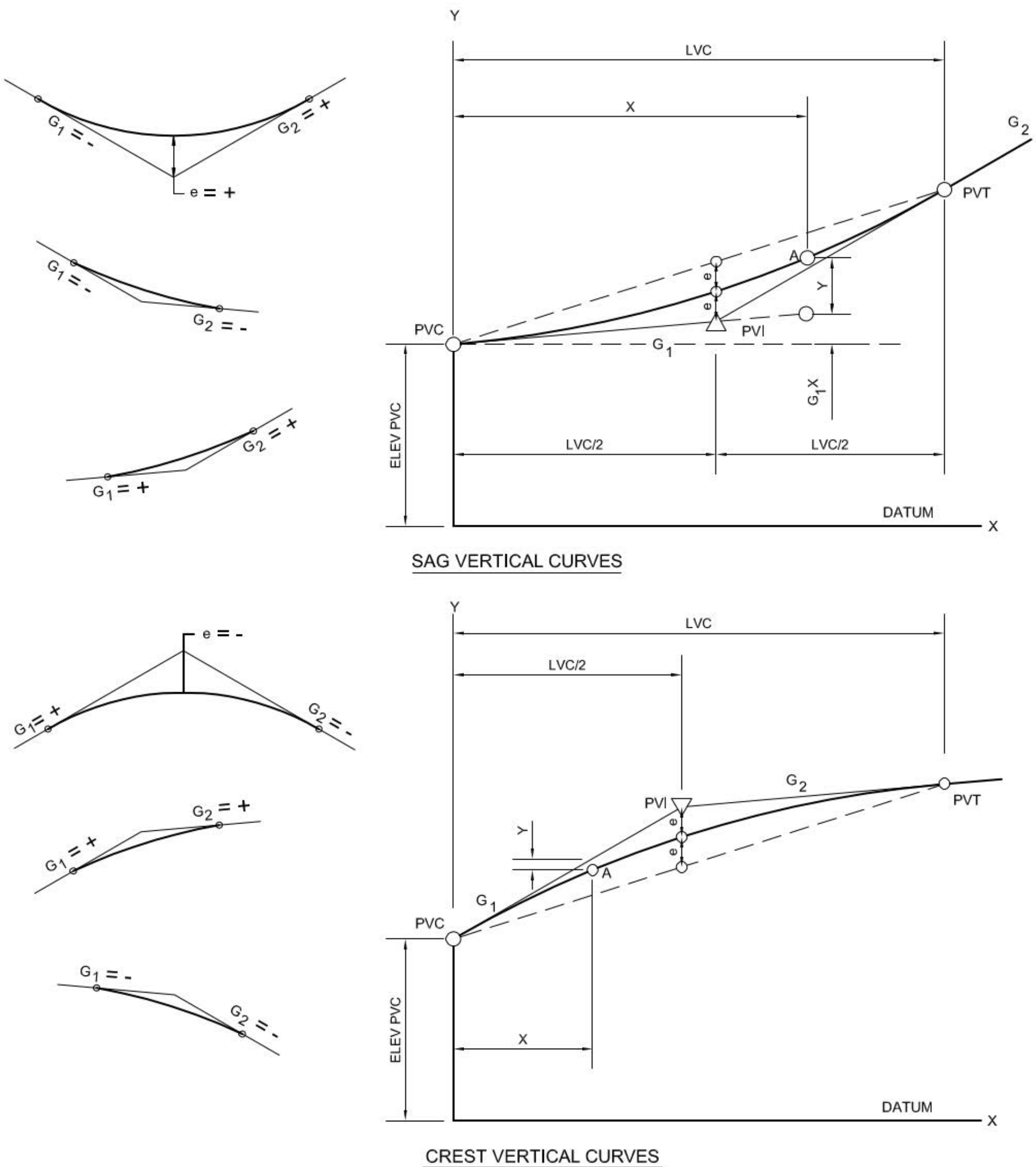
$$S.T. = \frac{Y_s}{\sin\Theta_s}$$

Figure 521-2: Superelevation Transitions for Reverse Curve



$$L_{s_1} \times E_{a_1} = L_{s_2} \times E_{a_2}$$

Figure 521-3: Standard Vertical Curves



PARABOLIC VERTICAL CURVE FORMULAS:

$$e = \left(\frac{G_2 - G_1}{8}\right) LVC = \frac{1}{8} A\,(LVC); \qquad r = \left(\frac{G_2 - G_1}{LVC}\right) = \text{RATE OF CHANGE IN GRADE}$$

$$y = \frac{1}{2}\left(\frac{G_2 - G_1}{LVC}\right) x^2 = \frac{1}{2} r x^2$$

$$\text{ELEV A} = \left(\frac{r}{2}\right) x^2 + XG_1 + \text{ELEV PVC}$$

521.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

521.7.1 Interface and Integration Management

521.7.2 Design Management

521.7.3 Manufacturing and Construction Management

521.7.4 Installation Management

521.7.5 Inspection and Testing Management

521.7.6 Training, Pre-Revenue Operations

521.7.7 Certification Management

521.8 APPENDICES (NOT USED)

END SET - 521

522 TRACK CONSTRUCTION

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TABLES

FIGURES

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SET - 522 TRACK CONSTRUCTION

522.1 INTRODUCTION

522.1.1 Document Scope

522.1.1.1 This set establishes the design criteria for Trackwork. All track material, special trackwork, and practices described herein must govern the design of track for the Link light rail system and include the required interfacing of trackwork with other elements of the system, such as tie and ballast and embedded trackway, subway, aerial guideway, bridges, track slabs, transition slabs, electrification system, signal system, and drainage.

522.1.1.2 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of Sound Transit Design Requirements Set 522 owner to determine the technical source for the design criteria.

522.1.2 Regulations, Codes, Standards, and Guidelines

522.1.2.1 International Regulations, Codes, Standards, and Guidelines

522.1.2.1.1 International Building Code.

522.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines (Not Used)

522.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

522.1.2.3.1 WAC 296-880-40005

522.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

522.1.2.4.1 AREMA Manual for Railway Engineering

522.1.2.4.2 AREMA Portfolio of Trackwork Plans

522.1.2.5 Other Jurisdictions (Not Used)

522.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines (Not Used)

522.1.3 Abbreviations and Acronyms

522.1.3.1 AHJ–authority having jurisdiction

522.1.3.2 AREMA- American Railway Engineering and Maintenance-of-Way Association

522.1.3.3 CIP–cast in place

522.1.3.4 CWR–continuous welded rail

522.1.3.5 DOR–designer of record

522.1.3.6 IJ–insulated joint

522.1.3.7 LRV–light rail vehicle

522.1.3.8 MOW–maintenance of way

522.1.3.9 MSE–mechanically stabilized earth

522.1.3.10 NFPA–National Fire Protection Association

522.1.3.11 OMF–operations and maintenance facility

522.1.3.12 PVC–point of vertical curve

522.1.3.13 PVT–point of vertical tangent

522.1.3.14 VC–vertical curve

522.1.3.15 WAC–Washington Administrative Code

522.1.3.16 WBM–welded boltless manganese

522.1.4 Definitions and Classifications

522.1.4.1 At-grade Crossing: see Set 001.

522.1.4.2 Ballast: see Set 001.

522.1.4.3 Bond, Track: see Set 001.

522.1.4.4 Commuter Rail: see Set 001.

522.1.4.5 Concrete Tie, Track: see Set 001.

522.1.4.6 Continuous Welded Rail: see Set 001.

522.1.4.7 Crossover: see Set 001.

522.1.4.8 Fastener, Track: A railway track part that is designed to fix steel rail and railroad ties.

522.1.4.9 Frog: see Set 001.

522.1.4.10 Gauge, Track: see Set 001.

522.1.4.11 Geotextile: see Set 001.

522.1.4.12 Guidance Drawings: see Set 001.

522.1.4.13 Guideway: see Set 001.

522.1.4.14 Joining of Rail: see Set 001.

522.1.4.15 Joint Bar: see Set 001.

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522.1.4.17 Lead Track: see Set 001.

522.1.4.18 Lubricator, Track: see Set 001.

522.1.4.19 Main Line Track: see Set 001.

522.1.4.20 Maintenance Walkway: see Set 001.

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522.1.4.28 Shop Track: see Set 001.

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522.1.4.32 Subgrade: see Set 001.

522.1.4.33 Switch: see Set 001.

522.1.4.34 Tail Track: see Set 001.

522.1.4.35 Tie, Track: see Set 001.

522.1.4.36 Top-down construction: type of construction method where permanent structures are built from the top to the bottom.

522.1.4.37 Track Modulus: see Set 001.

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522.1.4.40 Turnout, Switch: see Set 001.

522.1.4.41 Wayside Equipment: see Set 001.

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522.2.7 Environmental and Sustainability Needs

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522.5 SYSTEM INTERFACE REQUIREMENTS

Table 522-1 lists requirement sets that are typically coordinated and may have dependencies with this set.

The description of the interfaces below are provided to highlight only the major interface elements between Track and the other discipline sets. The list is not intended to capture all interface elements. The DOR must review and coordinate all interface requirements between Track and the other disciplines at each phase of the design and/or construction.

Table 522-1: Interface between Track and Other Disciplines

SET SERIES	SET NAMES	SET 522 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	X
500	Track	X
600	Fire–Life Safety	X
700	Structures	X
800	Architecture	
900	Civil	X
1000	Mechanical-Electrical and Building Systems	
1100	Technology	
1200	Security	

522.5.1 Train Control and Signals

522.5.1.1 Mainline negative return system must be coordinated with train control and signals.

522.5.1.2 Insulated joint must be coordinated with train control and signals.

522.5.1.3 Verify civil elements do not conflict with insulated joint locations and train-to-wayside communications loops.

522.5.1.4 Center-tap cables from the impedance bonds must be coordinated with train control and signals.

522.5.1.5 Switch machines must be coordinated with train control and signals.

522.5.1.6 Impedance bonds and cab signal interlocking must be coordinated with train control and signal.

522.5.2 Traction Electrification

522.5.2.1 Coordinate the usage and location of insulated joint bar to electrically isolate contiguous rails.

522.5.2.2 Yard track must be isolated from mainline and shop track.

522.5.2.3 Yard track must have resistant to ground.

522.5.2.4 Bonded joint bar usage must be coordinated with traction electrification.

522.5.3 Operational Communications

522.5.4 Vehicle

522.5.4.1 Coordinate direct fixation transition length at descending grade of 3 percent or more.

522.5.4.2 Track vibration control must be coordinated with vehicle.

522.5.4.3 Floating slab must be coordinated with vehicle.

522.5.5 Track

522.5.6 Fire/Life Safety

522.5.6.1 Track aprons must be designed to provide access for all emergency vehicles.

522.5.6.2 Track grade crossing must be coordinated with fire life safety.

522.5.6.3 Emergency/maintenance walkway must be coordinated with fire life safety.

522.5.7 Structures

522.5.7.1 Coordinate with structure for the requirements of direct fixation track usage.

522.5.7.2 Coordinate with structure for the usage of emergency guardrail.

522.5.7.3 Subgrade requirements for settlement and capacity must be coordinated with structure.

522.5.7.4 Coordinate with structure for drainage requirements on elevated guideway.

522.5.8 Civil

522.5.8.1 Coordinate with civil for duct bank/utilities clearances within the subballast ballast section.

522.5.8.2 Drainage requirement in embedded track must be coordinated with civil for location of drainage.

522.5.8.3 Requirements for track underdrain must be coordinated with civil.

522.5.8.4 Track grade crossing must be coordinated with civil.

522.5.8.5 Coordinate with civil for drainage requirements on elevated guideway.

522.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

522.6.1 Track Type

Commentary: Typical trackwork sections of ballasted, direct fixation, and embedded track are shown in the Standard and Directive Drawings.

522.6.1.1 Ballasted Track

Commentary: Ballasted track is commonly composed of steel rail, concrete tie, rail fasteners, and ballast bed. Ballasted track must be constructed wherever feasible at-grade.

522.6.1.2 Direct Fixation Track

Commentary: The direct fixation track consists of rail mounted on direct fixation fasteners that in turn are anchored to an underlying reinforced concrete plinth. The plinth is attached to a concrete slab that can be set at-grade, on an elevated structure deck surface, or on a concrete tunnel invert as shown in the Standard Drawings.

522.6.1.3 Embedded Track

Commentary: Embedded track is a type of trackway that is completely embedded in cast-in-place concrete-except for the tops and gauge sides of the rails within pavement.

522.6.1.4 Yard Track

Commentary: Yard tracks are tied into the mainline and consist of a series of turnouts and crossovers that function as a storage area for out of service trains and a staging area for their movements to and from the maintenance shops and train cleaning facilities.

522.6.1.4.1 Track aprons

Commentary: Concrete aprons with embedded tracks are constructed at the entrances of all shop doors and provide a safe walking surface for train operators, maintenance personnel, pedestrian traffic, and consist of a drivable surface capable of handling rubber-tired service and emergency vehicles.

522.6.1.5 Shop Track

Commentary: Shop tracks are constructed to serve the shop positions found within the shop building and can include vehicle maintenance, posted rail, service, and wash tracks.

522.6.2 Determination of Track Type

522.6.2.1 Ballasted Track Type

522.6.2.1.1 Ballasted track must be used except where other track types are required.

Commentary: The preferred construction type of trackwork used by Sound Transit is ballasted track constructed on at-grade, open cut and retained fill guideways, yards, and other secondary tracks or where designated by Sound Transit.

Commentary: Ballasted track could be used as an alternative on aerial structures less than 400 feet bounded by ballasted track.

522.6.2.2 Direct Fixation Track Type

522.6.2.2.1 Direct fixation track must be used for the following cases:

522.6.2.2.1.1 Direct fixation track must be used on elevated structures where adjacent trackwork is direct fixation or embedded track on either end of elevated structure.

522.6.2.2.1.2 Direct fixation track must be used on elevated structures greater than 400 feet.

522.6.2.2.1.3 Elevated structure less than 400 feet and bounded by ballasted track must either be ballasted track or direct fixation track.

522.6.2.2.1.4 Exclusive Link light rail tunnels ("Dual block tie" track construction may be used as an alternative Trackwork for the tunnel structures).

522.6.2.2.2 Direct fixation track must be used in at-grade sections of less than 800 feet, which are bounded on each side by either direct fixation track or embedded track.

522.6.2.2.2.1 At-grade tracks in excess of six percent grade and longer than 350 feet must use direct fixation track.

522.6.2.2.2.2 Direct fixation track on a descending grade must comply with Figures 522-1 and 522-2 for transitioning between direct fixation track and ballasted track.

Figure 522-1: Limit of Direct Fixation Track

At the end of a grade 3 percent or greater with existing ascending grade.

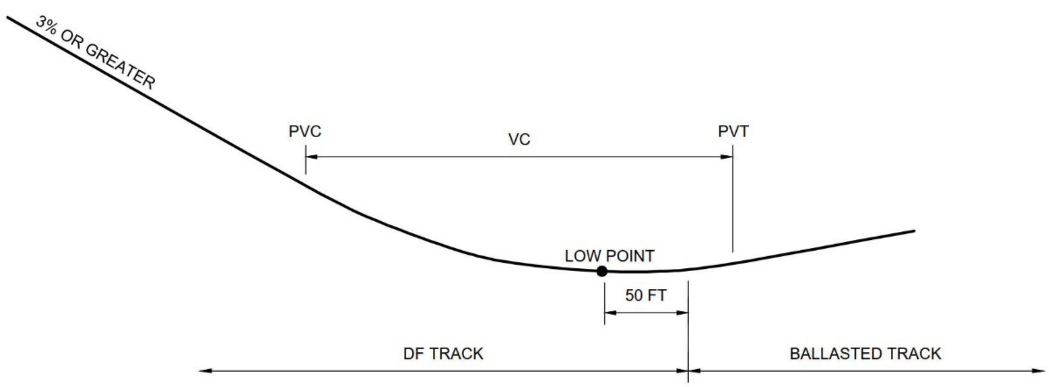
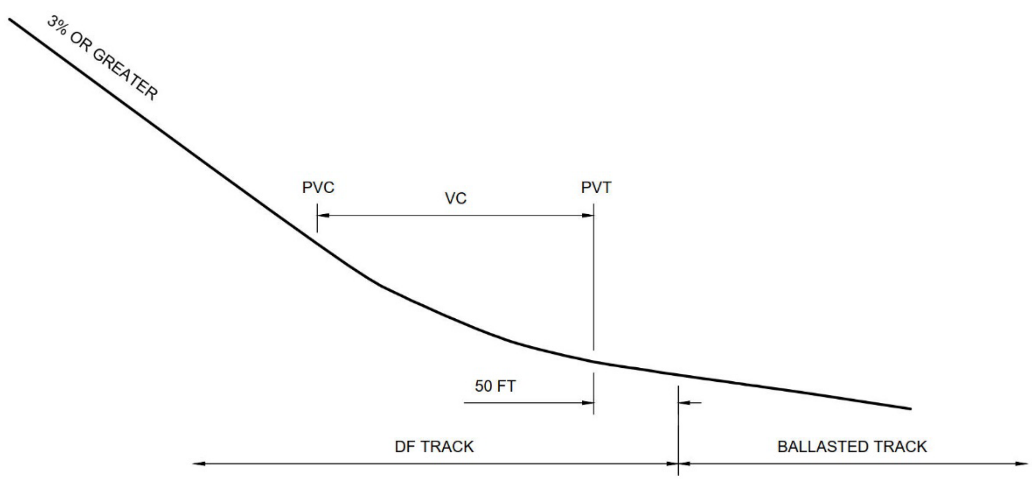


Figure 522-2: Limit of Direct Fixation Track

At the end of a grade 3 percent or greater with existing descending grade.



522.6.2.3 Embedded Track Type

522.6.2.3.1 Embedded track must be used where the Link light rail system shares the trackway with rubber-tired vehicles in mixed traffic and must comply with the standard and guidance drawings.

522.6.3 Track Type Requirements

522.6.3.1 Track construction must meet the requirements as shown on the standard drawings.

522.6.3.2 Ballasted Track

Commentary: The ballasted track section consists of rails fastened to concrete ties on a ballast layer with a layer of subballast between the ballast and a compacted subgrade.

522.6.3.2.1 Ballasted track must be constructed using 115RE CWR.

522.6.3.2.2 All structures protruding vertically from the ballast or ground and constructed within the ballasted bed width, must be a minimum 12 inches from the ends of the ties to the structure, except for station platforms.

Commentary: The minimum 12-inch ballast shoulder width is required for tamping, resurfacing, tie replacement, maintenance, and clear space for future renewals.

522.6.3.2.3 Station platforms along ballasted track must include wood blocks installed at the ends of the ties along the platform side of the track to restrain any lateral movement toward the platform to eliminate vehicle–platform impacts.

522.6.3.3 Direct Fixation Track

Commentary: Direct fixation track on elevated structures need to be protected from the large longitudinal forces, which exist in CWR. The top-down construction method is recommended for installing direct fixation track using a support system that holds each rail in correct alignment, gauge, and cant, and is external to the finished concrete prior to pouring of the second-pour plinths. The support system and the use of jigs must be capable of making adjustments to the line, grade, gauge, elevation, and cant of the rail. Once the rails have been set to the proper orientation, either the rail fasteners or accurate anchor insert templates can be attached to the rail. By attaching the rail fasteners with anchor bolts and anchor inserts to the rails during this process, it ensures accurate placement and saves the later step of removing the templates to install the permanent fasteners.

Commentary: Concrete plinths are a form of direct fixation. The plinths support several direct fixation fasteners under a single rail that can vary in length and that typically support between three to six fasteners. Longer plinths supporting up to 12 or more fasteners have been used in the past but have been found to produce transverse shrinkage cracks. Periodic gaps between the plinths are placed between the plinths to allow for cross drainage into a trough placed along the centerline of track. The gaps can also accommodate transverse raceway and cabling requirements of the traction power and train control systems. Plinths are constructed as a secondary pour of reinforced concrete. They are constructed on the concrete guideway surface and along superelevated track. The depths of the plinths vary to accommodate the calculated superelevation for that particular curve.

522.6.3.3.1 Direct fixation track must comply with the standard drawings.

522.6.3.3.2 Direct fixation track plinths must be cast as a secondary pour and not built integrally with the bridge deck.

522.6.3.3.3 Superelevation must be developed within the plinth and not accomplished by superelevating the bridge deck.

522.6.3.4 Embedded Track

Commentary: Embedded track is completely encased in concrete, except for the top and gauge sides of the rail head. The rail is encapsulated by either a rail boot or elastomeric grout in concrete to provide electrical isolation. Portland cement concrete is the preferred pavement material. Sound Transit currently uses rubber *rail boots in embedded track construction. However, in all future designs, the designer must use embedded track that is completely encapsulated in a polyurethane or an elastomeric grout to the top of rail and along the gauge side of the rail, thereby locking the rail in its final position, and holding it resiliently in position to provide electrical isolation and full bonding of the rail and trough to preclude water intrusion.*

Commentary: Details of embedment and fixation of rail onto track slab can be found in the Guidance Drawings or developed to suit site-specific situations.

Commentary: The flangeways provided for the Link light rail vehicle wheels in embedded track and along at-grade crossings form natural conduits for stormwater runoff. To prevent the formation of ponding and icing at low points of sag vertical curves, the DOR must evaluate the option to use embedded track drains that are installed between the rails as shown in the Standard Drawings.

522.6.3.4.1 Embedded track must meet the requirements as shown on the Standard and Guidance Drawings.

522.6.3.4.2 Rubber rail boots are required and must have drainage provisions that properly drain the rail flangeway, rail boots, and the pavement surface between the rails for all embedded track as shown in the Guidance Drawings.

522.6.3.5 Yard Track

522.6.3.5.1 Yard tracks must be ballasted track construction with 115RE rail.

522.6.3.5.2 Yard rails encased in paving materials must have rubber rail boots installed to utilize their electrical isolation technologies, similar to what is installed in mainline track, and must not come into direct contact with the paving materials.

522.6.3.5.3 Track Aprons

522.6.3.5.3.1 Track aprons must be constructed outside all shop doors.

522.6.3.5.3.2 Tracks aprons must be on 45 feet minimum tangent outside all shop doors.

522.6.3.5.3.3 Minimum length of track apron must be 100 feet from the door edge of the maintenance building unless that distance extends into a turnout.

Commentary: This minimum apron length of 100 feet allows one LRV loading and unloading, and high rail vehicle to park and turn around for exit.

522.6.3.5.3.4 For emergency vehicles access requirement at aprons, refer to Set 601 Fire/Life Safety.

522.6.3.5.3.5 Track aprons must be capable of handling service vehicle loads and pedestrian traffic that allows access to the shop.

522.6.3.6 Shop Track

522.6.3.6.1 Shop trackwork must be installed within the limits of the maintenance shop building.

522.6.3.6.2 Track sections within the vehicle shop facility must be installed as embedded, posted rail, or a combination of both.

522.6.3.6.3 Shop track must be embedded concrete slab CWR track using 115RE rail, with the exception of posted rail in service pit areas.

Commentary: This configuration provides for a suitable working environment to conduct daily servicing and inspection activities within the shop area.

522.6.3.6.4 In service pit areas, welded 115RE rail must be supported by steel girders installed longitudinally beneath the rail and fastened to the steel girders with crane rail clamps or similar rail fasteners.

522.6.3.6.5 Posted rail in service pit areas must not be welded to support girders.

522.6.4 Future Tie-ins

522.6.4.1 The DOR must design the track such that future extension tie-ins do not require destressing of revenue track to make future tie-ins.

Commentary: The DOR must avoid placing special trackwork at the end of the alignment to provide future designers to tie into the existing rail lines without having to go through the process of destressing the rail.

522.6.5 Track Components

522.6.5.1 Rails

522.6.5.1.1 Running Rail

522.6.5.1.1.1 115RE rail must be used for all primary and yard track.

522.6.5.1.1.2 115RE rail must conform to the standard specifications.

522.6.5.1.2 High Strength Rail

522.6.5.1.2.1 High strength rail must be used on grades of 5 percent or greater.

522.6.5.1.2.2 High strength rail must be used in curves with radius equal to or less than 500 feet.

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

522.6.5.1.2.3 High strength rail must be evaluated for usage in areas where high wear rates or internal rail stresses are anticipated at approaches to bridges, elevated structures, floating slabs, where there are track construction type changes, and to limit high stresses in the rail or its support where they are encountered.

522.6.5.1.2.4 High strength rail must be used throughout all special trackwork.

522.6.5.1.2.5 High strength rail must extend at least 100 feet beyond the ends of station platforms.

522.6.5.1.2.6 When two sections of high strength rail are close together and conformance to the above criterion would result in intermediate segment of standard hardness rail less than 156 (2 x 78) feet in length, the high strength rail must be made continuous through all three segments.

522.6.5.1.2.7 High strength rail must conform to standard specifications.

522.6.5.1.3 Precurved Rail

522.6.5.1.3.1 Rails with small radius curves must be precurved using standard roller bending method.

522.6.5.1.3.2 Horizontally curved shopped rail must lie flat after bending.

522.6.5.1.3.3 Inside and outside rail must be precurved under the following circumstances:

522.6.5.1.3.3.1 Running rail and restraining rail with horizontal curve less than 500 feet.

522.6.5.1.3.3.2 Running rail and restraining rail with vertical curve radius less than 1,000 feet.

522.6.5.1.3.4 Precurved rail lengths must comply with the Standard Drawings.

522.6.5.1.4 Restraining Rail

Commentary: Restraining rail is installed along the low rail on curves of tighter radius and provides a uniform flangeway and additional wheel steering action using the back face of the flange of the wheel that is riding the inside rail of the curve. The use of restraining rail in curve will reduce the tendency of the leading outside wheel to climb the outer rail thereby preventing a possible derailment.

522.6.5.1.4.1 Restraining rail must be used on tracks with a centerline radius of less than 500 feet.

Commentary: All track having a centerline radius less than or equal to 100 feet must require both running rails guarded. Other locations where restraining rail would be beneficial to use would be along the low running rail in curves where they are near bridge piers and abutments or under buildings to reduce lateral movement at excursion locations for protection of the structures.

522.6.5.1.4.2 Length of restraining rail must conform to the Standard Drawings.

522.6.5.1.4.3 Restraining rail design must use a 115RE inner rail mounted adjacent to the low rail in accordance with the standard drawings and standard specifications.

522.6.5.1.4.4 Embedded track that requires guarding must use a strap guard rail in addition to the 115RE running rail.

522.6.5.1.5 Emergency Guardrail

Commentary: Emergency guardrail is added to limit the lateral movement of light rail vehicle in case of derailment.

522.6.5.1.5.1 Emergency guardrail must be used on elevated structures or retained earth sections where the drop-off is greater than 5 feet.

522.6.5.1.5.2 Emergency guardrail must be used where adjacent columns and occupied buildings are within 25 feet from centerline of track.

Commentary: DOR shall consider adding emergency guardrails if future planned Transit Oriented Development is known.

522.6.5.1.5.3 Emergency guardrail extension length:

522.6.5.1.5.3.1 Speed > 20 mph: 100 feet before and beyond the hazard area.

522.6.5.1.5.3.2 Speed ≤ 20 mph: 50 feet before and beyond the hazard area.

522.6.5.1.5.4 Emergency guardrail must be fabricated from new or secondhand 115RE Class 4 or better as specified by AREMA.

522.6.5.1.5.5 Emergency guardrail must be installed in accordance with the Standard Drawings.

522.6.5.1.5.6 For double tracks with a hazard on each side, one guardrail is required on each track and must be located inside the running rail farthest from the hazard.

522.6.5.1.5.7 On multiple track areas where the hazard is located on one side only, only the track closest to the hazard must be equipped with emergency guardrail installed inside the running rail that is farthest from the hazard.

522.6.5.1.5.8 At pedestrian crossing panels, emergency guardrails must be interrupted.

522.6.5.1.5.9 Emergency guardrail must be positioned approximately 10 inches from the gauge side of the running rail.

522.6.5.1.5.10 Emergency guardrail end sections must be curved toward the track centerline and provided with vertical taper in accordance with the Standard Drawings.

522.6.5.1.5.11 When a curve requires use of both a restraining rail and an emergency guardrail, only a restraining rail is required.

522.6.5.1.6 Compromised Rail and Joint Bar

522.6.5.1.6.1 Compromise joint bars must be used to connect rails of dissimilar section wherever field welding is unfeasible or where the connection is temporary in nature.

522.6.5.1.6.2 Field welds when possible or forged compromise rails must be used for permanent connections between dissimilar rail sections.

522.6.5.1.6.3 Compromise rail must have similar mechanical properties as high strength rail.

522.6.5.1.6.4 Compromise joints, welds, and rails must not be located within special trackwork units or within 30 feet of the toe end of any turnout stock rail.

522.6.5.2 Ties and Fasteners

522.6.5.2.1 Concrete Tie

522.6.5.2.1.1 Use 8-foot-3-inch-long concrete ties for all primary, yard, and secondary track construction.

522.6.5.2.1.2 Special trackwork tie lengths must be a minimum 4 feet 1-1/2 inches from centerline of track to end of tie.

522.6.5.2.1.3 Special trackwork spacing must be in accordance with the current AREMA Portfolio of Trackwork Plans and Standard Drawings.

522.6.5.2.1.4 Concrete tie spacing must be in accordance with the Standard Specifications.

522.6.5.2.1.5 Track grade crossing ties must comply with the Standard Drawings.

522.6.5.2.1.6 Guardrail and restraining rail ties must comply with the Standard Drawings and Standard Specifications.

Commentary: Install guardrail ties to support guardrails and emergency guardrails or restraining rails that will include insulated threaded inserts to which these items can be attached.

522.6.5.2.1.7 Concrete ties must have lateral resistance patterns on the sides and bottom and must conform to current AREMA guidelines.

522.6.5.2.1.8 Rail seat pad must be in accordance with the Standard Specifications.

Commentary: Rail seat pad is used between the rail and concrete ties to reduce impact and vibration effects on the track structure and minimize rail seat deterioration. Rail seat pads are typically expected to provide electrical isolation as noted in AREMA Manual of Railway Engineering, Chapter 30, Table 30-1-2.

522.6.5.2.1.9 Concrete Tie Anchor

Commentary: To improve lateral stability in curved track, a tie anchor can be bolted to the end of the tie. The tie anchor is a vertical blade penetrating below the tie into the ballast bed. Tie anchors can be attached to all or alternate ties in the curve. Installation of tie anchors is a manual process that disturbs the ballast consolidation, requiring the track to be re-tamped.

522.6.5.2.1.9.1 Tie anchors must be installed on curves with radius of 250 feet or less.

522.6.5.2.2 Wood Ties for Derail Switch Ties

522.6.5.2.2.1 Wood ties must only be used for derail switch ties.

522.6.5.2.2.2 Wood ties must be made of Douglas fir and comply with the Standard Specifications.

522.6.5.2.2.3 Tie plates vary in length and width and must be sized for the spike hole punching to match the width of the rail base as shown on AREMA Portfolio of Trackwork Plan No. 213.

522.6.5.2.2.4 Track bolts, nuts, and spring washers must conform to AREMA Manual for Railway Engineering, Chapter 4 Rail, Part 1 “Design of Rail” and Part 2 “Manufacture of Rail.”

522.6.5.2.3 Concrete Tie Fasteners

522.6.5.2.3.1 Rail resilient elastic fastening system on concrete ties and special trackwork must comply with the Standard Specifications.

522.6.5.2.3.2 Concrete ties must use the fast clip system for open track.

522.6.5.2.3.3 Concrete ties must use the e-clips for special trackwork with insulators.

522.6.5.2.4 Direct Fixation Fasteners

Commentary: The direct fixation fastener is a system composed of clips with a thick elastomer and steel body unit that holds the rail to tie or concrete slab, provides electrical isolation, and has an additional function of providing major vibration, shock, and noise reduction to the track-car system as a whole.

522.6.5.2.4.1 Direct fixation rail fasteners size and spacing must be in accordance with the Standard Specifications and Standard Drawings.

522.6.5.2.4.2 Low restraint fasteners may be required to allow the structure to expand and contract without overstressing the rail.

522.6.5.2.5 Special Trackwork Fasteners

522.6.5.2.5.1 Special trackwork fasteners in direct fixation track must be compatible with the standard fastener used in the conventional special trackwork on concrete ties.

522.6.5.2.5.2 Special trackwork fasteners must be spaced as shown in the Standard Drawings.

522.6.5.2.6 Rail Seat Cant

522.6.5.2.6.1 Concrete ties and direct fixation fasteners must provide an inward (towards the centerline of track) rail seat cant of 40:1, except in special trackwork.

522.6.5.2.6.2 Rail seat must gradually transition from 40:1 to “0” prior to special trackwork over 10 feet.

522.6.5.2.6.3 Special trackwork must provide a rail seat of zero, “0”, cant.

522.6.5.3 Rail Joints

522.6.5.3.1 Insulated Joint Bar

522.6.5.3.1.1 Insulated joint bars of the epoxy-bonded type must be used in CWR wherever it is necessary to electrically isolate contiguous rails.

522.6.5.3.1.2 Insulated joint bars must be located as required per Set 123 Train Control and Set 220 Traction Power.

522.6.5.3.1.3 Insulated joints must comply with the Standard Drawings and Standard Specifications.

522.6.5.3.1.4 Insulated joints installed at the point of switch must be no closer than the end of turnout stock rail.

522.6.5.3.1.5 Insulated joints must not be placed in track grade crossings.

522.6.5.3.1.6 Insulated joints or bonds must be placed greater than 10 feet from the ends of all grade crossings.

522.6.5.3.1.7 Yard track must be electrically isolated from mainline and shop track using insulated rail joints.

522.6.5.3.1.8 The location of the insulated joints must be placed outside the shop doors and aligned with the OCS section insulator to reduce the possibility of a car or train bridging the insulator for a time period longer than that required to move into or out of the shop.

Commentary: Actual locations of isolators must ensure that parked vehicles cannot electrically connect the shop track or mainline track to the yard track for periods of time longer than that required to move a vehicle into or out of the yard. Provide multiple negative feeder cable connections throughout the yard spaced to minimize variations in track to earth voltage in the yard track system. There is no specific negative cable length requirement and traction power only needs a continuous rail connection for return current path when the insulated joint or Z-bond are placed in.

522.6.5.3.1.9 Insulated apron track must be provided with a rubber rail boot that properly drains the rail flangeway away from the shop building.

522.6.5.3.2 Bonded Joint Bar

522.6.5.3.2.1 Except in those tracks designated as being constructed with jointed rail, bolted joints must only be used between welded rail strings of different chemical compositions or metallurgy.

522.6.5.3.2.2 These joints must be of the epoxy-bonded type and must be fastened with high-strength pin type bolts.

522.6.5.3.2.3 Rail at such joints must be electrically bonded to provide a continuous path for traction power negative return current and signal circuits and must comply with the following:

522.6.5.3.2.3.1 Identical rail drilling pattern as standard joint bar.

522.6.5.3.2.3.2 Compatible with the standard rail fasteners used on the Link light rail project.

522.6.5.3.2.3.3 Comply with the current AREMA “Specifications for Quenched Carbon-Steel Joint Bars, Microalloyed Joint Bars, and Forged Compromise Joint Bars” and “Rail Drilling & Bar Punchings, and Bolts”.

522.6.5.3.3 Joint Bar

522.6.5.3.3.1 The use of bolted joints must be minimized during design except in those locations where the use of jointed rail is specified.

Commentary: The joint bars in exclusive Link light rail track may be the lightweight design in accordance with the Standard Drawings and Standard Specifications.

522.6.5.3.3.2 Joint bars must be 36-inch six-hole bars conforming to AREMA standard punching patterns.

522.6.5.3.3.3 Track bolts, nuts, and lock washers must conform to AREMA standards.

522.6.5.4 Rail Welding

522.6.5.4.1 All tracks must be CWR.

522.6.5.4.2 Rail welding must conform to the Standard Specifications and AREMA standard.

522.6.5.4.3 Field thermite welds must be located as suspended joints to avoid damaging the rail seat pads.

522.6.5.4.4 All special trackwork joints must be welded, except at joint locations as shown on the Standard Drawings.

522.6.5.4.5 Rail welds must not be placed in grade crossings.

522.6.5.4.6 Rail welds must be placed greater than 10 feet from end of grade crossing panels.

522.6.5.4.7 Rail welds must not occur within 3 feet of transition from embedded shop track to posted rail.

522.6.5.4.8 Flash butt welds must be used to join rail of different chemical composition or metallurgy.

522.6.5.4.9 Rail Temperature

Commentary: The rail temperature varies from the lowest ambient temperature to the highest ambient temperature. When rail is exposed to sunlight, its maximum rail temperature will be 35 degrees Fahrenheit greater than the highest ambient temperature (110 degrees Fahrenheit).

522.6.5.4.9.1 Exposed rails must use a temperature range of 0 degrees Fahrenheit to 145 degrees Fahrenheit.

522.6.5.4.9.2 Exposed rails must be installed at a rail neutral temperature between 90 degrees Fahrenheit to 105 degrees Fahrenheit.

Commentary: Neutral temperature is the temperature at which a rail of fixed length is neither in compression nor tension.

522.6.5.4.9.3 Rails more than 300 feet from portals that are not exposed to sunlight must be installed at a rail neutral temperature between 55 degrees Fahrenheit to 80 degrees Fahrenheit.

522.6.5.5 Derails

522.6.5.5.1 Double switch point type derails must be used to protect the main line tracks and controlled sidings.

522.6.5.5.2 Derails must be placed on the following tracks that connect to the main line:

522.6.5.5.2.1 At the end of a powered siding.

522.6.5.5.2.2 At the end of an unpowered siding with no vehicle traffic.

Commentary: Derails are only installed on tracks that are not part of the operating system.

522.6.5.5.2.3 Derails must be located so that the LRV derails away from the primary track.

522.6.5.5.2.4 For derails protecting the mainline, the derail must be placed a minimum of 100 feet behind the 14-foot clearance point to the mainline.

522.6.5.5.2.5 For derails protecting non-mainline track, the derail must be placed a minimum of 50-feet behind the 14-foot clearance point to the non-mainline track.

522.6.5.5.2.6 Derails must be placed on tangent track.

522.6.5.5.2.7 A “Derail” sign must be placed next to every derail.

522.6.5.5.2.8 Derails must conform to the details in the AREMA Portfolio of Trackwork Plan.

522.6.5.6 Ballast

522.6.5.6.1 Ballast must be of new crushed stone, containing no carbonates or slag, composed of hard, strong angular and durable particles, non- porous, well-drained, free from injurious amounts of deleterious substances, and conforming to the requirements of AREMA Manual for Railway Engineering.

522.6.5.6.2 A minimum 1-inch clearance must be provided between the ballast material and all metallic track components in electrical contact with the rail.

522.6.5.6.3 For primary track, ballast must conform to the Standard Specifications and AREMA ballast gradations No. 3.

522.6.5.6.4 For yard track, ballast must conform to the Standard Specifications and AREMA ballast gradations No. 3 or No. 4A.

522.6.5.6.5 For walkway areas at ballast level the ballast must conform to the Standard Specifications and AREMA ballast gradation No. 5.

522.6.5.6.6 Ballast Depth

522.6.5.6.6.1 The minimum ballast depth must be 12 inches as measured from the top of subballast to the bottom of tie except for transition areas where the ballast depth varies from 10 to 12 inches.

522.6.5.6.6.2 Calculate total depth of track substructure using AREMA Manual for Railway Engineering. For calculated track substructure depth greater than 18 inches, the ballast depth must be increased to meet the calculated section depth.

Commentary: The minimum ballast depth of 12 inches provides a maintainable ballast section and increases duration between ballast renewals. The ballast depth provides space for ballast particle interlocking supporting the longitudinal and lateral resistance for CWR track. The ballast depth supports the placement of signaling conduit routing.

522.6.5.7 Subballast

522.6.5.7.1 The minimum depth of the subballast layer must be 6 inches.

Commentary: The minimum subballast depth is designed to reduce subgrade loads and promotes surface water shedding to the toe of the subballast. The design of the subballast reduces subgrade water infiltration and mud pumping.

522.6.5.7.2 Additional depth must be used when necessary to decrease subgrade pressure.

522.6.5.7.3 Where widened shoulder service roads are provided, the full depth of the subballast must be extended across the full width of the service road.

522.6.5.7.4 The subballast layer for all tracks must be uniformly placed and compacted over the entire width of the subgrade following the profile and cross section.

522.6.5.7.5 Subballast must be crushed stone or gravelly sand with gradation in accordance with the Standard Specifications and site-specific additional design requirements.

522.6.5.8 Subgrades

Commentary: The subgrade must be analyzed to determine whether it has both uniform stability and the strength to carry the track loadings expected. Sound Transit recommends that, for most soils, pressure on subgrade be lower than 25 psi to maintain subgrade integrity.

522.6.5.8.1 Where the subgrade bearing capacity is insufficient, the subgrade must be improved to support the track loading.

522.6.5.8.2 Maximum subgrade settlement of at-grade ballasted track must not be greater than 1 inch in the first 10 years and 6 inches over lifetime.

522.6.5.8.3 Maximum differential settlement of at-grade ballasted track must be 1:1500 longitudinally, and 1:500 laterally.

522.6.5.9 Geotextile Fabrics

Commentary: Geotextile fabric must be placed for tracks where potential mud pumping and stability issues are identified and directed for use by the Geotechnical/Environmental study.

Commentary: The use of geotextiles or geogrids between the subgrade and subballast may be advantageous under some conditions.

522.6.5.9.1 Geotextile fabric must be used below the bottom of subballast layer if the subgrade soils within 2 feet contain more than 15 percent of fines (materials finer than U.S. #200 sieve opening of 0.075 mm).

522.6.5.9.2 Geotextile fabric must be placed under subballast layer for all special trackwork. Fabric must extend 20 feet before point of switch and 10 feet after the last long tie.

522.6.5.9.3 Geotextile fabric must extend the full width of the subballast and subgrade.

522.6.6 Special Trackwork

Commentary: Special trackwork on the Link light rail system will consist of ballasted and direct fixation. However, the designer is to use ballasted special trackwork whenever possible.

522.6.6.1 All special trackwork must be designed and constructed in accordance with the Standard Drawings.

522.6.6.2 All special trackwork must be located in horizontal and vertical tangent track.

522.6.6.3 Special trackwork switch must be designed for switch heater which includes space for cribs, carriages, etc.

522.6.6.4 Ballasted special trackwork must be constructed on concrete ties using insulated resilient rail fasteners.

522.6.6.5 Ballasted special trackwork for mainline and yard track must use resilient clips and insulated plates.

522.6.6.6 Direct fixation special trackwork must use resilient rail fasteners on concrete plinths.

522.6.6.7 Location of Special Trackwork Units

Commentary: Locate special trackwork to reduce the exposure of pedestrians to the movable mechanisms and to minimize requirements for special catenary and signal structures.

522.6.6.7.1 Pedestrian walkways and crossings must not be installed within special trackwork.

Commentary: If unavoidable, crosswalks may be located between the switch and frog provided pedestrians are not exposed to a metallic walking surface or flangeway wider than what would occur if the pedestrian crossing were located away from the special trackwork unit.

522.6.6.7.2 The point of switch or last long tie must be a minimum of 10 feet from the ends of the roadway track grade crossing (including sidewalks and bicycle lanes), pedestrian access, maintenance access, MOW, and any yard crossings.

Commentary: Location of special trackwork near track grade crossings must consider placement of insulated joints and spacing to end of crossings. See section "Insulated Joint Bar" in this set.

522.6.6.7.3 Embedded special trackwork is not allowed.

522.6.6.7.4 Special trackwork is not allowed within track aprons and over transition slabs.

522.6.6.7.5 Special trackwork must be located greater than 300 feet from beginning of new extension.

522.6.6.7.6 Special trackwork must be located greater than 300 feet from end of line.

Commentary*: Special trackwork is located away from the end of line and new extension to avoid revenue service impact to tie in the new extension.*

522.6.6.7.7 The minimum length of horizontal track between any point of switch and the end of a station platform, horizontal curve, or vertical curve must comply with Set 521 Track Geometry.

522.6.6.7.8 Special trackwork on elevated structures must be set on continuous spans, or approved equivalent, to limit movement on the structure.

522.6.6.7.9 The separation distance required between the points of intersection of various combinations and directions of turnouts are shown in Figure 522-7 through Figure 522-10.

522.6.6.7.10 On mainline track, the minimum distance between the heel of frog to point of switch for two adjacent turnouts must be 45 feet.

522.6.6.8 Special Trackwork Type and Speed

Commentary: Where a pair of crossovers are required, it is desirable that they be located as two single crossovers of opposite hand. If extraordinary site conditions make it more economical, a double crossover may be used. The size of turnout or crossover selected depends upon its purpose, desired design speeds, and local geometric constraints.

522.6.6.8.1 The normal and maximum operating speeds through various turnouts designated for use on the Link light rail system is shown in Table 522-2.

Table 522-2: Turnout Operation Speeds (mph)

Turnout No.	Maximum Operating Speed (Eu=3.5”)	Normal Speed (Eu=1-1/2”)
5	12	5
6	15	10
8	20	15
10	25	20
15	38	30
20	51	40
5 EQL	17	10

522.6.6.8.2 The DOR must select the required service application of the various turnouts designated for use on the Link system as shown in Table 522-3 below.

Table 522-3: Application of Turnouts – Turnout – Ballast/Direct Fixation

Frog No.	Curved Switch	Service
5	13’-0”	Link Yard Tracks only
5 EQL	13’-0”	For Pocket Tracks only
6	13’-0”	For replacement of existing No. 6 only
8	19’-6”	For replacement of existing No. 8 only
10	19’-6”	Main track turnout
15	26’-0”	Main track turnout
20	39’-0”	Main track turnout

Commentary: No. 15 and No. 20 frogs can be used in right-hand or left-hand single crossovers, but not for double crossovers.

522.6.6.8.3 The running surface supporting the tread of wheel must be treated to provide a minimum Brinell hardness in the Standard Specifications.

522.6.6.8.4 All rail joints must be bonded as required in accordance with Set 220 Traction Power and Set 123 Train Control.

522.6.6.9 Special Trackwork Noise and Vibration

522.6.6.9.1 As all special trackwork is a source of noise and vibration, it must be located away from noise and vibration sensitive land use areas near residential buildings, commercial buildings, or other noise sensitive locations.

522.6.6.9.2 Noise and vibration levels from special trackwork must be evaluated as part of the Noise and Vibration Analysis Report.

522.6.6.9.3 Where special trackwork is to be located in proximity to properties that are noise and vibration sensitive, appropriate low-impact frogs, such as movable point frogs and/or flange bearing, must be used to reduce the noise and vibration impacts. See Set 007 Noise and Vibration for additional information.

522.6.6.9.4 Frogs in primary track turnouts must be designed to eliminate all bolted joints in running surfaces.

522.6.6.10 Switch Machines – Power Operated and Manual

Commentary: Switches may be operated by power and lock movements, electrically locked hand-operated, or hand-operated switch stands, depending on the location and purpose of the switch.

522.6.6.10.1 Switch machines that are used in interlockings must be powered switch machines with secondary manual control.

522.6.6.10.2 Space requirements for switch machines must be coordinated with Set 123 Train Control and Set 520 Vehicle Clearance and Track Spacing.

522.6.6.10.3 The exact type of switch machine used must be selected following the requirements in Set 123 Train Control.

522.6.7 Rail Expansion Joints

Commentary: A continuous installation of CWR introduces high thermal stresses into the rail as it approaches the extreme high and low temperatures of the region that must be addressed if the track is installed on a bridge or elevated structure. In these situations, the installation of rail expansion joints allows the rails to expand and contract freely to reduce the thermal stresses in the rail on the structure.

Commentary: In situations where this occurs in sharp curves, it is desirable to limit the rail stresses from the thermal structural forces by allowing the rail to move longitudinally within defined distances. This is addressed by introducing a combination of low-restraint direct fixation fasteners and rail expansion joints to allow the rail to move safely. However, in this situation, the rails need to be either anchored or fixed between the rail expansion joints to control the movement by installing high-restraint fasteners or a specially designed rail anchor to control the rail movement that will also control the transfer of acceleration and braking forces into the structure.

Commentary: During final design, locations where rail expansion/contraction is anticipated to present a problem must be analyzed for methods of control on bridges and sharp curves on ballasted track.

522.6.7.1 The expansion capacity of the joints must be greater than the anticipated rail movement within the full range of rail temperatures.

522.6.7.2 Expansion joints must be bonded for negative return electrical conductivity.

522.6.8 Rail Grinding and Polishing

Commentary: Rail grinding is a means of maintaining a reasonably consistent wheel-rail interface that can improve the contact point between the rail head and wheel profile, improving wheel wear and controlling noise due to the wheel-rail interaction, and provide for better traction and electrical conductivity.

Commentary: Rail polishing follows rail grinding through the use of different grinder speed, pressure, and grit stones compared to rail grinding with the intention of smoothing out the rail to achieve the rail roughness limits defined in the Standard Specification.

522.6.8.1 Prior to tracks being opened for revenue service, the running rail must be reprofiled and comply with the Standard Specifications for rail grinding.

522.6.9 Transitions and Transition Slabs

Commentary: When two types of track structures are connected, a transition track section is constructed between them to transfer the differences in their track modulus from one type to the other. When one type is ballasted track, the crosstie spacing and ballast depth is adjusted within the transition track section to account for the difference in the track modulus of the more rigid track. The minimum ballast depth above a transition slab measured from bottom of tie varies from 10 to 12 inches in accordance with the Standard Drawings.

522.6.9.1 The crosstie spacing along the transition slab from ballasted track to direct fixation or embedded track must be adjusted to account for the difference in track modulus between the more rigid track and the adjoining ballasted track.

522.6.9.1.1 Tie spacing along the ballasted/direct fixation and ballasted/embedded transition slab must be in conformance with the Standard Drawings.

522.6.9.2 Track transition slabs, as shown on the Standard Drawings, must be installed at the interfaces between ballasted track and the following:

522.6.9.2.1 Direct fixation track

522.6.9.2.2 Embedded track

522.6.9.2.3 Track aprons

522.6.9.3 Transitions between direct fixation track and embedded track must be installed in accordance with the Standard Drawings.

522.6.9.4 Transitions between ballasted track and embedded track must be installed in accordance with the Standard Drawings.

522.6.9.5 Transitions between ballasted track and direct fixation track must be installed in accordance with the Standard Drawings.

522.6.9.6 Transitions between direct fixation track and ballast track must provide fully retained ballast between the last concrete tie and ballast retention curb or wall in superelevated or non-superelevated track per the Standard Drawings.

522.6.10 Track Gauge

522.6.10.1 Track gauge must use standard gauge of 4 feet 8-1/2 inches, measured between the inner (gauge) sides of the heads of rails at a distance of 5/8 inches (16 millimeters) below the top of rail.

522.6.11 Track Construction Tolerances

522.6.11.1 Track construction tolerances for gauge, alignment, and cross level must comply with the construction tolerances in the Standard Specifications.

522.6.12 Drainage

522.6.12.1 Ballasted Track Drainage

Commentary: The ballasted track roadbed depends on the ability of the trackbed to drain well. The ballast stone must be kept clean so that stormwater runoff can quickly drain down to the subballast surface layer and into a parallel drainage system such as open ditches or underdrains. Dirt, debris, and fines can foul the ballast section by causing slow drainage leading to a permanent saturated subgrade. This can result in deterioration and breakdown of the track structure with "pumping" track.

522.6.12.1.1 The top subgrade must be crowned a minimum 1:40 to drain water outside of the track structure in accordance with the Standard Drawings.

522.6.12.1.2 Underdrains must be 8-inch minimum perforated pipe.

522.6.12.1.3 Underdrains must be surrounded by gravel drain material and the gravel drainage material must be wrapped in filter fabric in accordance with the Standard Drawings.

522.6.12.1.4 Underdrains must include cleanouts spaced no greater than 300 feet.

522.6.12.1.5 Edge of cleanout concrete collar must be 12 inches minimum from edge of track tie.

522.6.12.1.6 Underdrains must be sloped a minimum of 6 inches in every 100 feet of length.

522.6.12.1.7 The maximum underdrain length must not exceed 1,200 feet.

522.6.12.1.8 Drains must be located at the low points of the profile

522.6.12.1.9 The top of underdrain pipe must be placed a minimum of 12 inches below top of subballast in accordance with the standard drawings except in the following locations:

522.6.12.1.10 Ballasted bridges underdrains

522.6.12.1.10.1 Filter fabric is not required on ballasted bridges.

522.6.12.1.10.2 Half round underdrains must be a minimum of 8 inches in diameter

522.6.12.1.10.3 Top of the half round underdrains must be a minimum of 12 inches below bottom of tie.

522.6.12.1.11 Ballasted track underdrains on MSE walls

522.6.12.1.11.1 The top of underdrain pipe must be placed a minimum 4 inches below top of subballast.

522.6.12.1.11.2 The underdrain pipe must have a minimum of 2 inches of drainage gravel backfill below bottom of pipe.

522.6.12.1.12 Short reverse drainage runs

Commentary: Short reverse drainage is used to redirect the slope of the underdrain system. This is usually used when the slope of the underdrain is continuing to run down below the bottom of the ballasted track structure.

522.6.12.1.12.1 Reverse drainage runs must be 150 feet length maximum.

522.6.12.1.12.2 Top of underdrain must be 3 inches or more below bottom of ballast.

522.6.12.1.12.3 Minimum slope of underdrain is 0.5 percent.

522.6.12.1.13 Track drains must be located adjacent to special trackwork.

522.6.12.2 In embedded track, track drains must also be placed at intervals as specified in the Set 901 Storm Drainage, along grades on the downhill side before crosswalks, and the downgrade end of embedded track segments which adjoin ballasted or direct fixation track.

522.6.12.2.1 Additional locations where track drains are to be installed in embedded track must be coordinated between the track and drainage design teams.

522.6.12.2.2 For ditches and subsurface drain requirements, refer to Set 901 Storm Drainage.

522.6.12.3 In direct fixation track, the cross-sectional drainage low point must not be in the emergency/maintenance walkway.

522.6.12.4 For drainage on elevated structure, refer to Set 901 Storm Drainage and Set 721 Bridges and Elevated Structures.

522.6.13 Track Grade Crossings

Commentary: Track grade crossings are intersections where vehicles, pedestrians, or bicyclists cross the train tracks at the same elevation. Track grade crossings should be clearly delineated and designed with public *safety, necessity, access, and economics in mind. Sound Transit has five types of track grade crossings: public roadway, public pedestrian, maintenance/emergency walkways, yard access, and maintenance of way access.*

522.6.13.1 At-grade crossings of roadways must conform to the Standard Drawings, Set 120 At-Grade Crossing, Set 123 Train Control, and the AHJs.

522.6.13.2 Grade crossings must have an angle greater than 75 degrees.

522.6.13.3 Crossing Panel Designs

522.6.13.3.1 Crossing panels must be slip resistant. See Set 601 Fire–Life Safety for slip resistant requirements.

Commentary: Crossing panels must be designed to minimize maintenance that may cause train service interruptions and requirement for lane or roadway closures.

522.6.13.3.2 Crossing panels must be constructed for removability for track maintenance.

522.6.13.3.3 Crossing panels must provide electrical isolation and non-interference with electrical track circuits or rail fastenings.

522.6.13.3.4 Ballasted Track Roadway Grade Crossing

Commentary: Roadway track grade crossings are at-grade intersections where one or more railroad tracks cross a public highway, road, or street, including sidewalks and pathways located at the edge and parallel to the road.

522.6.13.3.4.1 Ballasted track roadway grade crossings must incorporate pre-attached rubber flange-way fillers.

522.6.13.3.4.2 Flangeway width must be 2 1/2 inches maximum at the road crossing.

522.6.13.3.4.3 Flangeway width must be 2 1/4 inches maximum at the pedestrian/sidewalk crossing within the road crossing.

522.6.13.3.4.4 Ballasted track roadway grade crossing must be located in horizontal and vertical tangent track.

522.6.13.3.4.5 Parallel tracks must be coplanar through the ballasted track roadway grade crossing.

522.6.13.3.4.6 The limits of the ballasted track roadway grade crossing must comply with the Standard Drawings.

Commentary: Track grade crossing limits should consider AHJ comprehensive plan for roadway widths in determining the overall length of the grade crossing. Pavement and track repairs in the vicinity of a roadway track grade crossing can be extremely difficult, costly, and disruptive to both motorists and Sound Transit. To avoid these measures, the crossing panel limits should extend beyond the designed roadway width to prevent the need for any repairs or rehabilitation of the crossing panels or track alignment due to any future roadway widening projects.

522.6.13.3.4.7 Crossing panels must extend a minimum of one-half panel or 5 feet, whichever is greater, beyond the edge of roadway or back of curb.

Commentary: *Roadway track grade crossings should avoid having gaps with open ballasted track between roadway and pedestrian track grade crossings at an intersection.*

522.6.13.3.4.8 When a roadway track grade crossing is less than or equal to 20 feet from a pedestrian track grade crossing, the limits of the crossing panel must extend to the pedestrian track grade crossing.

522.6.13.3.4.9 Crossing panels must be made of precast modular concrete panels in accordance with the Standard Drawings.

522.6.13.3.4.10 Crossing panels must be flush with top of rail elevations for the entire length of the crossing.

522.6.13.3.4.11 End panels must have a 45 degree slope from bottom of rail to top of concrete panel in accordance with the Standard Drawings.

Commentary: Drainage and keeping debris and dirt from accumulating within or adjacent to the crossing are critical elements to grade crossing design. Debris accumulation may result in fouled ballast and a path for stray current leakage. Standing water may also shunt the signal circuits causing signal failures. An effective drainage system must be designed to intercept the surface and subsurface drainage and discharge away from the crossing.

522.6.13.3.4.12 Stormwater runoff and debris from the street must be directed away from the track section.

Commentary: All drainage water entering the track underdrain must be collected from within the track guideway or track section only. Sanitary sewer discharge is not allowed to enter the track drainage system.

522.6.13.3.4.13 Only water collected at the track grade crossing in the track underdrain can be connected to the track drainage system.

522.6.13.3.4.14 The grade crossing track underdrain must be connected to the track drainage system outside the track grade crossing limits.

522.6.13.3.4.15 Drainage water flowing out of the track grade crossing must be collected and routed separately from the track drain system.

522.6.13.3.4.16 An underdrain must be placed to drain the ballasted track for the length of the crossing panels.

522.6.13.3.4.17 The centerline of drainage pipe must be minimum 12 inches to outside edge of crossing panel.

522.6.13.3.4.18 Cleanouts must not be placed within the track grade crossing limits.

522.6.13.3.5 Ballasted Track Pedestrian Crossing

Commentary: Pedestrian track grade crossing is a separated sidewalk or pathway where only pedestrians cross the railroad tracks at grade. Pedestrian track grade crossings on Sound Transit Facilities are located at station platforms and sidewalk crossings that are greater than 20 feet from a track roadway crossing panel.

522.6.13.3.5.1 Ballasted track pedestrian crossing must incorporate pre-attached rubber flange-way fillers.

522.6.13.3.5.2 Flangeway width must be 2-1/4 inches maximum.

522.6.13.3.5.3 Ballasted track pedestrian crossing must be located in horizontal and vertical tangent tracks.

522.6.13.3.5.4 Parallel tracks must be coplanar through the ballasted track pedestrian crossing.

522.6.13.3.5.5 The limits of the ballasted track pedestrian crossing must comply with the Standard Drawings.

522.6.13.3.5.6 Crossing panels must be made of precast concrete panels in accordance with the Standard Drawings.

522.6.13.3.5.7 Crossing panels must be flush with top of rail elevations for the entire length of the crossing.

Commentary: Asphalt filler ramps are used to reduce possible damage from dragging equipment and to prevent shifting.

522.6.13.3.5.8 Asphalt filler ramp must be installed at the ends of the ballasted track pedestrian crossing in accordance with the Standard Drawings.

522.6.13.3.5.9 Asphalt filler ramps must be built for the capacity of MOW vehicles and other vehicle weights such as emergency vehicles.

522.6.13.3.5.10 Ballasted track pedestrian crossing drainage must comply with the requirements in Ballasted Track Roadway Grade Crossing.

522.6.13.3.6 Direct Fixation Crossings for Maintenance/Emergency Walkways

Commentary: Maintenance walkway crossings on direct fixation tracks are provided to accommodate maintenance and emergency walkway continuity where safety walks are discontinued on one side and continued on the opposite side.

522.6.13.3.6.1 Direct fixation track maintenance walkway pedestrian crossing must comply with the Standard Drawings.

522.6.13.3.6.2 Flangeway width must be 2-1/8 inches with a tolerance of +1/4 inch and -0.0 inch.

522.6.13.3.6.3 Maintenance/emergency walkway crossing panels must be at least 6 feet wide.

522.6.13.3.6.4 Direct fixation track maintenance walkway pedestrian crossing must be located in horizontal and vertical tangent track.

522.6.13.3.6.5 Crossing panels must be made of precast concrete panels in accordance with the Standard Drawings.

522.6.13.3.6.6 Crossing panels must be recessed 3/4 inch below top of rail.

522.6.13.3.6.7 Drainage openings must be provided within each of the concrete bases that support the concrete crossing panels.

522.6.13.3.6.8 Drainage opening must have a minimum depth of 3 inches.

522.6.13.3.7 Maintenance of Way Crossing

Commentary: MOW crossings are located where MOW vehicles cross the tracks at-grade along the mainline and in the yard. MOW crossings in the yard include track crossings at driveway entrances. Refer to Set 906 Roadways and Non-Motorized Facilities for additional requirements on MOW crossing.

522.6.13.3.7.1 Ballasted Track Maintenance of Way Crossing

522.6.13.3.7.1.1 Ballasted track MOW crossing must comply with the crossing panel design for Ballasted Track Pedestrian Crossing.

522.6.13.3.7.2 Direct Fixation Maintenance of Way Crossing

522.6.13.3.7.2.1 Flangeway width on the gauge side must be 2-1/2 inches wide.

522.6.13.3.7.2.2 Flangeway width on the field side must be 1-1/2 inches wide.

522.6.13.3.7.2.3 The field and gauge side crossing panels must be skid resistant steel plates over a concrete slab.

522.6.13.3.7.2.4 Steel plates must be recessed 1/4 inch below top of rail.

522.6.13.3.7.2.5 Concrete slab must provide 6-inch minimum depth drainage openings.

522.6.13.3.7.3 Embedded Track Maintenance of Way Crossing

522.6.13.3.7.3.1 Embedded track MOW crossings must comply with embedded track requirements.

522.6.13.3.7.4 Mainline Maintenance of Way Track Crossing

522.6.13.3.7.4.1 MOW crossing limits must be a minimum of 120 feet long with:

522.6.13.3.7.4.1.1 A maximum track grade of 2 percent, which includes the gradient within a vertical curve.

522.6.13.3.7.4.1.2 A minimum of 60 feet of grade crossing on tangent track.

522.6.13.3.7.4.1.3 A maximum 1/2 inch superelevation.

522.6.13.3.7.4.1.4 Tracks with a horizontal curve radius 5,000 feet or greater and with 1/2 inch or less superelevation can be considered tangent track for meeting the 60 feet minimum tangent track length.

522.6.13.3.7.4.1.5 MOW access must provide a minimum of 7 feet of paved surface from centerline of track.

522.6.13.3.7.4.1.6 The paved surface must be clear of obstructions.

522.6.13.3.8 Yard Ballasted Track Crossing

Commentary: For tight radius curves in yard driveways, the MOW crossing may be embedded track instead of panelized. Restraining rails are required in panelized crossings but may be excluded within the limits of an embedded track MOW crossing.

522.6.13.3.8.1 Restraining rails must be used in horizontally curved panelized yard driveway crossings per the restraining rail requirements.

522.6.13.3.8.2 The maximum number of adjacent tracks crossing the yard driveway must meet the requirements in OMF Site Access section in this set.

522.6.13.3.8.3 Yard driveway crossings must be on level grade.

522.6.13.3.8.4 Yard driveway crossings must have zero superelevation.

522.6.14 Track appurtenances

522.6.14.1 Bumping post

522.6.14.1.1 Bumping post must be designed to engage the anti-climber of the Link light rail vehicles.

522.6.14.1.2 Bumping post calculations must be provided to show required bumping post space requirements and meeting deceleration requirements. Increase length of track from face of bumping post to meet the required slide distance from the calculations. The minimum length of rail provided for slide distance must be at least 28 feet.

522.6.14.1.3 The design must be coordinated with the signal design, trackwork design, and civil requirements.

522.6.14.1.4 Track bumping posts must be installed at the ends of all stub-end tracks and in accordance with the Standard Drawings and Standard Specifications.

522.6.14.1.5 The face of the bumping post must begin at a minimum 28 feet beyond the end station, storage tracks, or tail tracks.

522.6.14.1.6 Bumping post must provide a minimum of 10 feet from face of bumping post to a train stop position.

522.6.14.1.7 Bumping post must be capable of providing 0.3g of deceleration at an impact speed of 10 mph, and 5 mph in yards.

522.6.14.2 Hinged Wheel Stop

Commentary: Hinged wheel stops are required in locations that are also used for through movements of trains. They allow the stopping and/or blocking of vehicles and can be easily folded outward when not in use to allow rail traffic to pass. They may also be used to replace existing bumping posts or at locations designated by Sound Transit.

522.6.14.2.1 Hinged wheel stops must be installed at the end of an unpowered yard delivery track.

522.6.14.2.2 Hinged wheel stops may be used when extending an existing rail line and replacing an existing bumping post during construction.

522.6.14.2.3 The wheel stops must fold to the outside/field side of the track when not in use.

522.6.14.3 Wayside Rail Lubricator

Commentary: Sections of track with tight curves may create a nuisance noise condition referred to as wheel squeal that typically occurs along curves in the track with a radius less than 600 feet. However, this noise can occur on larger radius curves depending on other factors that may affect the potential for wheel squeal that can include speed of the LRV, rail vehicle truck geometry and rigidity, the conditions of the wheels and tracks, wheel or rail damping technology, and contact-surface frictional characteristics.

522.6.14.3.1 Rail lubricator locations must be coordinated with Sound Transit.

522.6.14.3.2 A wayside rail lubrication system must be included in the track design for all curves with a radius less than or equal to 600 feet, except in tunnels, and be in accordance with the Standard Specifications.

522.6.14.3.3 Track curves must be evaluated as part of the noise and vibration analysis found in Set 007 Noise and Vibration to determine whether additional rail lubricators are required.

Commentary: Rail lubricators are to be installed in areas where excessive rail wear or wheel squeal near noise-sensitive areas are anticipated. The Track DOR and Noise and Vibration Specialist are to coordinate the mitigation measures in reducing the wheel squeal by placing wayside rail lubricators at the locations recommended in the Nosie and Vibration Analysis Report.

522.6.14.3.4 The potential for wheel squeal must be identified at locations where tight-radius curve trackwork is near residential or commercial buildings, or other noise-sensitive receivers.

522.6.14.3.5 Provisions for wayside lubrication must be incorporated in the project design at all curves up to a 1,250-foot radius near commercial or residential areas or as noted in the noise and vibration analysis.

522.6.14.3.6 During the design, special provisions must be made for provisional rail lubricators by providing the necessary power supply and space for installation of rail lubricator areas that would require mitigation as noted in the noise and vibration analysis.

522.6.14.3.7 If audible wheel squeal or flanging noise is present on curves with a radius between 601 feet to 1,250 feet during pre-revenue service, then mitigation, such as wayside lubrication, must be applied to the rail gauge face and wheel flange.

522.6.14.3.8 Lubricator Provisions

Commentary: The parameters and expectations for the wayside rail lubrication includes the following.

522.6.14.3.8.1 The electric equipment must be designed for power needs to all lubricators with the lubricator equipment operating on 24-volt DC power supplied or charged by 110-volt power.

522.6.14.3.8.2 The unit must be contained in a metal, watertight cabinet of maximum dimensions 24 inches wide by 40 inches tall by 40 inches deep and include all electric controls, a pump unit, a drive unit, and a lubricant metal reservoir.

522.6.14.3.9 Collection Mat for Rail Lubricator Locations

522.6.14.3.9.1 An environmental mat for collection of waste (flung off) grease to eliminate track contamination must be provided.

Commentary: The mats address contamination of soil and ballast over the length of track where the lubricant is spread and is placed over the ties on both the gage and field sides of the rails and secured to the ties to collect grease that would fall into those areas. They should be durable and resistant to temperature, moisture, punctures, solvents, and high volumes of traffic.

522.6.15 Walls

Commentary: Where the construction of a wall places it on the slope beyond the guideway structure, the following cases need be addressed in the design:

i. For a wall constructed along a fill slope outside of the guideway structure, a ditch or swale along the guideway side of the wall will be required to divert and convey the drainage to a drainage structure.

ii. For a wall constructed along a cut slope outside of the guideway structure, a ditch or swale along the back side of the wall (opposite side from the track) will be required when the ground line slopes toward the proposed wall to divert and convey the drainage to a drainage structure.

Commentary: For further information regarding structures along ballasted track, refer to the Guidance Drawings for typical sections and additional track details for the ballasted light rail track guideway.

522.6.15.1 In ballasted track where ballast curbs, MSE walls, cast-in-place fill walls, sound walls, and retaining walls are constructed along the guideway, the structure must be a minimum 6 inches wide at the top of wall and the top of wall must be a minimum 6 inches above the top of ballast.

522.6.16 Track Vibration Control

Commentary: Vibration isolation on direct fixation trackway can be achieved by incorporating a floating slab, high-resilient fasteners, ultra-straight rail, flange-bearing diamond frogs, moveable point frogs, and/or ballast mats that would be options recommended in the Noise and Vibration Analysis Report. The following lists commonly used methods.

522.6.16.1 Floating Slab

Commentary: Floating slab construction may be a suitable approach to mitigating vibration if no other method can be determined. The DOR is to coordinate with Sound Transit Maintenance the procedures that will be necessary regarding concerns relating to maintaining drainage, the ease of eventual pad and slab replacement, and incorporate them into the design.

Commentary: Both cast-in-place and precast methods are acceptable approaches for floating slab designs. Expected locations where noise and vibration levels require mitigation and floating slabs are recommended will be identified in the Noise and Vibration Analysis.

522.6.16.2 High Resilient Fastener

Commentary: Vibration isolation may also be achieved by using high resilient fasteners between the invert slab and the rail.

522.6.16.2.1 High resilient direct fixation fasteners must be used in tunnels and through trenches to reduce vibration.

Commentary: Near developments and highly sensitive areas, the DOR is to determine whether and/or when high resilient direct fixation fasteners are required based on the investigation and findings of the Noise and Vibration Analysis.

522.6.16.2.2 High resilient fasteners must provide the same longitudinal restraint force as the standard direct fixation fasteners.

522.6.16.3 Ultra-straight Rail

Commentary: Ultra-straight rail can be used in areas where the generation of low frequency vibration is undesirable, and by installing it in these areas as a mitigation measure can be an alternative method to meet the requirements and locations that are found in the Noise and Vibration Analysis.

522.6.16.3.1 Ultra-straight rail must have a maximum 0.0079-inch deviation over any 10 feet of length and must meet the requirement of tee rail and girder rail.

522.6.16.4 Flange-bearing Diamonds/Frogs

Commentary: Flange-bearing diamonds/frogs may also be a suitable method to reduce vibration by eliminating the impact of the wheel tread as it crosses the gap.

522.6.16.4.1 The flange-bearing section must extend a minimum of 12 inches ahead of the theoretical frog point to 8 inches beyond the actual frog point.

522.6.16.4.2 A transition ramp from ordinary flangeway depth to the flange-bearing depth must be 1:120 or a minimum of 1 over twice the design speed, whichever is less.

522.6.16.5 WBM Frogs

Commentary: WBM frogs eliminate all rail joints on the frog providing a continuous running surface unaffected by CWR stresses. WBM frog provides a smooth transition and reduce maintenance. WBM frogs may be used when appropriate to mitigate vibration on turnouts.

522.6.16.6 Moveable Point Frogs

Commentary: Moveable frogs may be used to mitigate vibration on turnouts by eliminating the gap at the common crossing.

522.6.16.7 Ballast Mat

Commentary: Ballast mats are installed directly beneath the ballast bed, which may also offer vibration isolation and protection of the track components. This layer of protection can reduce the frequency of required maintenance over the lifetime of the railway. Items to be considered in the ballast mat design are the concrete slab thickness, depth of ballast required, track drainage, and details as to how the mat is to be installed along all wall types (MSE, soil nail, ballast walls, etc.), including all penetration locations in the mat for stormwater or electrical/communications hand holes and vaults.

522.6.17 Signals

522.6.17.1 Traction Electrification – Impact on Track

522.6.17.1.1 Bolted joints in negative return rail segments must be electrically bonded across the joint bars with high conductivity bonds.

522.6.17.1.2 The negative return rails of parallel tracks must be cross-bonded to equalize the currents that traverse them in accordance with the Standard Specifications.

522.6.17.1.3 In segments that use both running rails for return, all rails of parallel tracks must be cross-bonded.

Commentary: Cross-bonding locations will be identified by the systems DOR.

522.6.17.1.4 Rail joints and electrical track connections must be electrically “bonded.”

522.6.17.1.5 Electrically bonded connections to the track must be done by the cembre process.

Commentary: The cembre connection provided a low resistance interface between the rail web and the terminal plug.

522.6.17.1.5.1 Mainline track (two rails), special trackwork, grade crossings, and all ancillary system connections must have the following in-service resistance to ground:

522.6.17.1.5.1.1 Direct fixation track and concrete – 500 ohms/1,000 feet

522.6.17.1.5.1.2 Embedded track – 200 ohms/1,000 feet

522.6.17.1.5.2 Yard track must have the following minimum, uniformly distributed, in-service resistance to ground:

522.6.17.1.5.2.1 Tie and ballast track with non-insolated rail fasteners – 85 ohms/1,000 feet

522.6.17.1.6 Mainline Negative Return System:

Commentary: Appropriate measures must be taken during the design of all types of trackwork, including embedded track *and highway grade crossings, to minimize the stray current requirements determined for each type of track construction. The criteria must be met through designed insulating track fastening devices, such as tie plates, insulated rail clips, direct fixation fasteners, rail encasement in dielectric materials, or other methods approved by Sound Transit that meet the requirements of the Standard Specifications and details.*

522.6.17.1.6.1 Embedded track must meet the following minimum provisions:

522.6.17.1.6.1.1 Rail support and fixation devices must not damage the rail encasement.

522.6.17.1.6.1.2 Track encasement material must have a minimum resistivity value of 1×10^{12} ohms-cm.

522.6.17.1.6.1.3 Reinforcing steel within the track slab must be electrically continuous and provisions for maintaining electrical continuity across expansion joints must be included.

522.6.17.1.6.1.4 The track slab reinforcing steel must be electrically continuous for the entire length of embedded track.

522.6.17.1.6.1.5 Mainline track must be electrically insulated from foreign railroad connections (sidings) by use of insulating rail joints. Location of the insulating joints must be chosen to reduce the possibility of a vehicle bridging the isolators for a time period longer than required to move onto or off the mainline.

522.6.17.1.6.1.6 Grade crossing track segments must include provisions for continuous dielectric isolation of the rail from the grade crossing panels and all components of the grade crossing system through the use of a dielectric rail boot or other type of rail isolation technology approved by Sound Transit.

522.6.17.1.6.1.7 The isolation technology must include no seams or joints throughout the grade crossing.

522.6.17.1.6.1.8 The fixation hardware must be designed so damage to the isolation will not occur and to provide long term isolation at grade crossings and meet the required track-to-earth resistance for embedded track.

522.6.17.1.6.2 Reference requirements Set 222 Stray Current Corrosion Control and Standard Drawings for installation of test boxes for measurement of stray current flow on the track slab reinforcing steel.

522.6.17.1.6.3 Location of the insulating joints must be coordinated with Set 220 Traction Power and Set 123 Train Control to reduce the possibility of a vehicle bridging the isolators for a time period longer than required to move onto or off the mainline.

522.6.17.2 Signal and Train Control – Impact on Track

Commentary: The train control design may affect the selected trackwork design concept and coordination between the disciplines will be required because it can affect specific parts of the design. An example is when the track design limits the maximum authorized speed through a curve that may change cab signal speed, which in turn may result in the reduction of the speed code, which will have an operational impact. Another example of this interrelationship is the need for the location of insulated joints in the running rails to accommodate train control requirements. Insulated joints are located at wayside signals, and within interlockings using track circuits other than audio frequency track circuits.

Commentary: The Link light rail signaling system may include both track circuits and wayside magnetic loop detector signal systems along with the use of cab signaling loops within interlockings to suit both ballasted and embedded track zones, respectively.

522.6.17.2.1 Cembre process must be used on rail connections for track circuit usage.

522.6.17.2.2 At locations where the insulated joints are staggered, the length of the center-tap cable from the impedance bonds must be coordinated with Set 123 Train Control.

522.6.17.2.3 Signal equipment must be placed where it does not conflict with track and civil components within the guideway.

Commentary: On the track guideway, it is preferred that for cabinets and wayside signal junction boxes containing equipment to be installed on the guideway, the door must open outward toward the center of the guideway allowing individuals in the work area to access the equipment inside the cabinet while remaining clear of the vehicle dynamic envelope at all times, and allowing the individual access to the equipment while the system remains in service. The work area needs to be clear of plinths, raceways, signal boxes, etc., to allow maintenance personnel to perform their assigned tasks.

522.6.17.2.4 Placement of signal equipment must be checked by the Track DOR to verify there are no conflicts between other track and civil components.

522.6.17.2.5 Placement of insulated joints and impedance bonds must be coordinated with the track, train control, traction electrification, and civil teams such that ducting to support the equipment is facilitated with the final decision of their locations being made by Sound Transit Train Control and Sound Transit Traction Electrification.

522.6.17.2.5.1 Train control determines the locations of the insulated joints but must be placed clear of all track and civil elements.

522.6.17.2.5.2 Impedance bond installation areas and requirements must be coordinated with the Train Control designer.

522.6.17.2.6 Insulated joints must not be placed in curves with a radius less than 500 feet.

522.6.17.2.6.1 At curve locations where the radius is less than 500 feet and a signal is required for operational needs, the signal must be placed at the end of the curve with sufficient space to place the insulated joint along the tangent prior to the curve.

Commentary: Although the need to install insulated joints within a tight radius curve is unlikely, occasions may occur in the design where a tight radius curve ends at an interlocking or station platform within a tunnel, both of which would require signals to be placed at the ends of the curves. In any instance that would require the signal to be placed at the end of the sharp curve, there needs to be sufficient space for the insulated joint and associated signal placement at that location.

522.6.17.2.7 Embedded track must accommodate requirements for track circuit connections to the rails, and allowance for embedded wayside equipment, which may include switch machines and impedance bonds along with train-to-wayside communications and cab signaling loops.

522.6.17.2.8 Cables

Commentary: Signal and Traction Power communication cables will require conduits, hand holes, pull boxes, and Train Control manholes. Niches may be required to house signaling equipment in underground segments. Reference Set 123 Train Control and Set 220 Traction Power for specific criteria.

522.6.17.2.8.1 All raceways (with Systemwide Electrical team's approval), cables and duct banks must be installed on the field side of the track and not interfere with other track elements within the guideway.

522.6.17.2.8.2 Duct banks/raceways must be placed on the field side of the running rail and beneath the subballast in ballasted track.

522.6.17.2.8.3 Duct banks/raceways on direct fixation track must be placed such that they do not interfere with the track structure.

522.6.17.2.9 Switch Machines

Commentary: See Set 123 Train Control for switch machine requirements.

522.6.17.2.9.1 Both Track and Train Control disciplines must coordinate regarding placement of switch ties or plinths and the placement of switch machines.

522.6.17.2.9.2 Both Track and Train Control teams must coordinate to ensure adjustment of throw, detector, and lock rods of the switch mechanism conform to AREMA requirements.

522.6.17.2.9.3 Clearances to all signal equipment must conform to Set 520 Vehicle Clearances and Track Spacing.

522.6.17.2.9.4 For walkway requirements, refer to "Emergency/Maintenance Walkways" in this Set.

522.6.18 Operational Trackwork

522.6.18.1 Emergency/Maintenance Walkways

522.6.18.1.1 General

Commentary: An emergency walkway is a continuous path for passengers to evacuate a train at any point along an at-grade, tunnel, or elevated guideway so that they can proceed to the nearest station, emergency exit, or wait for an evacuation train to arrive. See Set 602 Fire–Life Safety for additional requirements on emergency walkway.

Commentary: The emergency walkway often coincides within the maintenance walkway.

Commentary: Maintenance walkways provide access for inspections and maintenance personnel along the guideway. Emergency and maintenance walkways should be continuous by providing crosswalks at track level.

522.6.18.1.1.1 Emergency walkways must meet the requirements of NFPA 130.

522.6.18.1.1.2 Lighting must be provided for safe navigation at walkways, stairs, ramps, and must meet the requirements of Set 601 Fire–Life Safety.

Commentary: Minimum widths for walkways were determined by Sound Transit's Operations and Safety Department to address the operational and safety needs for maintenance activities. Maintenance walkway widths include emergency passenger egress, which may be larger than NFPA guidelines. Minimum walkway widths for walkways on the outside of the tracks and inside tunnels must adhere to the requirements herein. For center walkways, the walkway is included within the 56-inch clear space between the LRV clearance envelopes per Set 520 Vehicle Clearance and Track Spacing. The clear space between the two tracks allows a larger space to reduce the safety risk and hazard for maintenance activities occurring during revenue service hours with moving LRVs.

522.6.18.1.1.3 Maintenance walkways must be minimum 30 inches wide.

522.6.18.1.1.4 Maintenance walkways must be provided along the entire length of the track alignment alongside the mainline, pocket, siding, and tail or terminus tracks.

Commentary: Maintenance walkways at tail tracks may be a temporary interim condition until further extension of the light rail system. Duration of the interim walkway may vary depending on the project scope and schedule. Temporary walkways must be removable.

Commentary: An outside walkway is located on the outer side of the tracks and serve one track. A center walkway is located between two tracks and may serve both tracks.

522.6.18.1.1.5 A walkway may serve two adjacent tracks that are next to the center walkway.

522.6.18.1.1.6 Maintenance walkways must be continuous through special trackwork sections.

522.6.18.1.1.7 Maintenance walkways must be clear of all special trackwork elements, such as switches, switch machines, frogs, and diamonds.

522.6.18.1.1.8 Maintenance walkways must be uniform, level, and slip resistant.

522.6.18.1.1.9 Maintenance walkways must not interfere with track drainage.

522.6.18.1.1.10 Clearance calculations must be provided on all maintenance walkways per Set 520 Vehicle Clearances and Track Spacing.

522.6.18.1.2 At-grade Walkway

522.6.18.1.2.1 At-grade Walkway on Direct Fixation Track and Elevated Guideway

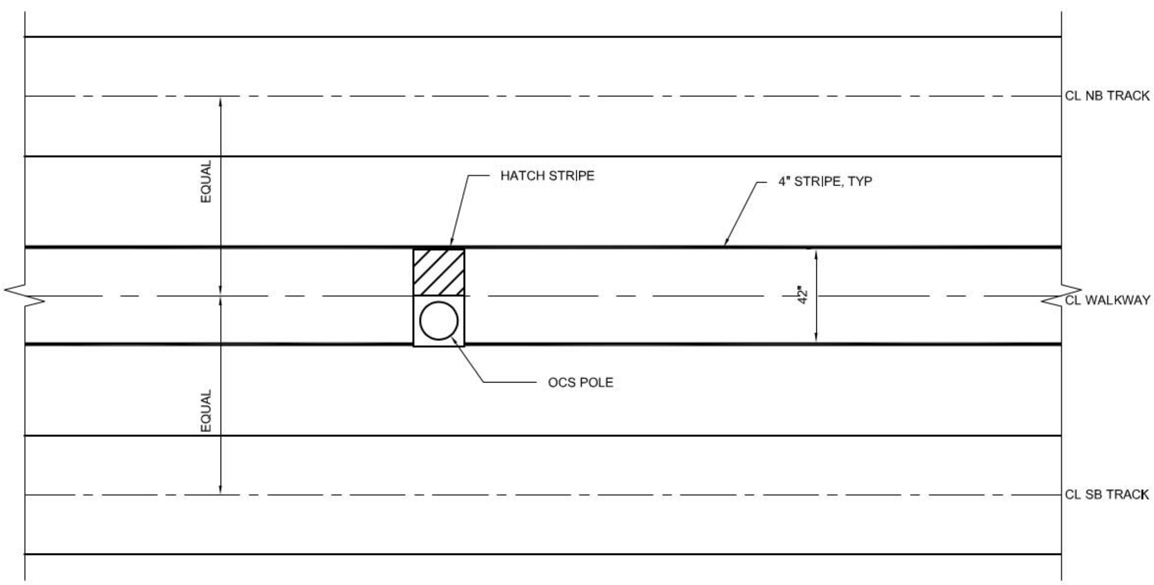
Commentary: Walkway striping is used to delineate a safe work zone for maintainers. Walkway striping is used to indicate maintenance walkways only and must be outside of the LRV dynamic envelope. While emergency walkways coincide within the maintenance walkway on ST facilities, they do not require striping and emergency walkway widths must be achieved within the LRV static envelope.

522.6.18.1.2.1.1 Maintenance walkway width must be delineated by a 4-inch yellow stripe.

522.6.18.1.2.1.2 Center maintenance walkway width must be striped 42 inches wide measured from inside of stripes.

522.6.18.1.2.1.3 At OCS pole locations, the stripe must be skipped over the base of the OCS pole. A yellow hatch stripe must be adjacent to the OCS base plate where maintenance walkway width is obstructed and reduced at these locations. See Figure 522-3 for Center Maintenance Walkway Striping on Elevated Guideway.

Figure 522-3: Center Maintenance Walkway Striping on Elevated Guideway



522.6.18.1.2.2 At-grade Walkways on Ballasted Track

522.6.18.1.2.2.1 Ballasted walkways must be tamped to maintain a level surface.

522.6.18.1.2.2.2 Ballasted walkways must meet ballast material requirements in this set.

522.6.18.1.2.2.3 Ballasted walkways at turnouts must meet the minimum requirements of the standard drawings.

522.6.18.1.3 Raised Walkway

522.6.18.1.3.1 Raised Walkway on Elevated Guideway or Ballasted Track

Commentary: The following section applies to raised walkways parallel to tracks that serve as emergency and maintenance walkways subject to emergency egress and worker safety requirements. Raised walkways are needed where the vehicle door threshold height affects safe evacuation of passengers, entry by emergency responders or access for maintainers and operators. The vertical height threshold includes plinths that are raised above the standard height and creates a low rail plinth height greater than the standard 6 inches.

Commentary: Raised walkways may be used adjacent to mainline tracks in tunnels and on elevated guideway. Sometimes they are placed over duct banks at fire hose valve connections. Raised walkways may also be used at siding, pocket, and tail tracks. The raised walkway requirements in this section do not apply to raised walkways at storage tracks in the Yard.

Commentary: See Set 601 Fire–Life Safety for requirements on non-combustible materials. Raised walkways may be fiberglass. The use of fiberglass walkways will require an approval letter from NFPA to meet the non-combustible materials requirement and must be accepted by the AHJ. Acceptance by the AHJ for this material is required prior to design-build for the project.

522.6.18.1.3.1.1 Raised walkways must be constructed of non-combustible materials.

522.6.18.1.3.1.2 Raised walkways must provide visibility and access to infrastructure below the walkway.

522.6.18.1.3.1.3 Raised walkways must be closed mesh.

Commentary: Grated walkways should be appropriate for many diverse types of shoes, see Set 601 Fire–Life Safety.

522.6.18.1.3.1.4 Closed mesh raised walkways must have an integral yellow walkway surface. The yellow must not be painted onto the walkway surface.

Commentary: The yellow colored raised walkway is for maintainer's safety. This applies in open track only and not in tunnels with concrete walkways or on standard crossing panels.

522.6.18.1.3.1.5 Raised walkways must be free draining unless otherwise noted.

522.6.18.1.3.1.6 Raised walkway between tracks with no railing must be at least 44 inches wide.

522.6.18.1.3.1.7 Raised walkway heights must be below the top of rail plane and meet the clearances in Set 520 Vehicle Clearances and Track Spacing.

522.6.18.1.3.1.8 Anchor supports for raised walkways must be placed more than 1 foot from the edge of drain inlets.

522.6.18.1.3.1.9 Raised walkways on unprotected sides or edges that are greater than 30 inches above the floor or grade below must be provided with a guard that meets the requirements of WAC 296-880-40005 and additional requirements in this section.

522.6.18.1.3.1.10 Guards are not required on walkways between tracks or along the trainway side where the bottom of the trainway is closed by a deck or grating.

522.6.18.1.3.1.11 Raised walkways must transition down to the floor or grade via steps or ramps.

522.6.18.1.3.1.12 Stairs must be used if the rise is greater or equal to 12 inches.

522.6.18.1.3.1.13 Stairs with two or more risers must have a handrail.

522.6.18.1.3.1.14 Placement and type of railing must comply with Set 721 Bridges and Elevated Structures and Set 601 Fire–Life Safety.

522.6.18.1.3.1.15 Stairs with 4 or more risers must have a guard.

Commentary: Where maintenance and cleaning activities take place at siding, pocket, and tail tracks, ramps are needed to roll equipment up and down the walkway.

522.6.18.1.3.1.16 Stairs are not allowed at the ends of the walkway for siding, pocket, and tail tracks.

522.6.18.1.3.1.17 Ramps must have a non-slip surface.

522.6.18.1.3.1.18 Ramps must be used if the rise is less than 12 inches.

522.6.18.1.3.1.19 Ramps must have a maximum slope of 1:12.

522.6.18.1.3.2 Raised Walkway in Tunnels

Commentary: Bored tunnels are circular and present geometric constraints when designing the placement of emergency walkways for elevated curves. On tangent track, the location of the emergency walkway edge angle will be symmetrical on both sides of the track. For superelevated curves, the emergency walkway edge angle is referenced from the low rail for both tracks.

Commentary: For cut and cover sections, the emergency walkway must meet all walkway conditions, including both horizontal and vertical offsets.

Commentary: See Set 601 Fire/Life Safety for additional emergency walkway requirements.

522.6.18.1.3.2.1 Emergency walkway must be provided for each track in the tunnel.

522.6.18.1.3.2.2 Emergency walkway must be concrete in the tunnel.

522.6.18.1.3.2.3 Emergency walkways must be 14 inches above top of low rail, minimum of 5 feet horizontally and increase to meet the minimum clearance envelope requirement from Set 520 Vehicle Clearances and Track Spacing.

522.6.18.1.3.2.4 Emergency walkway in the tunnel must have a maximum cross slope of 0.5 percent sloped toward the trackway.

522.6.18.1.3.2.5 Emergency walkway in the tunnel must have continuous handrails in accordance with Set 601 Fire–Life Safety.

522.6.18.1.3.3 Raised Maintenance Walkway Special Conditions at Siding, Pocket, and Tail Tracks

522.6.18.1.3.3.1 Raised maintenance walkways at siding, pocket, and tail tracks must be continuous for duration of the LRV length instead of raised individual platforms at each car consist.

522.6.18.1.3.3.2 Maintenance walkways must be continuous through the siding, pocket, and tail tracks.

522.6.18.1.3.3.3 Top of walkway must be 7 inches above top of rail at pocket tracks.

522.6.18.1.3.3.4 Top of walkway must be 7 inches above top of rail at siding and tail tracks when cleaning carts are not required during maintenance cleaning activities.

Commentary: Cleaning access is only needed on one side of the LRV.

522.6.18.1.3.3.5 Top of walkway must be 14 inches above top of rail at siding and tail tracks for level boarding when cleaning carts are required during maintenance cleaning activities.

Commentary: Maintenance walkways where maintainers perform light servicing of the LRVs or where operators take a break at siding, pocket, or tail tracks require more accessibility for operational activities. These special situations require the gap between the raised walkway and LRV to be reduced to facilitate maintenance and operational activities along the walkway.

522.6.18.1.3.3.6 The horizontal distance from the centerline of the track to the edge of walkway must be to the vehicle dynamic envelope at siding, pocket, and tail tracks where LRV servicing is performed. The siding, pocket, or tail track must not be adjacent to revenue track at these locations.

Commentary: If the walkway at siding, pocket, or tail tracks are built as a temporary condition for LRV servicing, it must be removable and/or rebuilt to the permanent condition after removal.

522.6.18.1.3.3.7 The horizontal tolerance for the walkway at siding, pocket, and tail tracks must be +0.25 inches and -0.0 inches.

522.6.18.1.3.3.8 See Set 601 Fire/Life Safety for additional requirements.

522.6.18.2 Maintenance Walkway Envelope

Commentary: The walkway clearance envelope is the space in which a person may stand free of any obstructions, including passing trains.

522.6.18.2.1 The walkway clearance envelope must be 30 inches wide by 80 inches tall above the walking surface.

Commentary: Handrails that overhang more than 27 inches and not more than 80 inches is the only exception that is permitted to protrude horizontally 4-1/2 inches maximum from the wall or guard into the walkway in accordance with the International Building Code.

522.6.18.2.2 Walkway must be clear of all obstructions, including guards, signal cases, OCS pole plates, conduits, track drains, switches, and the vehicle clearance envelope, unless otherwise noted.

522.6.19 Maintenance of Way Access

Commentary: MOW track grade crossings provide access to the guideway for Sound Transit approved maintenance vehicles. A service road and access to the track for maintenance and emergency work must be provided in accordance with the civil design. This requires provision for MOW vehicles and for vehicles equipped with flanged wheels to drive onto the track at strategic locations.

522.6.19.1 The location of MOW access points must be documented in the basis of design report during the environmental design phase of the project.

Commentary: MOW access points should be coordinated with Sound Transit Operations to ensure adequate access to the guideway is provided for maintenance. Access points should also be in close proximity to station platforms when at-grade.

522.6.19.2 MOW access points must be spaced at maximum 3-mile intervals, except in tunnels.

522.6.19.2.1 Where tunnels create spacing between MOW access points greater than 3 miles, the MOW access points must be placed within 1,000 feet from the tunnel entrance.

522.6.19.3 Access roads must connect to the track grade crossing.

Commentary: In special cases where the MOW access is agreed to be used by agencies other than Sound Transit and a second gate is required on the far side of the tracks, the placement of this gate must be designed to prevent vehicles from becoming stopped on the tracks. Refer to Set 906 Roadways and Non-Motorized Facilities for additional access road requirements.

522.6.19.4 Gates for access roads to track grade crossings must be a minimum of 7 feet from centerline of nearest track.

522.6.19.5 Gates within 40 feet of nearest track centerline must open away from the tracks.

522.6.19.6 MOW vehicle requirements while mounted on the rail:

522.6.19.6.1 Maximum vehicle width 8 feet 6 inches

522.6.19.6.2 Maximum vehicle height 12 feet

522.6.19.6.3 Maximum axle loads must not exceed the LRV axle loads defined in Set 721 Bridges and Elevated Structures.

522.6.19.6.4 Vehicle clearances must comply with the LRV clearances defined in Set 520 Vehicle Clearances and Track Spacing.

522.6.20 Yard Track Layout

Commentary: Yard track layout is designed to optimize LRV storage positions, provided for efficient trains operations, and configured in a manner to allow train sets to exit the Yard to the mainline in the event of a fouled turnout.

522.6.20.1 LRV Storage Track

Commentary: LRV storage tracks provide the space for a four-car consist to be stored. The quantity of storage positions is determined in the project scope.

522.6.20.1.1 Each LRV storage position must be a minimum of 400 feet long for a four-car consist.

Commentary: For efficient shuffling of trains in the Yard and cost-effective design of special trackwork, each storage track should allow independent movement of the stored trains in at least one direction.

522.6.20.1.2 Each LRV storage track must contain a maximum of two LRV storage positions.

522.6.20.1.3 A 12-foot minimum track spacing must be provided between each storage position.

522.6.20.1.4 Storage track spacing must meet the requirements of Set 520 Vehicle Clearances and Track Spacing.

522.6.20.2 Service Corridor

Commentary: A service corridor is provided along the storage tracks with a platform that allows staff to step up into parked LRVs. The service corridor should be elevated for the maximum length possible between Yard access aisle crossings.

522.6.20.2.1 A service corridor must be provided on at least one side of each train storage position.

522.6.20.2.2 Sides of train not accessed by a service corridor platform must be provided with a maintenance walkway on walkway ballast surface or better.

522.6.20.2.3 Service corridor platform must be located on horizontal and vertical tangent tracks.

522.6.20.2.4 Service corridor platform edge angle must be 14 inches above top of rail.

522.6.20.2.5 The distance from the centerline of track to the edge of service corridor platform must be 56 inches.

522.6.20.2.6 The service corridor platform edge horizontal construction tolerance must be +0.50 inches and -0.0 inches.

522.6.20.2.7 The service corridor platform edge vertical construction tolerance must be +0.25 inches and -0.25 inches.

522.6.20.2.8 The maximum service corridor platform cross slope must be 2 percent.

522.6.20.2.9 The service corridor platform ends must slope down to the Yard access aisle crossing at no greater than a 5 percent slope.

522.6.20.3 Yard Access Aisle

Commentary: Yard access aisles are at-grade crossings for maintenance staff to cross and access the storage tracks with MOW vehicles within the Yard.

522.6.20.3.1 Yard access aisle crossings must use a rubber rail boot with rubber extrusion flangeway formers.

522.6.20.3.2 Flangeway width must be maximum 2-1/2 inches.

522.6.20.3.3 Yard access aisle must be located in horizontal and vertical tangent track.

522.6.20.3.4 Tangent track must extend a minimum of 40 feet beyond the limits of the yard access aisle crossing so that the service corridor, including ramps, do not encroach the vehicle dynamic envelope.

522.6.20.3.5 Dead ended service corridors must not be allowed.

522.6.20.3.6 Circular driving routes must provide truck access to all trains for ease of security inspection.

522.6.20.3.7 A minimum 12-foot-wide asphalt Yard access aisle must be provided between each LRV storage position and at both ends of the storage tracks.

522.6.20.3.8 The Yard access aisle must continue perpendicularly straight through all service corridors between storage tracks.

522.6.20.3.9 Asphalt crossing must be a minimum depth of 7.5 inches with:

i. Ballast layer minimum depth of 12 inches.
ii. Subballast layer minimum depth of 8 inches.
iii. Concrete ties spaced 2 feet on center.

522.6.20.3.10 Geotextile must be used to separate ties and ballast from the asphalt.

522.6.20.3.11 Asphalt must be tapered into and out of each crossing.

522.6.20.3.12 Yard access aisle must provide stray current isolation.

522.6.20.4 Service and Clean Bay

Commentary: It is anticipated that movement to the service and clean bay will occur as trains return from service in the evenings and into the night.

522.6.20.4.1 Must provide a minimum of 1,200-foot track to queue outside of the service and clean bay.

Commentary: Storage track (S1) is the closest track to the OMF building and provides the shortest walking distance for train operators to access the building.

522.6.20.4.2 Queueing of LRVs for the service and clean bay can include the S1 storage track.

522.6.20.5 LRV Delivery Track

522.6.20.5.1 Delivery track must be a minimum of 270-foot paved track without overhead OCS for the purpose of LRV delivery.

522.6.20.5.2 Delivery track must be asphalt embedded ballasted track.

522.6.20.5.3 Reinforced concrete slabs must be provided at the beginning of the nominal LRV delivery truck trailer parked position where jack stands are used for LRV unloading with the following requirements:

522.6.20.5.3.1 Reinforced concrete slabs provided on the field sides of the rail must be placed as shown in the standard drawings.

522.6.20.5.3.2 Reinforced concrete slab length must comply with the standard drawings.

522.6.20.5.3.3 Reinforced concrete slab cross section must comply with the standard drawings.

522.6.20.5.3.4 Reinforced concrete slab must be cast on subballast layer with geotextile soil stabilization fabric.

522.6.20.5.3.5 The asphalt section between the rails must be must be placed as shown in the standard drawings.

522.6.20.5.4 Access to the delivery track must be provided for the LRV delivery truck.

522.6.20.5.5 A minimum 150-foot paved roadway preceding the delivery track, leveled with the top of rail, and clear of the Yard circulation roadway must be provided for LRV delivery truck.

522.6.20.5.6 Delivery track must be crowned with a 2 percent maximum cross slope from edge of field side of rail.

522.6.20.5.7 Delivery track must be uninsulated.

522.6.20.5.8 An insulated joint must be provided in advance of the connection to the Yard track from the delivery track.

522.6.20.5.9 The end of the delivery track must provide a hinged derail that recesses in the paved roadway when not in use.

522.6.20.5.10 The LRV delivery track must provide a minimum of 24 feet of track spacing to an adjacent Yard track.

522.6.20.5.11 The LRV delivery track must provide a minimum of 7-foot clearance to any adjacent vehicle access road.

522.6.20.5.12 Pavement must be designed for the delivery truck loads and comply with Set 906 Roadway and Non-Motorized Facilities.

522.6.21 Yard Circulation

Commentary: Track layout needs to provide efficient facilities operation with no single points of failure. All origin-destination pairs should have a backup movement in case of a single piece of equipment or track failure. The preferred circulation within the yard is counterclockwise.

522.6.21.1 Circulation within the Yard

522.6.21.1.1 All storage track positions must be able to move to any other shop or yard position without passing through a building, other storage tracks or shop track positions.

Commentary: LRVs may travel from both sides of the storage tracks and maintenance facility.

522.6.21.1.2 Yard circulation must provide simultaneous movement of LRVs in each hemisphere between the storage tracks and shop tracks.

522.6.21.1.3 Yard circulation must provide direct access from storage track positions to the shop tracks without a turnback.

522.6.21.1.4 Turnback movements for four-car consists between storage track positions must not foul the run around track.

522.6.21.1.5 Yard circulation from the storage positions to the OMF shop tracks must be done with no single point of failures.

522.6.21.2 Yard Access from Mainline

Commentary: The Yard access needs to support rapid sequential train movements between the mainline and the Yard directly and efficiently. These movements must not interfere with routine turnback switching of single cars between vehicle shop tracks.

Commentary: Trackwork must be configured such that no vehicle or pedestrian grade crossing is located between the LRV storage Yard and the primary lead turnout. This is to minimize cross traffic between LRVs entering service and operators beginning their shifts.

522.6.21.2.1 Access from mainline to the yard must provide two points of access.

522.6.21.2.2 Access from mainline must be provided for both directions.

522.6.21.2.3 Access from mainline to the yard must not have a single point of failure.

522.6.21.2.4 Backup routes must be available to deploy to any yard position from the mainline in the event of any single point of failure on the primary yard access track.

522.6.21.2.5 Backup routes must not require a turnback or routing through either a building or the yard.

Commentary: In the event of a single point of failure, a backup option must be provided without moving trains back onto the mainline.

522.6.21.2.6 Backup routes must be provided without moving trains back onto the mainline.

522.6.21.2.7 Access from the mainline must minimize cross traffic between moves to access the yard. The maximum travel distance in one direction before going to next turnout from yard lead track must be 200 feet.

522.6.21.2.8 Access from the mainline in each direction must allow simultaneous movement of entering and exiting trains without conflicting with each other.

522.6.21.2.9 The entry and exit circulation between mainline and yard must be determined by the end of the preliminary engineering or environmental phase of the project and must be coordinated with Sound Transit Operations.

Commentary: Service aisles to the storage tracks and the employee only OMF site access are not considered grade crossings for this requirement.

522.6.21.2.10 The primary access to the yard must be able to directly access the service and clean position without crossing a pedestrian or grade crossing.

522.6.21.3 Runaround Track

Commentary: Runaround tracks provide connection between the Yard lead turnouts, Yard positions, shop positions, and service and wash track to allow routing options for trains to be pulled in, switched, sorted, broken apart, serviced, and pulled out with maximum operational flexibility.

522.6.21.3.1 A runaround track must be provided around the site that does not pass through a storage track, shop track, or building.

522.6.22 OMF Site Access

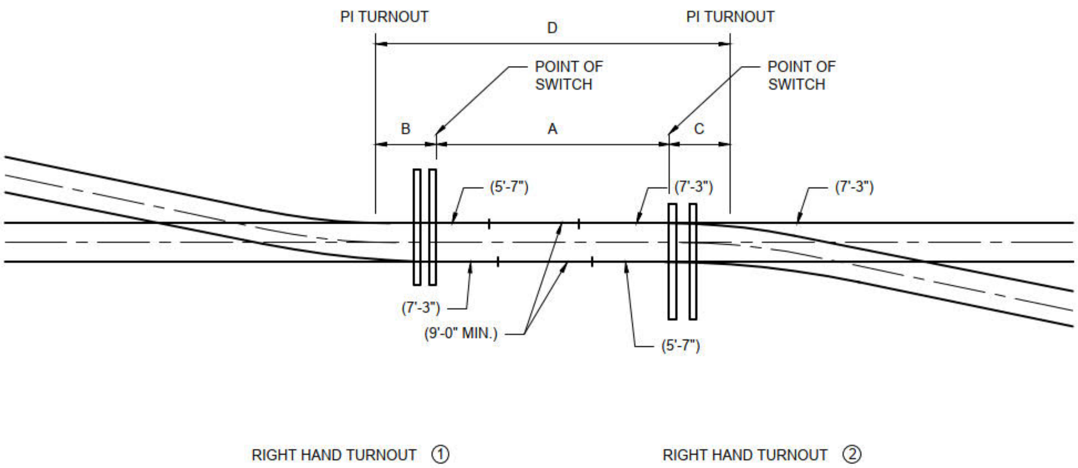
522.6.22.1 Two access points to the OMF must be provided from public roads.

522.6.22.2 Grade crossing access into the OMF must not cross more than three tracks.

522.6.22.3 Grade crossing must not be greater than 35 feet from the first track centerline to the last when crossing multiple tracks.

522.6.22.4 Access points must meet the crossing angle in the Track Grade Crossings section in this set.

Figure 522-4: Point of Switch to Point of Switch (Similar Hand Turnouts)

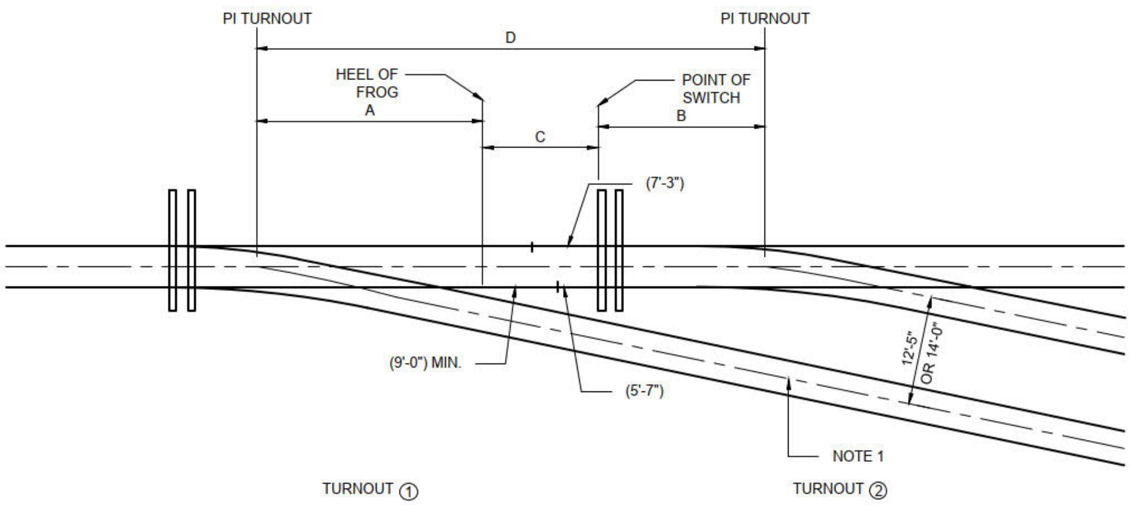


TURNOUTS		DIMENSIONS			
①	②	A	B	C	D
NO. 5 TO NO. 5		22' ABS. MIN. 45' DESIRABLE	20'-9 1/2"	20'-9 1/2"	63'-7" ABS. MIN. 86'-7" DESIRABLE
NO. 8 (MODIFIED) TO NO. 8 (MODIFIED)		29' ABS. MIN. 45' DESIRABLE	33'-7 3/4"	33'-7 3/4"	63'-7" ABS. MIN. 112'-3 1/2" DESIRABLE
NO. 8 TO NO. 8		29' ABS. MIN. 45' DESIRABLE	31'-0"	31-0"	91'-0" ABS. MIN. 107'-0" DESIRABLE
NO. 8 TO NO. 10		29' ABS. MIN. 45' DESIRABLE	31'-0"	31'-5"	91'-5" ABS. MIN. 107'-5" DESIRABLE
NO. 10 TO NO. 10		29' ABS. MIN. 45' DESIRABLE	31'-5"	31'-5"	91'-10" ABS. MIN. 107'-10" DESIRABLE

NOTES:

1. THE ABOVE FIGURES ARE BASED ON 36' TRUCK CENTERS AND 6' AXLE CENTERS.
2. DISTANCE "A" SUBJECT TO CHANGE BASED ON ACTUAL VEHICLE DIMENSIONS.

Figure 522-5: Heal of Frog to Point of Switch (Similar Hand Turnouts)

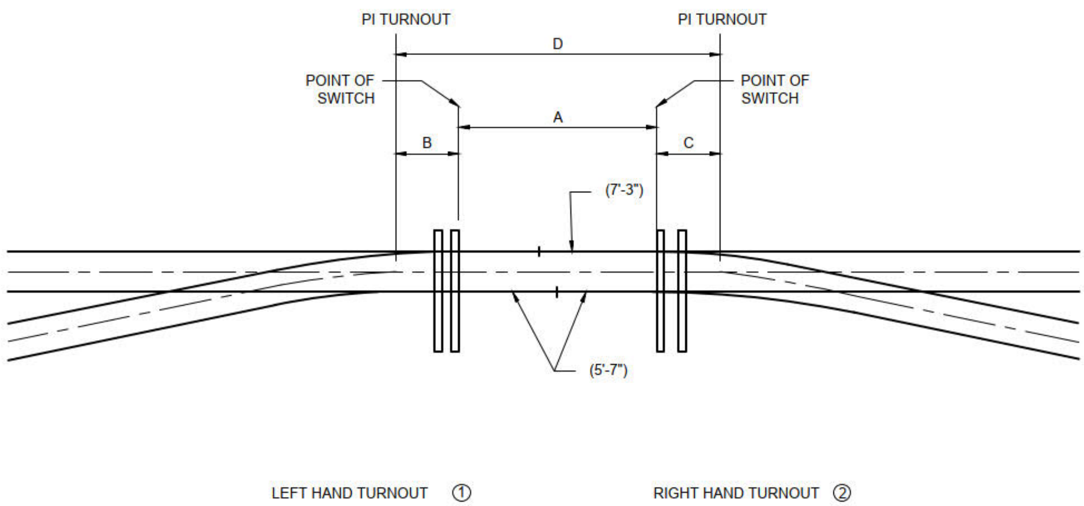


TURNOUTS		DISTANCES				DESIGN REMARKS
①	②	A	B	C	D	
NO. 5 TO NO. 5		29'-2 1/2"	20'-9 1/2"	12.7083'	62.7100'	11°25'16" LADDER TRACK FOR 12'-5" TRACK CENTERS
NO. 5 TO NO. 5		29'-2 1/2"	20'-9 1/2"	20.6979'	70.6691'	11°25'16" LADDER TRACK FOR 14'-0" TRACK CENTERS
NO. 5 TO NO. 5		29'-2 1/2"	20'-9 1/2"	14.7291'	64.7303'	MINIMUM 9'-0" RAIL PLUS THERMITE WELDS-HEEL OF FROG TO END OF STOCK RAIL
NO. 8 (MODIFIED) TO NO. 8 (MODIFIED)		49'-3 1/2"	33'-9 1/2"	14.7291'	97.6666'	
NO. 8 TO NO. 8		47'-5"	31'-0"	14.7291'	93.1458'	
NO. 8 TO NO. 10		47'-5"	31'-5"	14.7291'	93.5625'	
NO. 10 TO NO. 8		58'-10"	31'-0"	14.7291'	104.5625'	
NO. 10 TO NO. 10		58'-10"	31'-5"	14.7291'	104.9791'	

NOTES:

1. TURNOUT ① TRACK MUST CURVE AWAY FROM TURNOUT ② LATRERAL TRACK.
2. NO. 8 (MODIFIED) = NO. 8 TURNOUT WITH LATERAL SWITCH AND FROG CURVED WITH 645' RADIUS.

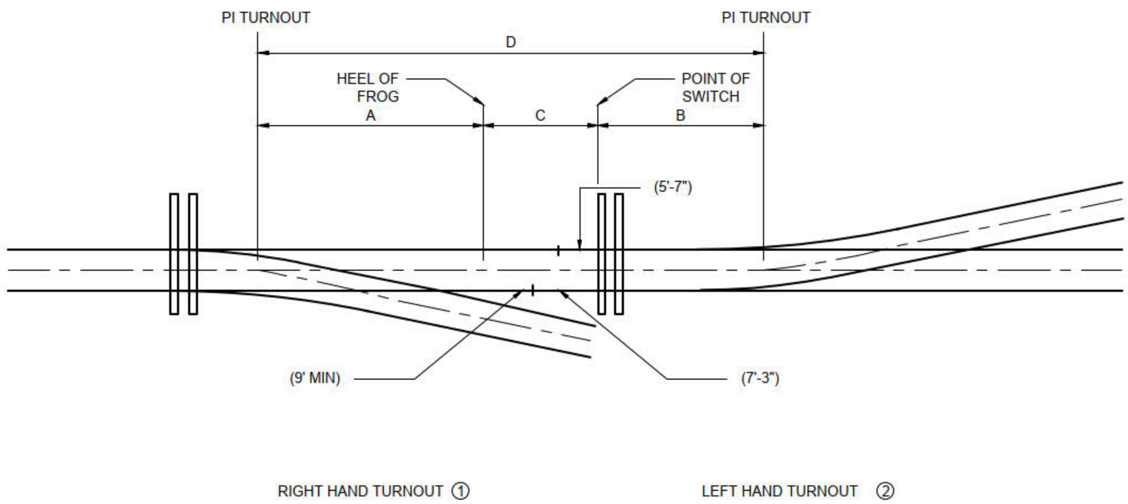
Figure 522-6: Point of Switch to Point of Switch (Opposite Hand Turnouts)



TURNOUTS		DIMENSIONS			
①	②	A	B	C	D
NO. 5 TO NO. 5		(1) 11'-3" ABS. MIN. 45' DESIRABLE	20'-9 1/2"	20'-9 1/2"	52'-10" ABS. MIN. 86'-7" DESIRABLE
NO.8 (MODIFIED) TO NO.8 (MODIFIED)		29' ABS. MIN. 45' DESIRABLE	33'-7 3/4"	33'-7 3/4"	96"-3 1/2" ABS. MIN. 112'-3 1/2" DESIRABLE
NO. 8 TO NO. 8		29' ABS. MIN. 45' DESIRABLE	31'-0"	31'-0"	91'-0" ABS. MIN. 107'-0" DESIRABLE
NO. 8 TO NO. 10		29' ABS. MIN. 45' DESIRABLE	31'-0"	31'-5"	91'-5" ABS. MIN. 107'-5" DESIRABLE
NO. 10 TO NO. 10		29' ABS. MIN. 45' DESIRABLE	31'-5"	31'-5"	91'-10" ABS. MIN. 107'-10" DESIRABLE

NOTES:
1. BUTTING STOCK RAILS PLUS THERMITE WELD.
2. THE ABOVE FIGURES ARE BASED ON 36' TRUCK CENTERS AND 6' AXLE CENTERS DISTANCE "A" SUBJECT TO CHANGE BASED ON ACTUAL VEHICLE DIMENSIONS.

Figure 522-7: Heal of Frog to Point of Switch (Opposite Hand Turnouts)



TURNOUTS		DISTANCES				DESIGN REMARKS
①	②	A	B	C	D	
NO. 5 TO NO. 5		29'-2 1/2"	20'-9 1/2"	16.3958'	66.3975'	MINIMUM 9'-0" RAIL PLUS THERMITE WELDS-HEEL OF FROG TO END OF STOCK RAIL.
NO.8 (MODIFIED) TO NO.8 (MODIFIED)		49'-3 1/2"	33'-7 3/4"	16.3958'	99.3333'	
NO. 8 TO NO. 8		47'-5"	31'-0"	16.3958'	94.8125'	
NO. 8 TO NO. 10		47'-5"	31'-5"	16.3958'	95.2292'	
NO. 10 TO NO.8		58'-10"	31'-0"	16.3958'	106.2292'	
NO. 10 TO NO. 10		58'-10"	31'-5"	16.3958'	106.6458'	

522.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

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522.7.2 Design Management

522.7.3 Manufacturing and Construction Management

522.7.4 Installation Management

522.7.5 Inspection and Testing Management

522.7.6 Training, Pre-Revenue Operations

522.7.7 Certification Management

522.8 APPENDICES (NOT USED)

END SET - 522

530 TRACK CLEARANCE AND SPACING—COMMUTER RAIL

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TABLES

FIGURES

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SET - 530 TRACK CLEARANCE AND SPACING—COMMUTER RAIL

530.1 - INTRODUCTION

530.1.1 Document Scope

530.1.1.1 This set covers the design criteria for track spacing and vehicle clearances of commuter rail vehicles, adjoining structures, or other obstructions. The criteria in this set establish the clearances for safe passage of vehicles to provide proper operation, maintenance, safety, and vehicle stability.

530.1.1.2 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of Sound Transit Design Requirements Set 530 owner to determine the technical source for the design criteria.

530.1.2 Regulations, Codes, Standards, and Guidelines

530.1.2.1 International Regulations, Codes, Standards, and Guidelines (Not Used)

530.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines (Not Used)

530.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

530.1.2.3.1 Title 81 Revised Code of Washington.

530.1.2.3.2 Washington Administrative Code Title 480-60.

530.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

530.1.2.4.1 AREMA Manual for Railway Engineering, Chapter 8, “Concrete Structures and Foundations,” Part 2, “Reinforced Concrete Design,” Section 2.1.5.1, “Pier Protection,” and Commentary Section C-2.1.5.

530.1.2.4.2 AREMA Chapter 28, “Clearances.”

530.1.2.5 Other Jurisdictions (Not Used)

530.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

530.1.2.6.1 Sound Transit Sounder Commuter Rail Engineering Standard Drawings.

530.1.3 Abbreviations and Acronyms

530.1.3.1 AREMA –American Railway Engineering and Maintenance-of-Way Association

530.1.4 Definitions and Classifications (Not Used)

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530.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

530.4.1 System Breakdown Structure

530.4.2 System Sites and Locations

530.4.3 System Architecture

530.4.4 System Layout

530.4.5 Concept of Execution

530.5 SYSTEM INTERFACE REQUIREMENTS

Table 530-1 lists requirement sets that are typically coordinated and may have dependencies with this set.

Table 530-1: Interface between Track and Other Disciplines

SET SERIES	SET NAME	SET 530 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	
300	Operational Communications	
400	Vehicle	X
500	Track	X
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	
1100	Technology	
1200	Security	

530.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

530.6.1 Mainline Track Clearance

530.6.1.1 The horizontal clearance must be 15 feet from centerline of track to a fixed object except as follows:

530.6.1.2 The minimum clearance to face of crash wall must be at least 10 feet plus 1½ inches per degree of curve from centerline of track.

530.6.1.2.1 The size, location, and requirements for crash walls must meet the requirements of AREMA Manual for Railway Engineering, Chapter 8, “Concrete Structures and Foundations,” Part 2 Reinforced Concrete Design, Section 2.1.5.1, “Pier Protection,” and the Commentary Section C-2.1.5.

530.6.1.3 Station platforms must comply with Figure 530-2.

530.6.1.4 Signage must have a minimum clearance of 8 feet 6 inches to the nearest face of pole or edge of sign.

Commentary: Typical signage installations are set at 15 feet from centerline of track.

530.6.1.5 For fencing clearances, see Set 903 Fencing.

530.6.1.6 Minimum clearance for signals, switch stands, and block signals, must comply with clearances in Figure 530-3.

530.6.2 Yard and Industrial Track Clearance

530.6.2.1 The minimum distance from the centerline of track to a fixed obstruction must at least 10 feet plus 1 ½ inches per degree of curve.

530.6.2.2 The minimum clearance to structures adjacent to yard track must comply with building clearances in Figure 530-1.

530.6.3 Vertical Clearances to Overhead Structures

530.6.3.1 Minimum Vertical Clearance

530.6.3.1.1 For mainline and yard track, the minimum vertical distance from the top of rail to the nearest point of obstruction must be 23.5 feet.

530.6.3.1.2 The temporary construction vertical clearance must be at least 21.5 feet above the top of rail.

530.6.3.1.3 At clearance locations where the superelevation is present, measure vertical clearance from the high rail.

530.6.3.1.4 For vertical clearance to overhead utilizes, see Set 902 Utilities.

530.6.4 Track Spacing Requirements

530.6.4.1 Minimum Track Spacing Requirements

530.6.4.1.1 Follow the minimum track spacing in Table 530-2 below.

Table 530-2: Minimum Spacing of Tracks on Curves

Degree of Curve (degree)	Distance between Track Centers* (same superelevation on both tracks or less on outside track)	
	Mainline and Adjacent Tracks	Industry and Yard Tracks
0° (Tangent)	15’-0”	14’-0”
1°	15’-0”	14’-0”
2°	15’-0”	14’-0”
3°	15’-0”	14’-0”
4°	15’-0”	14’-0”
5°	15’-0”	14’-0”
6°	15’-2”	14’-2”
7°	15’-4”	14’-4”
8°	15’-6”	14’-6”
9°	15’-8”	14’-8”
10°	15’-10”	14’-10”
11°	16’-0”	15’-0”
12°	16’-2”	15’-2”
12.5°	16’-3”	15’-3”

Notes*:

1. When adjacent outside track has higher superelevation, track spacing must increase 3 inches for each inch difference in superelevation.
2. Track spacing between a ladder track and adjacent track is 20 feet.

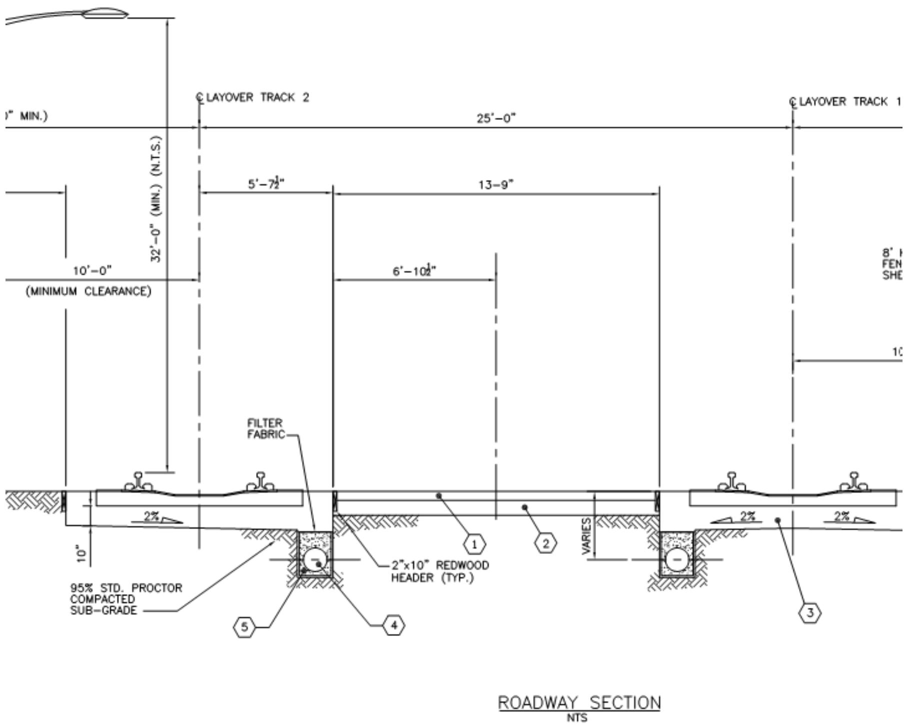
530.6.4.1.2 Track spacing at station platforms must be at least 18 feet apart to allow for inter-track fencing.

530.6.5 Layover and Yard Track Spacing

530.6.5.1 Where a service road is located between yard and layover tracks, track spacing must be 25 feet minimum.

530.6.5.2 Provide yard service road between every other yard and layover track with minimum road width of 13 feet 9 inches with the edge of pavement located 5 feet 7 ½ inches from the track centerline per Figure 530-1.

Figure 530-1: Yard Service Road



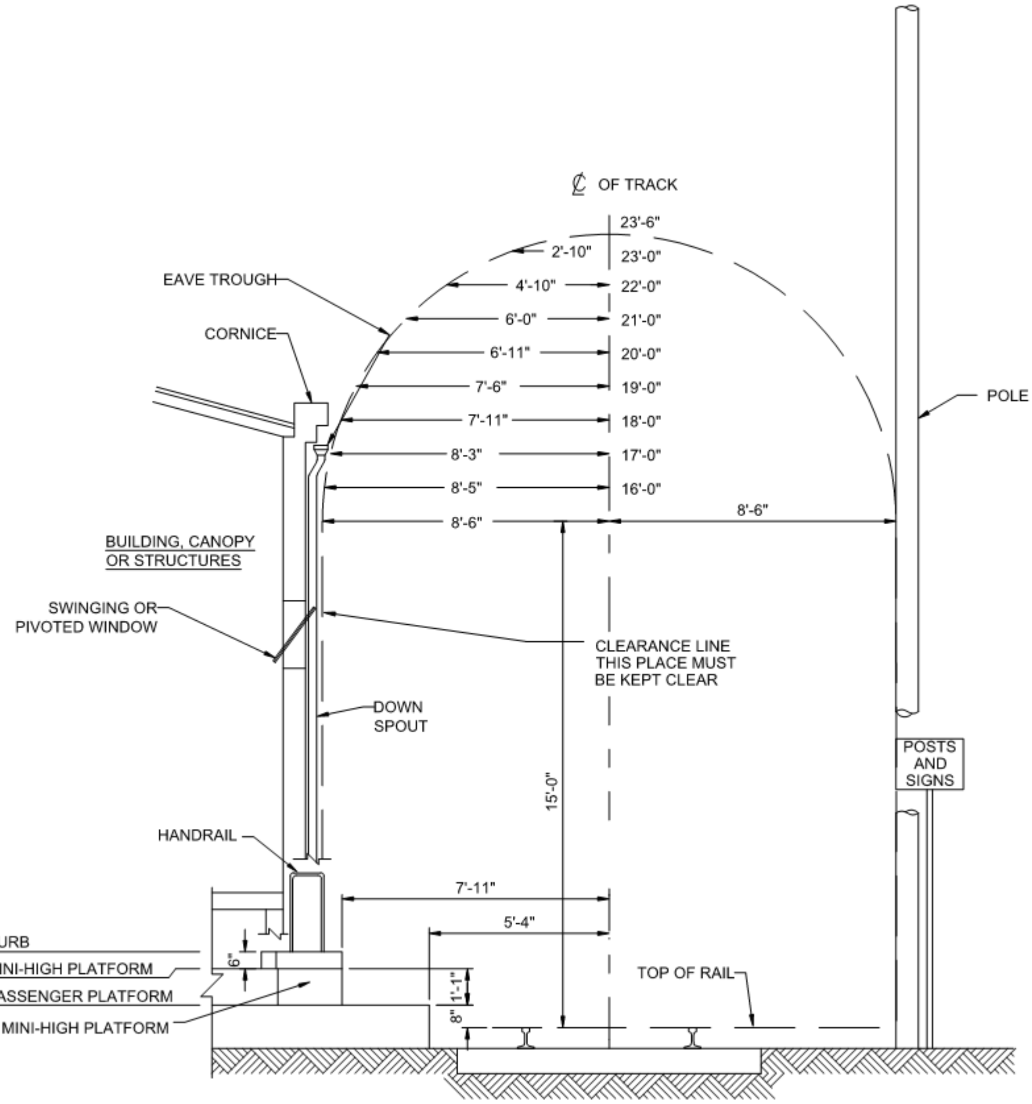
530.6.5.3 The distance from the yard or layover track to the right-of-way must be 18 feet minimum.

530.6.5.4 The track centers between the mainline track and the first yard or layover track inside the security fence must be 22 feet minimum to meet the security fence requirements.

530.6.6 Industry Track

530.6.6.1 Industry track spacing to a mainline track must be at last 25 feet minimum.

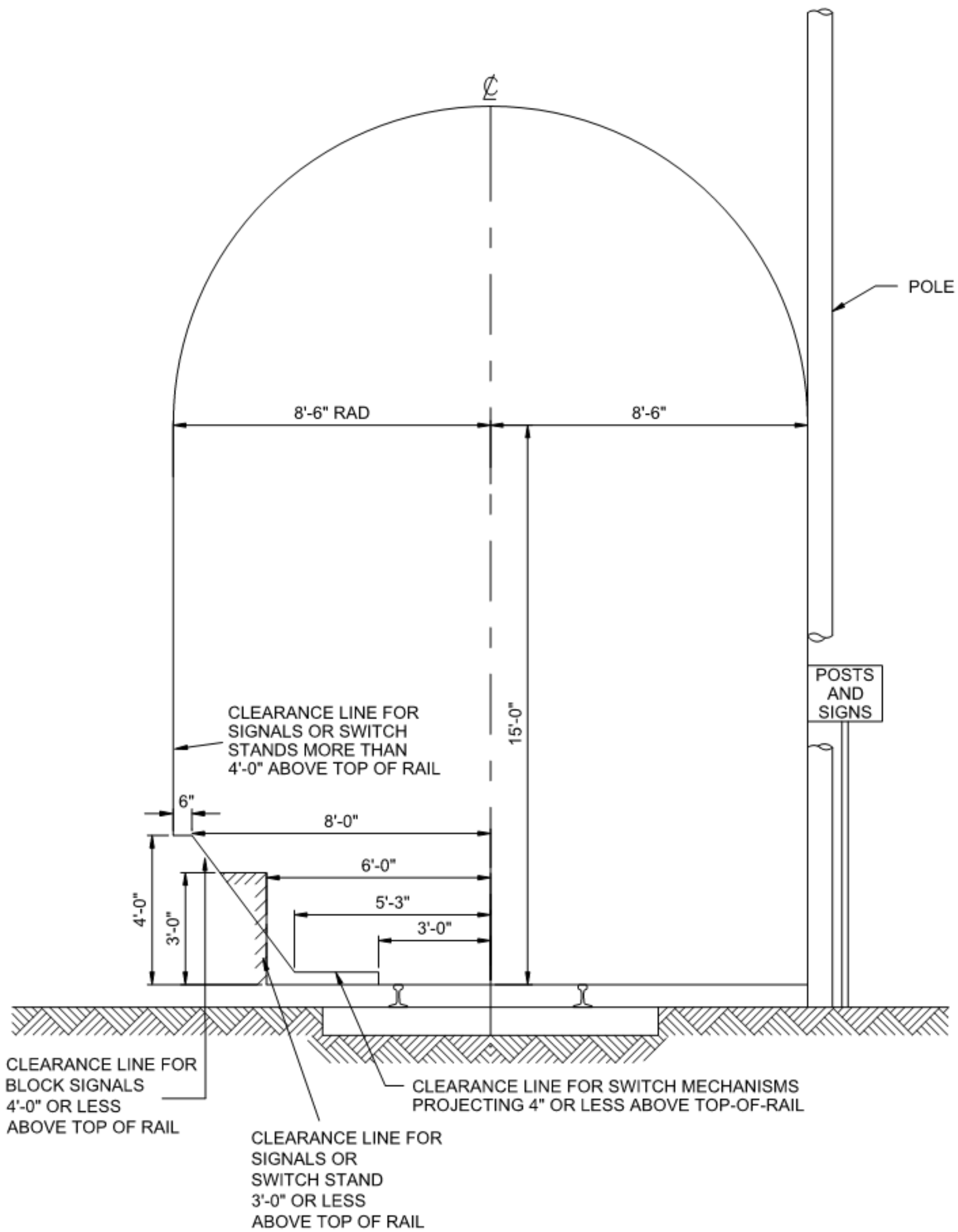
Figure 530-2: Clearances to Station Platform



NOTES:

1) RAISED PLATFORM DESIGN TO ARCHITECTURE REQUIREMENTS

Figure 530-3: Clearances at Signals and Switch Stands



530.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

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530.7.2 Interface and Integration Management

530.7.3 Design Management

530.7.4 Manufacturing and Construction Management

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530.8.2 Quality Management

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END SET - 530

532 TRACK CONSTRUCTION—COMMUTER RAIL

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FIGURES

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SET - 532 TRACK CONSTRUCTION – COMMUTER RAIL

532.1 - INTRODUCTION

532.1.1 Document Scope

532.1.1.1 This set covers track materials, track structure, special trackwork, and construction of the Sounder commuter rail. This set also covers the application and criteria of trackwork at track grade crossings, and the requirements to store Sounder commuter rail vehicles in the yard or layover facilities.

532.1.1.2 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 532 owner to determine the technical source for the design criteria.

532.1.2 Regulations, Codes, Standards, and Guidelines

532.1.2.1 International Regulations, Codes, Standards, and Guidelines (Not Used)

532.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines (Not Used)

532.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines (Not Used)

532.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

532.1.2.4.1 AREMA Manual for Railway Engineering

532.1.2.4.2 AREMA Portfolio of Trackwork Plans

532.1.2.5 Other Jurisdictions (Not Used)

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532.1.3 Abbreviations and Acronyms

532.1.3.1 AHJ– authority having jurisdiction

532.1.3.2 AREMA- American Railway Engineering and Maintenance-of-Way Association

532.1.3.3 CWR– continuous welded rail

532.1.3.4 DOR – designer of record

532.1.4 Definitions and Classifications (Not Used)

532.1.5 References (Not Used)

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532.2.2 Operational Needs

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532.4.3 System Architecture

532.4.4 System Layout

532.4.5 Concept of Execution

532.5 SYSTEM INTERFACE REQUIREMENTS

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400	Vehicle	X
500	Track	X
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	
1100	Technology	
1200	Security	

532.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

532.6.1 Track Construction

532.6.1.1 The typical ballasted track section for new construction must comply with Sound Transit Sounder Commuter Rail Engineering Standard Drawings. For drainage requirements Set 901 Storm Drainage.

532.6.1.2 Shop Track

532.6.1.2.1 Shop track must be installed within the limits of the maintenance shop building. Except in pit areas, installation is similar to the embedded track.

532.6.1.2.2 Shop track must be constructed with zero grade, 115 RE rail, reinforced concrete rail foundation, and CWR.

532.6.1.3 Track Transition Slab

Commentary: When two types of track structures are connected, a transition track section is be constructed in between to smoothly transfer the track modulus from one type of track into another. Within the transition track section, the concrete crosstie spacing must be adjusted to account for the difference in track modulus between the more rigid track and the adjoining ballasted track on subgrade.

532.6.1.3.1 Track transition slab must be installed at the following interfaces:

i. Ballasted track on grade and ends of ballasted concrete bridges.
ii. Ballasted track on grade and shop track.

532.6.1.3.2 Track transition slabs and concrete ties must be constructed per Sound Transit Sounder Commuter Rail Engineering Standard Drawings.

532.6.1.3.3 The minimum ballast depth above a transition slab measured from bottom of tie must be 12 inches.

532.6.2 Track Gauge

532.6.2.1 Track gauge must use standard gauge of 4 feet 8 1/2 inches, measured between the inner (gauge) sides of the heads of rails at 5/8 inches (16 millimeters) below the top of rail.

532.6.3 Track Construction Tolerance

532.6.3.1 Track construction tolerances for gauge, alignment, and cross level must comply with construction tolerances in the Sounder Commuter Rail Engineering Standard Specifications.

532.6.4 Ballast

532.6.4.1 Ballast Specification

532.6.4.1.1 Ballast must be of new crushed stone, containing no carbonates or slag, composed of hard, strong, angular, and durable particles, free from injurious amounts of deleterious substances, and conforming to the requirements of AREMA Manual, Chapter 1, Part 2, Article 2.4.

532.6.4.1.2 For primary track, ballast must conform to Sounder standard specifications and AREMA ballast gradations No. 3 or No. 4A.

532.6.4.1.3 For yard track, ballast must conform to Sounder standard specifications and AREMA ballast gradations No.3, No.4 or No. 4A.

532.6.4.1.4 For walkways at ballast level and trainman walkways, ballast must conform to Sounder standard specifications and AREMA ballast gradation No.5.

532.6.4.2 Minimum Ballast Depth

532.6.4.2.1 Calculate total depth of track substructure using AREMA Manual, Chapter 1, Part 2, Article 2.1.1.5.1.

532.6.4.2.2 For calculated track substructure depth greater than 24 inches, the ballast depth must be increased to meet the calculated section depth.

532.6.4.2.3 For primary track, the minimum depth of ballast layer measured from the top of sub-ballast to the bottom of tie under rails must be 12 inches. Ballast depth must be increased to meet the minimum requirement for total track substructure calculations.

Commentary: The minimum ballast depth of 12 inches provides a maintainable ballast section and increases duration between ballast renewals. The ballast depth provides space for ballast particle interlocking supporting the longitudinal and lateral resistance for CWR track. The ballast depth supports the placement of signaling conduit routing.

532.6.4.2.4 For secondary and yard tracks, the minimum depth of ballast layer measured from the top of sub-ballast to the bottom of tie under rails must be 10 inches. Ballast depth must be increased to meet the minimum requirement for total track substructure calculations.

532.6.5 Sub-ballast

532.6.5.1 The minimum depth of sub-ballast layer measured from the top of the subgrade to the bottom of ballast layer under rails must be 12 inches.

Commentary: The minimum sub-ballast depth is designed to reduce subgrade loads and promotes surface water shedding to the toe of the sub-ballast. The design of the sub-ballast reduces subgrade water infiltration and mud pumping.

532.6.5.2 The sub-ballast layer for all tracks must be uniformly placed and compacted over the entire width of the subgrade following the profile and cross section.

532.6.5.3 Where widened shoulder service roads are provided, the full depth of the sub-ballast must be extended across the full width of the service road.

532.6.5.4 Sub-ballast must be crushed stone or gravelly sand with gradation in accordance with Standard specifications and site-specific additional design requirements.

532.6.6 Ballast Track Maintenance Walkway

532.6.6.1 Track section must provide a minimum 30-inch maintenance walkway per Figures 532-1, 532-2 and 532-3.

Figure 532-1: Single Track Maintenance Walkway

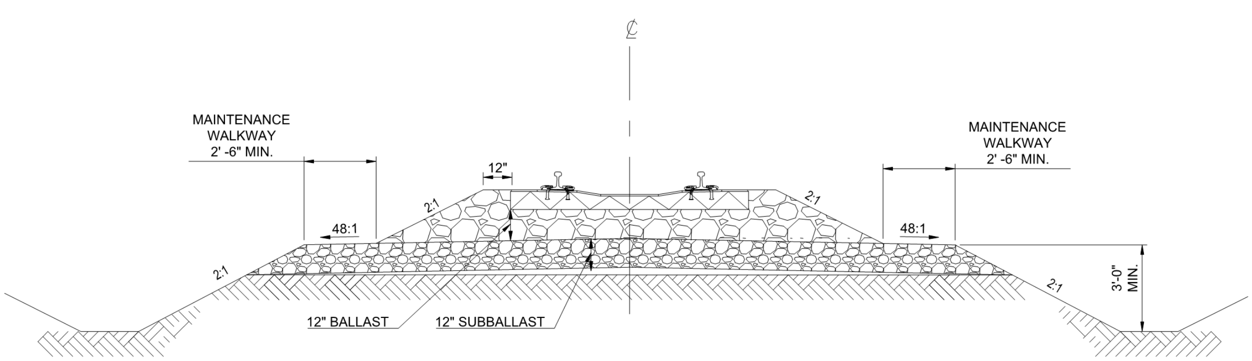


Figure 532-2: Double Maintenance Track Walkway

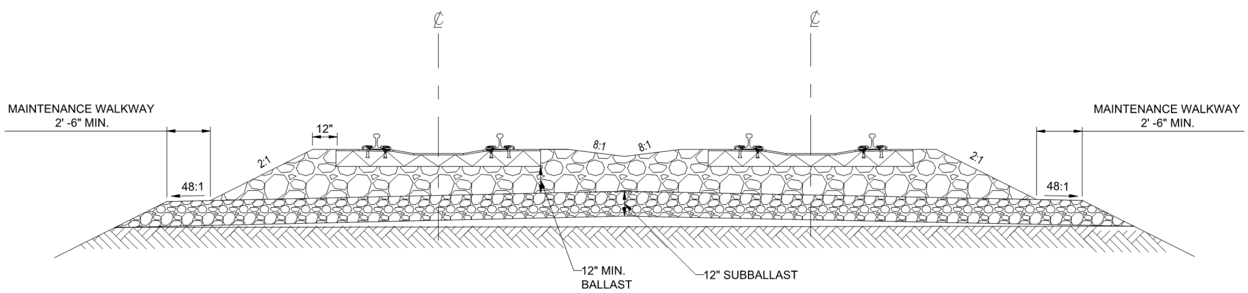
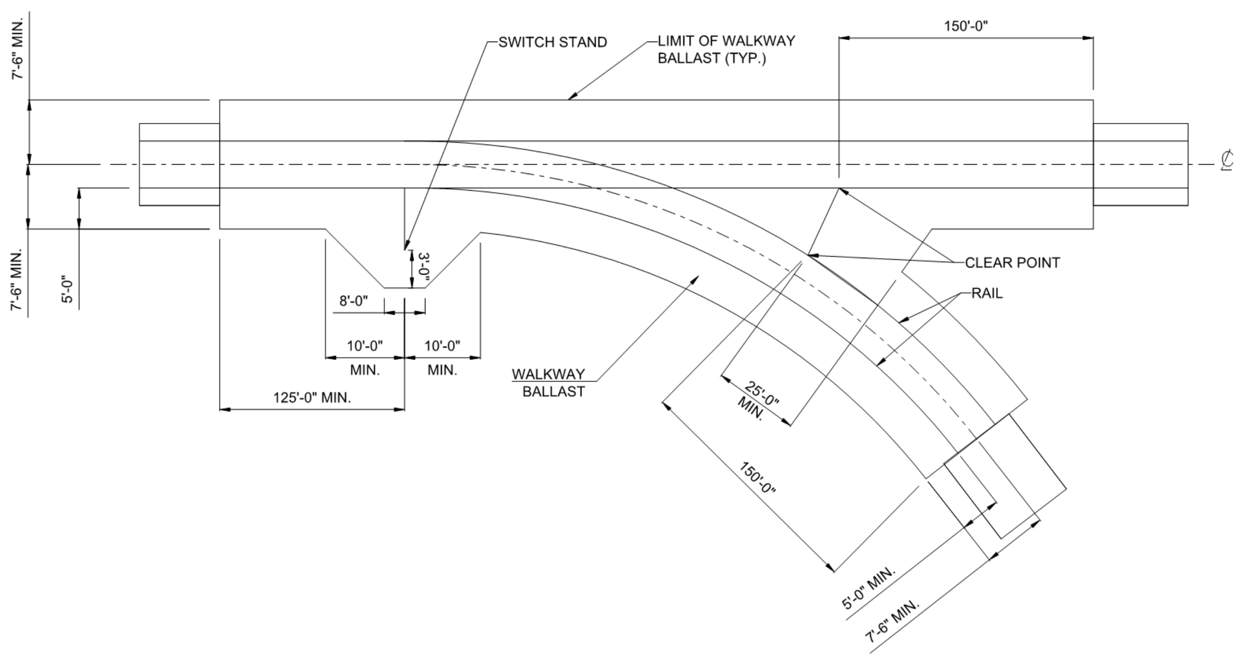


Figure 532-3: Turnout Walkway



532.6.7 Geotextile Fabrics

532.6.7.1 Geotextile fabric must be used below the bottom of sub-ballast layer if the subgrade soils within two feet contain more than 15 percent of fines (materials finer than US #200 sieve opening of 0.075 millimeters).

532.6.7.2 Geotextile fabric must be placed under sub-ballast layer for all special trackwork. Fabric must extend 20 feet before point of switch and 10 feet after the last long tie.

532.6.7.3 Geotextile fabric must be placed for tracks with potential mud pumping and stability issues.

532.6.7.4 Geotextile fabric must extend the entire interface zone between the sub-ballast and subgrade.

532.6.8 Subgrade

532.6.8.1 The subgrade must be analyzed to determine whether it has both uniform stability and the strength to carry the track loadings expected. AREMA recommends that, for most soils, pressure on subgrade be lower than 25 pounds per square inch to maintain subgrade integrity.

532.6.8.2 Maximum subgrade settlement of at-grade ballasted track must be 1 inch in first 10 years and 6 inches over life.

532.6.8.3 Maximum differential settlement of at-grade ballasted track of 1:1500 longitudinally, and 1:500 laterally.

532.6.9 Concrete Crossties and Switch Ties

532.6.9.1 Concrete Tie Application

532.6.9.1.1 Use new 8 feet- 6 inches-long concrete ties for all primary, yard, and secondary track construction except in special trackwork and track grade crossing.

532.6.9.1.2 Special trackwork tie lengths must comply be a minimum of 4 foot 3 inches from centerline of track to end of tie.

532.6.9.1.2.1 Concrete ties must have lateral resistance patterns on the sides and bottom and must conform to current AREMA guidelines.

532.6.9.2 Fastener Type

532.6.9.2.1 Rail resilient elastic fastening system on concrete ties and special trackwork must comply with Sounder standard specifications.

532.6.9.2.2 Concrete ties must use spring clips.

532.6.9.3 Rail Seat Cant

532.6.9.3.1 Concrete ties must provide an inward (towards the centerline of track) rail seat cant of 40:1 except in special trackwork.

532.6.9.3.2 Special trackwork must provide a rail seat of zero cant.

532.6.9.3.3 Rail seat cant must gradually transition from 40:1 to 0 prior to special trackwork over ten concrete ties.

532.6.9.3.4 Rail seat pad must be made of high-elastic materials in accordance with Standard Specifications. Rail seat pads must be used between the rail and concrete ties to reduce impact and vibration effects on the track structure and minimize rail seat deterioration. Rail seat pads are typically expected to provide electrical isolation as noted in 2020 AREMA MRE, Chapter 30, Table 30-1-2.

532.6.9.4 Tie Spacing

532.6.9.4.1 All concrete ties must be spaced at 24 inches for primary tracks and 26 inches for yard and secondary tracks except in special trackwork and roadway crossings.

532.6.9.4.2 Special trackwork spacing must be in accordance with AREMA Portfolio of Trackwork Plans.

532.6.9.5 Emergency Guardrail

532.6.9.5.1 Guardrail ties must comply with Sounder Commuter Rail Engineering Standard Drawings and Standard Specifications.

532.6.10 Wood Ties

532.6.10.1 General

532.6.10.1.1 Wood ties must be made of Douglas Fir and comply with Standard Specifications.

532.6.10.1.2 For primary, secondary, and yard tracks wood ties must only be used in track grade crossings and special trackwork switch ties for derails.

532.6.10.1.3 Industry tracks may use wood ties.

532.6.10.2 Length and Spacing

532.6.10.2.1 For wood tie length and spacing see Section Track Grade Crossings and Section Special Trackwork derail requirements.

532.6.10.2.2 Standard wood tie lengths are 8 feet 6 inches and must only be used for industry tracks.

532.6.10.2.3 Standard wood tie spacing is 19 1/2 inches and must only be used for industry tracks.

532.6.10.3 Tie Plates

532.6.10.3.1 Tie plates vary in length and width and must be sized for the spike hole punching to match the width of the rail base.

532.6.10.3.2 For double shoulder tie plates, the distance between the shoulders must be at most 1/8 inch larger than the rail base width.

532.6.10.3.3 On single shoulder plates, the spike holes on the gage side (opposite the shoulder) must keep the inside face of the spike within 1/8 inch of the rail base when the opposite edge of the base is against the shoulder.

532.6.10.3.4 Either single or double shoulder tie plates can be used.

532.6.10.3.5 Plates with different cants on the same tie (i.e., those with level rail seats and those with a 1:40 slope) must not be mixed.

Commentary: Tie plates of different lengths and widths may be used, and single shoulder plates may be mixed with double shoulder plates.

532.6.10.4 Spikes

532.6.10.4.1 On tangent track and curves up to 4 degrees, one spike on the gage and field side of each rail must be used for a total of four spikes on each tie.

532.6.10.4.2 On curves greater than 4 degrees, one spike on the field side and two spikes on the gage side of each rail must be used for a total of six spikes on each tie.

532.6.10.5 Track Bolts, Nuts, and Spring Washers

532.6.10.5.1 Track bolts, nuts, and spring washers must conform to AREMA, Chapter 4 Rail, Part 1 Design of Rail and Part 2 Manufacture of Rail.

532.6.10.6 Rail Anchors for Jointed Rail to CWR

532.6.10.6.1 Rail anchors must be used to transition from jointed rails on wood ties to CWR on concrete ties and comply with Sounder Commuter Rail Engineering Standard Drawings.

532.6.10.6.2 Each anchored tie must have four anchors applied per tie (box anchored).

532.6.10.6.3 Rail anchors must either be spring or drive-on anchors.

532.6.10.7 CWR Wood Tie Transition to Concrete Tie

532.6.10.7.1 Ten 10-foot-long wood ties at 19 1/2 inch spacing must be installed in a transition zone from wood ties to concrete ties.

532.6.11 Rail

532.6.11.1 Rail Standard Conformance

532.6.11.1.1 Rails must be control-cooled carbon steel rail meeting current AREMA Specifications for Steel Rail and Sound Transit Standard Specifications.

532.6.11.2 Primary/Yard Track Rail

532.6.11.2.1 136 RE rail must be used for all primary track.

532.6.11.2.2 115 RE rail must be used for yard, secondary, and shop track.

532.6.11.3 Industry Track

532.6.11.3.1 115 RE rail or heavier must be used for industry track.

532.6.11.4 High Strength Rail

532.6.11.4.1 High strength rail must extend 100 feet beyond each end of the platform.

532.6.11.4.2 High strength rail must be used for curves 3 degrees and greater.

532.6.11.4.3 High strength rail must extend 10 feet into tangent track on the approach and departure ends of the curve.

532.6.11.4.4 High strength rail must be used in areas where high wear or internal rail tensile stresses exceed 30 kilopounds per square inch in the rail structure interaction calculations.

532.6.11.4.5 Rail stresses include, braking/tractive, thermal, wheel load/deflection, and rail structure interaction (20 kilopounds per square inch maximum).

532.6.11.4.6 High strength rail must be used throughout all special trackwork.

532.6.11.4.7 When two sections of high strength rail are close together and conformance to the above criteria would result in an intermediate segment of standard hardness rail less than 156 (2 x 78) feet, the high strength rail must be made continuous throughout all three segments.

532.6.11.4.8 High strength rail must conform to AREMA standards and Sounder Standard Specifications.

532.6.12 Rail Grinding

532.6.12.1 Rail grinding must be performed on all rail to remove surface imperfections and mill scale in accordance with Sounder Standard Specifications.

532.6.13 Rail Precurving

532.6.13.1 Running rails and restraining rails in horizontal curves with radius less than 500 feet must be precurved using standard roller bending method.

532.6.13.2 On spiraled curves, rail must extend 13 feet into the tangent beyond end of spiral.

532.6.13.3 On simple curves, rail must extend 13 feet into the tangent beyond end of curve.

532.6.13.4 Rail base must lie flat after bending.

532.6.13.5 Rails in vertical curves with a radius less than 1,000 feet must be precurved using standard roller bending method.

532.6.13.6 Rail must extend 13 feet into the tangent beyond end of curve.

532.6.14 Restraining Rail

532.6.14.1 Restraining rails must comply with AREMA Track Portfolio Guardrail details.

532.6.14.2 Restraining rails must have a flared end per AREMA Track Portfolio details.

532.6.14.3 Restraining rail must be used on horizontal curves of less than 500 feet radius and extend the length of the rail precurving requirements.

532.6.15 Emergency Guardrail

532.6.15.1 Emergency guardrail must be used to limit the lateral movement of derailed vehicles on bridge structures.

532.6.15.2 Emergency guardrail must be used to limit the lateral movement of derailed vehicles on vertically retained fill sections where the drop-off is greater than 5 feet.

532.6.15.3 Emergency guardrail must be used to limit the lateral movement of derailed vehicles where adjacent columns, retaining walls, and occupied buildings are within 25 feet from centerline of track.

532.6.15.4 Emergency guardrail must be fabricated from 112 RE or heavier rail and the rail must be Class 2 or better as defined by AREMA Chapter 4, Part 3.

532.6.15.5 Emergency guardrail must be installed in accordance with the Sounder Commuter Rail Engineering Standard Drawings.

532.6.15.6 For double tracks on open-deck bridge with a hazard on each side, all running rails need to be guarded with emergency guardrails.

532.6.15.7 On multiple tracks areas where the hazard is located on one side only, only the track closest to the hazard must be equipped with emergency guardrail installed inside the running rail that is farthest from the hazard.

532.6.15.8 Emergency guardrail must extend 100 feet beyond the requirements listed above.

532.6.15.9 At track grade crossings where emergency guardrails are required, restraining rails must be used instead.

532.6.15.10 Emergency guardrail must be positioned approximately 18 inches from the gauge side of the running rail per AREMA standard.

532.6.15.11 Emergency guardrail end sections must be curved toward the track centerline and provided with vertical taper per Sounder Commuter Rail Engineering Standard Drawings.

532.6.16 Bonded Insulated Rail Joints

532.6.16.1 Insulated joint bars must be located as required to support track signals.

532.6.16.2 All insulated joints must be factory-made bonded type and must comply with AREMA and Sound Transit Specifications.

532.6.16.3 Factory-made insulated joint length must be a minimum of 19 1/2 feet.

532.6.16.4 Joint bars must be 36-inch six-hole bars conforming to AREMA standard punching patterns and standard drawings.

532.6.16.5 Track bolts, nuts, and lock washers must conform to AREMA standards.

532.6.16.6 Field installed insulated joints must only be used in Special Trackwork as shown in Standard Plans.

532.6.16.7 Insulated joint bar locations at grade crossings must comply with Section Track Grade

Crossings.

532.6.17 Non-insulated Joint Bar

532.6.17.1 Joint bars must be 36-inch six-hole bars conforming to AREMA standard punching patterns and standard drawings.

532.6.17.2 Track bolts, nuts, and lock washers must conform to AREMA standards.

532.6.18 Rail Welding

532.6.18.1 All tracks must be CWR.

532.6.18.2 Rail welding must conform to Sounder standard specifications and AREMA Standards.

532.6.18.3 Field thermite welds must be 10 feet or more from a track grade crossing.

532.6.18.4 Field thermite welds must be located as suspended joints to avoid damaging the rail seat pads.

532.6.18.5 All special trackwork joints must be welded, except at joint locations as shown on the Sounder Commuter Rail Engineering Standard Drawings.

532.6.19 Compromise Joint

532.6.19.1 Compromise joints must be used to connect rails of dissimilar rail section and comply with AREMA Track Portfolio standard drawing.

532.6.19.2 Forged compromise rails may be used if available for the rail sections involved and connected with field welds.

532.6.19.3 Forged compromise joints must comply with AREMA requirements.

532.6.19.4 Center of compromise joints must not be located within special trackwork units or within 30 feet of point of switch or heel of frog.

532.6.20 Rail Temperature

532.6.20.1 The rail temperature varies from the lowest ambient temperature to highest ambient temperature. When rail is exposed to sunlight, its maximum rail temperature will be 35 degrees Fahrenheit greater than the highest ambient temperature (110 degrees Fahrenheit).

532.6.20.2 For exposed rails, the rail temperature must use a range of 0 degrees Fahrenheit to 145 degrees Fahrenheit.

532.6.20.3 Exposed rails must be installed at a rail neutral temperature between 90 degrees Fahrenheit to 105 degrees Fahrenheit.

532.6.20.4 Rails more than 300 feet from portals that are not exposed to sunlight must be installed at a rail neutral temperature between 55 degrees Fahrenheit to 80 degrees Fahrenheit.

532.6.21 Special Trackwork

532.6.21.1 General

Commentary: Turnouts are set to provide connections to primary tracks, branch lines, storage tracks, industrial sidetracks, and to merge two main tracks into a single track at the end of a double track segment. Crossovers consist of two turnouts located to allow traffic to cross over from one track to another, both tracks usually being in parallel. Where a pair of crossovers are required, one right-hand and the other left-hand, it is desirable that they be located as two single crossovers. If this is not possible, or if extraordinary site conditions make it more economical, a double crossover may be used. The size of turnout or crossover selected depends upon its purpose, desired design speeds, and local geometric constraints.

532.6.21.1.1 Turnouts and crossovers must be located to allow suitable placement of switch machines or switch stands and associated WUTC walkways, and with consideration of the placement and visibility of control signals.

532.6.21.1.2 All special trackwork design must comply with AREMA and BNSF standard drawings.

532.6.21.1.3 Special trackwork turnouts must match the track classification of 115 RE or 136 RE for which it is installed on.

i. Turnouts on mainline must be 136 RE.
ii. Turnouts in the yard must be 115 RE or heavier.
iii. Turnouts on industry track must match the rail type being utilized.

532.6.21.1.4 Turnout rails must be continuously welded, high strength rail with elastic fasteners, concrete ties, and insulated.

532.6.21.1.5 See Set 531 Track Geometry – Commuter Rail for geometric constraints for special trackwork.

Commentary: When siting special trackwork locations, the designer should locate special trackwork on long tangents and on grades less than 1% and preferably 0.5%.

532.6.21.1.6 No actual rail superelevation and cant are allowed within special trackwork limits.

532.6.21.1.7 See Section Track Grade Crossings for special trackwork requirements at track grade crossings.

532.6.21.1.8 The limits of any trackwork design or construction contract must not be located within a special trackwork unit.

532.6.21.1.9 The distance between facing point turnouts (i.e., points of switch) must be 150 feet or greater for mainline track.

532.6.21.1.10 Crossovers must be tangent between opposing frogs.

532.6.21.1.11 Do not place curve between opposing frogs in a crossover.

532.6.21.2 Turnout Maximum Allowable Diverging Speed

532.6.21.2.1 Turnout number must be selected based on the maximum diverging operating speeds. If speed and traffic volume are different for turnout's tangent and diverging routes, use turnout's tangent route for higher-speed and higher-tonnage operation.

532.6.21.2.2 The turnout maximum allowable diverging speeds are listed in Table 532-2 below.

Table 532-2: Turnout Maximum Allowable Diverging Speeds

Turnout Data	Passenger (mph)	Freight (mph)	High Speed Passive Tilt Technology Trains (mph)
#7 (Yard)	10	10	10
#9 (Yard)	15	15	20
#11	25	15	25
#15	35	30	35
#20	40	40	40
#24	50	40	50

532.6.21.3 Operation-based Turnout Numbers

532.6.21.3.1 Turnouts in all main line track must be No. 11 or larger and include a spring-rail frog.

532.6.21.3.2 Yard track must be No. 9 turnout or larger.

532.6.21.3.3 Yard track turnouts may use a No.7 turnout on existing spurs or yard tracks when the use of a No. 9 turnout cannot meet its turnback curve requirements.

532.6.21.3.4 No.11 turnouts or larger must be used at connections from main line to industry tracks and yards.

532.6.21.3.5 No. 15 turnouts or larger must be used at main line interchange to foreign carrier.

532.6.21.4 Turnouts outside Sound Transit Property

532.6.21.4.1 For secondary or yard track turnouts placed outside of Sound Transit property and/or maintained by the industry and operated by Sound Transit, the turnout number must be a No. 7 or larger with 115-pound rail or heavier.

532.6.22 Derail

532.6.22.1 Double switch point type derails must be used to protect the main line tracks and controlled sidings.

532.6.22.2 Derails must be placed on all tracks that connect a main line to a siding, secondary, yard, layover, or industrial lead.

532.6.22.3 Switch-point derails are used at locations where operating locomotives are stored and where cars are moved or switched by non-railroad personnel.

532.6.22.4 For standard derail detail see Sounder Commuter Rail Engineering Standard Drawings.

532.6.22.5 Derails must be located so that they derail equipment in a direction away from the primary track.

532.6.22.6 For derails protecting the mainline, the derail must be placed a minimum of 100 feet behind the 14-foot clearance point to the mainline.

532.6.22.7 For derails protecting non mainline track, the derail must be placed a minimum of 50 feet behind the 14-foot clearance point to the non-mainline.

532.6.22.8 Derails must be placed on tangent track.

532.6.22.9 A "Derail" sign must be placed next to every derail.

532.6.23 Track Bumping Post

532.6.23.1 Stub-end storage/pocket/tail tracks used in main line operation must be equipped with track bumping post with sliding friction buffers capable of absorbing the kinetic energy of a train to bring it safely to a stop.

532.6.23.2 The buffer stop must be capable of providing 0.3 deceleration of gravity at an impact speed of 5 miles per hour.

532.6.23.3 A bumping post must be installed at the end of each open-ended operating track.

532.6.23.4 A minimum distance 18 feet of rail from face of bumping post to end of track. Bumping post calculations must be provided to show required bumping post space requirements and meeting deceleration requirement. Increase length of track from face of bumping post to meet required slide distance from the calculations.

532.6.23.5 Must provide a minimum of 10 feet from face of bumping post to train stop position.

532.6.23.6 The design and placement of bumping posts must be coordinated with the signal design, trackwork design and civil requirements.

532.6.24 Switch Machines – Power Operated and Manual

532.6.24.1 Switches must be operated by power and lock movements or automatic spring-loaded switch movements, depending on the location and purpose of the switch. Selection of a switch operating device and the space requirements for such devices must be coordinated with design of the train control system.

532.6.24.2 Switch machines must conform to the standards of the railroad involved.

532.6.24.3 Switch machines must be designed to be compatible with switch heaters.

532.6.24.4 Ballasted track switch heaters must be stainless steel type with a rectangle shape flat jacket to fit against the rail.

532.6.24.5 Embedded track switch heaters must have electric heating elements installed in a cavity under the switch tongue rail. The heating element must be readily accessible for removal and replacement.

532.6.24.6 Switch heaters are not required in areas more than 100 feet inside of tunnels.

532.6.24.7 Switch heaters must be electrically rated for the local environment.

532.6.24.8 Switch heaters must be controllable manually at the control case, automatically via rail temperature, automatically via ambient temperature, and automatically via moisture sensing.

532.6.24.9 Gas or propane switch heaters are not allowed.

532.6.24.10 All switch stands must include a 30-degree handle.

532.6.25 Track Grade Crossings

532.6.25.1 All track grade crossings must be constructed with 136 RE rail, ten-foot wood ties at 19 1/2-inch centers per Standard Drawing, CWR, and precast concrete roadway crossing panels.

532.6.25.2 Roadway Track Grade Crossing Geometry

532.6.25.2.1 Roadway track grade crossings must be in horizontal and vertical tangent track except at the locations listed below.

532.6.25.2.2 Accepted curved roadway track grade crossing locations include the following:

i. East C St.
ii. S C St.
iii. S Pine St.
iv. S 60th St.
v. S 74th St.

532.6.25.2.3 Minimum distance between a horizontal or vertical curve and the ends of a roadway track grade crossing is 75 feet.

532.6.25.3 Roadway Track Grade Crossing Flangeway

532.6.25.3.1 Roadway track grade crossings must incorporate precast concrete panels with pre-attached rubber flange-way fillers.

532.6.25.3.2 Flangeway width must be maximum 2 1/2 inches.

532.6.25.4 Joining of Rails

532.6.25.4.1 Running rail through the roadway track grade crossing area must be electric flash butt-welded.

532.6.25.4.2 Roadway track grade crossings must be free of exothermic rail welds, insulated joints or bonds.

532.6.25.4.3 Exothermic rail welds, insulated joints or bonds must be placed greater than 10 feet from end of grade crossing panels.

532.6.25.5 Special Trackwork

532.6.25.5.1 Turnouts or crossovers must not be located in a crossing.

532.6.25.5.2 The point of switch and last long tie must be a minimum of 100 feet from the ends of the roadway track grade crossing (including sidewalks and bicycle lanes).

532.6.25.6 Track Grade Crossing Limits

Commentary: Limits of crossing panels are to provide provisions for future roadway changes without needing to necessarily change track grade crossing panels. Widening the roadway or sidewalk which extend beyond the panel limits will require new track grade crossing panels.

Commentary: Track grade crossing limits should consider current AHJ comprehensive plan for roadway widths in determining the overall length of the grade crossing.

532.6.25.6.1 Track grade crossing panels must extend minimum one-half panel or five feet, whichever is greater, beyond the edge of roadway or sidewalk.

532.6.25.7 Track Grade Crossing Transitions

532.6.25.7.1 Space ten-foot wood ties 19 1/2 inches apart beyond crossing limits 19 1/2 inches in transition zone at each end of the track grade crossing.

532.6.25.8 Grade Crossing Drainage

532.6.25.8.1 Track drainage channel at road crossings must be a minimum 8-inch perforated pipe. The drainage pipe must be minimum 8 feet 6 inches from centerline of track. The top of subgrade roadbed must be crowned to drain water outside of track structure. See Sounder Commuter Rail Engineering Standard Drawings.

532.6.25.8.2 Track underdrain must be connected to track drainage system outside the track grade crossing limits.

532.6.25.8.3 All drainage water flowing into the roadway track grade crossing, public roadway or Sound Transit ditches must not be connected to the underdrain.

532.6.25.8.4 Drainage water flowing out of the track grade crossing must be collected and routed separately from the track drain system.

532.6.25.9 Maintenance Of Way Grade Crossing Limits

532.6.25.9.1 Grade crossing limits must be a minimum 100 feet long.

532.6.25.9.2 Grade crossings must be on horizontal and vertical tangent track.

532.6.25.9.3 Design of crossing panels and transition lengths must comply with roadway track grade crossings.

532.6.25.9.4 Access roads must connect to the track grade crossing.

532.6.25.9.5 Gates for access roads to track grade crossings must be a minimum of 25 feet from centerline of nearest track.

532.6.25.9.6 Gates within 40 feet of nearest track centerline must open away from the tracks.

532.6.25.10 Station Layout Provisions

532.6.25.10.1 Station layouts must include provisions for maintenance trucks to access the tracks.

532.6.25.11 Roadway Grade Separations

532.6.25.11.1 Provide a maintenance of way grade crossing if nearest grade crossing is more than two miles upstation or downstation from the roadway grade separation.

532.6.26 Sounder Commuter Rail Vehicle Yard Facility Storage.

532.6.26.1 Yard track layout provides efficient facilities operation and is configured to allow train sets to exit the yard to the mainline in the event of a stuck turnout, having the ability to “run the switch” to exit the yard. Yard and layover track are designed to optimize the most storage positions for full train consists of two locomotives and ten cars. Other storage options are ten cars and one locomotive and providing storage for locomotives and cars for servicing. The quantity of storage positions is determined in the project scope.

532.6.26.2 Car length is 85 feet 0 inches.

532.6.26.3 Locomotive length is 68 feet 0 inches.

532.6.26.4 A 20-foot train separation distance must be provided between train sets on the same track.

532.6.26.5 The storage position must begin a minimum 50 feet beyond the 14-foot foul point to adjoining track.

532.6.26.6 The storage position must end 10 feet before a bumping post.

532.6.26.7 Storage positions must not obstruct access aisles.

532.6.26.8 Storage positions must not include any special trackwork.

532.6.26.9 The longest train must be able to enter the rail yard and proceed directly to the shop including the exterior service and inspection track or the storage yard.

532.6.26.10 Trains must be capable of moving directly into any of the storage yard tracks from any shop run-through tracks or the exterior service and inspection track in one direct move.

532.6.26.11 From the mainline to any yard position, a direct train movement must be provided which does not move through shop track or exterior service and inspection track.

532.6.26.11.1 Moves which require reversing direction is not considered a direct move.

532.6.26.12 The longest train must be allowed to index over the wheel truing machine or the drop table on the progressive maintenance track without fouling track access to the service & inspection tracks, shop tracks, yard tracks and mainline access.

532.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

532.7.1 Requirements Management

532.7.2 Interface and Integration Management

532.7.3 Design Management

532.7.4 Manufacturing and Construction Management

532.7.5 Installation Management

532.7.6 Inspection and Testing Management

532.7.7 Training, Pre-Revenue Operations

532.7.8 Certification Management

532.8 APPENDICES (NOT USED)

END SET - 532

601 FIRE/LIFE SAFETY

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SET - 601 FIRE/LIFE SAFETY

601.1 INTRODUCTION

601.1.1 Document Scope

601.1.1.1 This set establishes FLS design criteria for Sound Transit facilities for emergency access, construction type, fire separations, fire command centers, means of egress, exits/point of safety, emergency walkways, guardrails/handrails, fire alarm/detection, gas detection, emergency communications, emergency lighting, fire protection, standpipes, clean agent, and emergency ventilation/smoke control.

Commentary: System and subsystem requirements are provided in two sections. Section 601.6.1 provides general requirements. Section 601.6.2 clarifies when the general requirements apply to each building and facility and includes additional requirements specific to the building or facility. Review both sections to determine all applicable requirements.

601.1.1.2 This Set establishes minimum requirements. If there is a conflict between these requirements and adopted codes and standards, the most restrictive will apply.

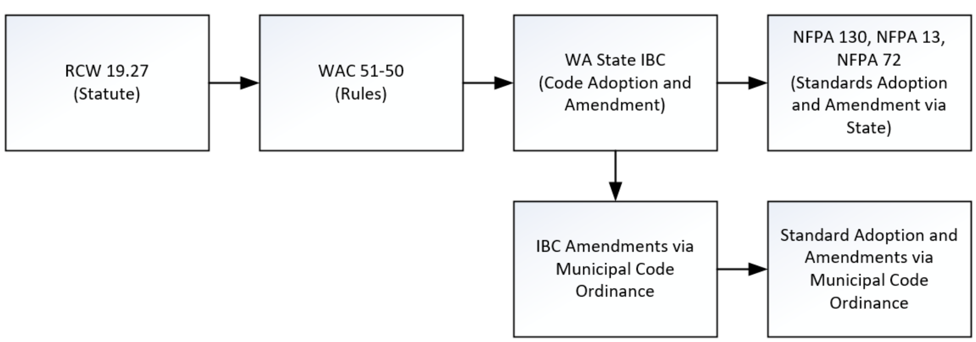
601.1.1.3 For light rail or commuter rail stations where the building code does not apply (e.g., WSDOT ownership exemption) and the building department will not be reviewing and approving plans or conducting inspections. A qualified third-party building code consultant must be hired to review the design for conformance to the IBC and other codes and standards referenced in the basis of design. See 601.7.7 Certification Management for additional requirements.

601.1.1.4 Local amendments of FLS subject matter are common. Design teams must perform a code study during preliminary design and update it at each stage of the design.

601.1.1.5 To determine which edition of a code or standard applies design teams must research the Washington State Building Code, local municipal codes, and local code amendments. Many standards are adopted via IBC Chapter 35 and IFC Chapter 80. Specifying standards not adopted may also be referenced and used when detailed and approved within the basis of design.

601.1.1.6 Understanding code hierarchy and “charging language” is critical to correctly apply adopted standards. Standards are often adopted in whole or part by a particular code. The code path must be clear.

Figure 601-1: Building Code Hierarchy Example



601.1.1.7 The proposed design must comply with code and standards applicable at the time of permit.

Commentary: Some Sound Transit projects extend over many years. It may be necessary to begin a design to a future code or standard not adopted by the state or local AHJ. When this is necessary, the applicable codes will be determined in collaboration with the Sound Transit and AHJ.

601.1.1.8 This set includes references to specific code sections to help the user. The code references are based upon the 2021 IBC, 2021 IFC and adopted standards, including the 2020 version of NFPA 130. Those code section references (e.g., IBC 1009) may change under future editions and reorganization of the codes and standards and the references herein may not clearly align.

601.1.1.9 This set applies to all transportation modes.

601.1.1.10 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 601 owner to determine the technical source for the design criteria.

601.1.2 System Context Information

601.1.2.1 FLS as it relates to fixed guideway transit and passenger rails systems can be broken down into six common principles, including fire prevention, detection/alarm, communication, containment, evacuation, and fire response. Each of these principles include design elements that support operations, maintenance, and emergency response. Some of the elements are listed below.

601.1.2.1.1 Fire prevention: noncombustible construction, fire load of building contents, preventing ignition, and limited combustible components.

601.1.2.1.2 Fire detection: automatic fire detection, LRV operation observation reported to LCC, sprinkler water flow, elevator recall)

601.1.2.1.3 Alarm/emergency communication: fire alarm, PA, VMS, PETS, ETELS, emergency radio, LRV PA, elevator lobby/cab communications.

601.1.2.1.4 Containment: fire-rated walls/floors, fire suppression, station smoke control, tunnel smoke control (EVS), (BMS), redundant power, protected cable and wire, robust fans/dampers, and reliable controls.

601.1.2.1.5 Evacuation (human behavior, station-timed egress, elevated guideway emergency walkway, tunnel emergency walkway and cross passages, emergency lighting, areas of refuge, and emergency procedures.

601.1.2.1.6 Fire response: central station monitoring, LCC visibility/awareness, access/security, hydrants, FDC, standpipes, and FCC/FCR.

601.1.2.2 FLS design is a highly interdisciplinary topic that requires significant coordination and collaboration to produce an effective design. See EP-03 for expectations and project management.

601.1.3 Regulations, Codes, Standards, and Guidelines

601.1.3.1 International Regulations, Codes, Standards, and Guidelines

601.1.3.1.1 International Building Code (IBC) with State and local amendments.

601.1.3.1.2 International Fire Code (IFC) with State and local amendments.

601.1.3.1.3 International Mechanical Code (IMC) with State and local amendments.

601.1.3.2 Federal and National Regulations, Codes, Standards, and Guidelines

601.1.3.2.1 ANSI ASME 17.1, Safety Code for Elevators, Dumbwaiters and Escalators.

601.1.3.2.2 ANSI ASC A14.3, American National Standards for Ladders - Fixed - Safety Requirements.

601.1.3.2.3 ANSI A117.1 Accessible and Useable Buildings and Facilities.

601.1.3.2.4 National Fire Protection Agency (NFPA) 10, Standard for Portable Fire Extinguishers.

601.1.3.2.5 NFPA 13, Standard for the Installation of Sprinkler Systems.

601.1.3.2.6 NFPA 14, Standard for the Installation of Standpipe and Hose Systems.

601.1.3.2.7 NFPA 20, Standard for the Installation of Stationary Pumps for Fire Protection.

601.1.3.2.8 NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances.

601.1.3.2.9 NFPA 30, Flammable and Combustible Liquids Code.

601.1.3.2.10 NFPA 70, National Electrical Code (NEC) with State and Local amendments.

601.1.3.2.11 NFPA 72, National Fire Alarm and Signaling Code.

601.1.3.2.12 NFPA 92, Standard for Smoke Control Systems.

601.1.3.2.13 NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems.

601.1.3.2.14 NFPA 241, Standard for Safeguarding Construction, Alteration and Demolition Operations.

601.1.3.2.15 NFPA 1221, Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems.

601.1.3.2.16 NFPA 2001, Standard on Clean Agent Fire Extinguishing Systems.

601.1.3.2.17 ASTM E84 Standard Test Method for Surface Burning Characteristics of Building Materials, 2016.

601.1.3.2.18 ASTM D635 Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position.

601.1.3.2.19 FM Data Sheet 4-9, Halocarbon and Inert Gas (Clean Agent) Fire Extinguishing Systems.

601.1.3.3 State and Local Regulations, Codes, Standards, and Guidelines

601.1.3.3.1 Washington Administrative Code (WAC) 51-50 State Building Code Adoption.

601.1.3.3.2 WAC 51-54A State Fire Code Adoption.

601.1.3.3.3 WAC 296-96 Safety Regulations for Elevators and Escalators.

601.1.3.3.4 WAC 296-800 Safety and Health Core Rules.

601.1.3.3.5 WAC 296-880 United Safety Standard for Fall Protection.

601.1.3.3.6 WAC 296-809 Confined Spaces.

601.1.3.3.7 WAC 296-876, Ladders, Portable and Fixed.

601.1.3.3.8 Other standards when applicable as adopted by reference in IBC Chapter 35, IFC Chapter 80, IMC Chapter 15, and the NEC.

601.1.3.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

601.1.3.5 Other Jurisdictions

601.1.3.5.1 Local municipal codes often amend the IBC, IBF and other FLS codes and standards. Throughout this set local amendments are referenced periodically when anticipated but it is not complete. All local amendments apply, including those adopted during design, unless the design has been formally vested in writing with the AHJ.

601.1.3.6 Sound Transit Regulations, Codes, Standards, and Guidelines

601.1.3.6.1 Sound Transit Equipment and Facilities Numbering Standards - Rev 4.

601.1.3.6.2 Interface Coordination and Integration Plan – Rev 0.

601.1.3.6.3 General Testing and Commissioning Plan - Rev 1.

601.1.3.6.4 Systems Guidance Drawings Set - Rev 1.

601.1.3.6.5 Sound Transit Systems Guidance Drawings.

601.1.4 Abbreviations and Acronyms

601.1.4.1 AFF-Above Finished Floor

601.1.4.2 AHJ–authority having jurisdiction

601.1.4.3 BMS–building management system

601.1.4.4 CES–Customer Emergency Station

601.1.4.5 EFN–Emergency Fire/Life Safety Network

601.1.4.6 ERER–emergency responder equipment room

601.1.4.7 ERM–emergency response matrix

601.1.4.8 ETEL–emergency telephone system

601.1.4.9 EVS–emergency ventilation system

601.1.4.10 EVACS–emergency voice/alarm communication system

601.1.4.11 EVCP–emergency ventilation control panel

601.1.4.12 EOR–engineer of record

601.1.4.13 ESS-Energy storage systems

601.1.4.14 FACP–fire alarm control panel

601.1.4.15 FCC–fire command center

601.1.4.16 FCR–fire control room

601.1.4.17 FDC–fire department connection

601.1.4.18 FFSCP–Firefighter Smoke Control Panel

601.1.4.19 FHRR–fire heat release rate

601.1.4.20 FLS–fire and life safety

601.1.4.21 FM–Factory Mutual

601.1.4.22 GPM–gallons per minute

601.1.4.23 HVAC–heating, ventilation, and air conditioning

601.1.4.24 IBC–International Building Code

601.1.4.25 ICIP-Interface Control Integration Plan

601.1.4.26 ICC-International Code Council

601.1.4.27 IFC–International Fire Code

601.1.4.28 IMC–International Mechanical Code

601.1.4.29 LRV–Light Rail Vehicle

601.1.4.30 LCC–Link control center

601.1.4.31 MEP–mechanical/electrical and building systems

601.1.4.32 NEC–National Electrical Code

601.1.4.33 NFPA–National Fire Protection Agency

601.1.4.34 OMF–operations and maintenance facility

601.1.4.35 PA–public address

601.1.4.36 PETS–passenger emergency telephone

601.1.4.37 PSI-Pounds per square inch

601.1.4.38 SCADA–supervisory control and data acquisition

601.1.4.39 SCU–station control unit

601.1.4.40 SOC-Security Operations Center

601.1.4.41 ST–Sound Transit

601.1.4.42 SSCRS-Sound Transit Safety & Security Certification Review Subcommittee

601.1.4.43 TPSS–traction power substation

601.1.4.44 TCS–train control system

601.1.4.45 UL–Underwriter's Laboratories

601.1.4.46 UPS–uninterruptible power supply

601.1.4.47 VMS–variable message sign

601.1.4.48 VES–voice evacuation system

601.1.4.49 WAC-Washington Administrative Code

601.1.4.50 WSDOT–Washington State Department of Transportation

601.1.4.51 See Set 010 Operations for other acronyms and abbreviations.

601.1.5 Definitions and Classifications

601.1.5.1 Area of Rescue Assistance: A space meeting the requirement for an area of refuge per IBC 1009 except for the separation requirement.

601.1.5.2 Emergency Walkway: A walkway meeting the dimensional requirements of NFPA 130 that must not conflict with the train static envelope or be obstructed by any permanent structure, fixture, or equipment.

601.1.5.3 VES: A fire alarm speaker system provided to meet EVACS as defined in the IFC and NFPA 72.

601.1.6 References (Not Used)

601.2 STAKEHOLDER NEEDS

601.2.1 Passenger Experience

601.2.1.1 Passengers must be able to evacuate from stations and trainways. Means of egress must be intuitive, readily identifiable, and code conforming. Persons with disabilities must be provided with accessible means of egress as outlined in the IBC with clear and intuitive signage.

601.2.1.2 Emergency communication systems must be intelligible so that passengers may be provided with clear instruction on what to do in the event of a fire or other emergency.

601.2.2 Operational Needs

601.2.2.1 FLS systems must have a service life as defined in Set 001 General.

601.2.2.2 FLS systems must be intuitive, easy to operate, and reliable per the applicable codes and standards and referenced herein.

601.2.2.3 FLS system status must annunciate at the LCC in sufficient detail for operators to make informed decisions regarding rail operations and safety. See Set 001 General for additional requirements.

601.2.2.4 Stations and garages must operate without a continual presence of operators or maintenance people. Designs must account for unattended facilities.

601.2.2.5 Maintenance facilities must operate continuously in support of operating transportation service and maintaining the associated systems, buildings, and infrastructure.

601.2.3 Maintenance Needs

601.2.3.1 FLS systems design must be consistent from site to site to minimize the need for site-specific references and testing procedures.

601.2.3.2 Safe access must be provided so that the system may be tested and maintained without having to rent lifts or provide temporary scaffolding.

601.2.3.2.1 Equipment requiring periodic testing and maintenance must be accessed from the floor, an equipment platform, or with portable ladders per WAC 296-876-400.

601.2.3.2.1.1 The designer must account for portable ladder set up rules, ladder angle, and proximity to floor level change to ensure safe portable ladder use is possible.

601.2.3.2.2 Where portable ladder access is not possible, an alternate means of safe access must be provided.

Commentary: Examples *include area smoke detectors, beam detectors, duct detectors and other wall and ceiling-mounted devices requiring inspecting, cleaning, or calibration.*

601.2.3.3 See Set 804 Fall Protection for additional requirements.

601.2.3.4 System interfaces must be intuitive to improve reliability, simplify troubleshooting, and minimize effort to resolve issues.

601.2.3.5 Designs must account for narrow maintenance windows.

Commentary: Maintenance at stations and garages is limited to periods that do not impact passengers, limiting maintenance windows to non-revenue periods unless the work has no passenger impact.

601.2.4 Safety Needs

601.2.4.1 Passenger, operator, and maintainer safety needs must be accounted for in the design.

601.2.5 Security Needs

601.2.5.1 Station and garage elements accessible to the public must be theft and vandal resistant.

601.2.5.2 Facility perimeter security must be designed so that it cannot adversely affect means of egress or defeat positive latching of fire rated doors and other fire rated openings.

601.2.5.3 Means of egress and public circulation must be integrated with Crime Prevention Through Environmental design principles.

601.2.6 Reliability, Availability, and Maintainability Needs

601.2.6.1 See requirements throughout this set for reliability, availability, and maintenance needs.

601.2.7 Environmental and Sustainability Needs

601.2.7.1 Facility designs must promote stewardship of resources and utilities when selecting material, equipment selection, and operational strategies with the goal of conservation and efficiency.

601.3 SYSTEM REQUIREMENTS (NOT USED)

601.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

601.4.1 System Breakdown Structure

601.4.1.1 FLS is broken down into the following 20 elements of general requirements. Elements (general requirement) are listed in 601.4.1. Each site and location in 601.4.2 use the same 20-element structure to outline when the requirements apply:

601.4.1.1.1 Emergency Access

601.4.1.1.2 Construction Type/Finishes/Furnishings

601.4.1.1.3 Fire Separations

601.4.1.1.4 FCC/FCR/ERERs

601.4.1.1.5 Means of Egress

601.4.1.1.6 Exits/Point of Safety

601.4.1.1.7 Emergency Walkways

601.4.1.1.8 Guardrails/Handrails

601.4.1.1.9 Fire Alarm and Detection System

601.4.1.1.10 Gas/Refrigerant Detection/Mitigation Systems

601.4.1.1.11 Emergency Communication Systems

601.4.1.1.12 Emergency Lighting

601.4.1.1.13 Fire Hydrants

601.4.1.1.14 Automatic Sprinkler Systems

601.4.1.1.15 Fire Department Connections

601.4.1.1.16 Standpipes

601.4.1.1.17 Underground Fire Service Mains

601.4.1.1.18 Portable Fire Extinguishers

601.4.1.1.19 Clean Agent Systems

601.4.1.1.20 Emergency Ventilation/Smoke control

601.4.2 System Sites and Locations

601.4.2.1 FLS safety elements are applied at the following buildings and structures:

601.4.2.1.1 At-grade Guideway – Light Rail

601.4.2.1.2 Elevated Guideway – Light Rail

601.4.2.1.3 Tunnels (Enclosed Guideway) – Light Rail

601.4.2.1.4 Stations – Light Rail

601.4.2.1.5 Operation Maintenance Facilities (Link)

601.4.2.1.6 Bus Maintenance Facilities

601.4.2.1.7 Parking Garages

601.4.2.1.8 Bus Rapid Transit Stations

601.4.2.1.9 Commuter Rail (Sounder) Stations

601.4.2.1.10 Wayside Traction Power Substation

601.4.2.1.11 Wayside Signal Bungalow

601.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirements set and other requirement sets. Interfaces must be provided in the design.

Table 601-1: Interfaces with other disciplines

SET SERIES	SET NAMES	SET 601 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	X
400	Vehicle	X
500	Track	X
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

601.5.1 Train Control and Signals

601.5.1.1 Train control must interface with Opticom and other automated control systems for fire department emergency access across the trainway when required by the AHJ.

601.5.1.2 Signal house fire detection must be interfaced with signal house PLC.

601.5.2 Traction Electrification

601.5.2.1 TPSS Fire detection/power shunt must be integrated with the TPSS PLC.

601.5.3 Operational Communications

601.5.3.1 The following systems provide emergency voice communication for light rail stations, OMFs), and parking garages require interface and coordination. See Set 301 Operational Communication.

601.5.3.1.1 Two-way communication systems:

i. Emergency telephones (ETEL)
ii. Passenger Emergency Telephones/Customer Emergency System (PETS/CES)
iii. Radio
iv. Mobile phone
v. PBX phone

601.5.3.1.2 One-way communications systems:

i. PA and VES
ii. Fire alarm
iii. VMS
iv. LRV Intercom

601.5.3.1.3 The table below indicates the points between which direct emergency voice communication capabilities must be provided for light rail stations and the method to be used for Light rail stations.

Table 601-2: Method of Communication with Direct Emergency Voice Communication

	To						
From	**Patrons in LRVs**	**Patrons in Stations**	**Vehicle Operator**	**Operations Control Center**	**On-Duty Transit Personnel**	**Emergency Responders (911)**	**Patrons in Elevators**
Patrons in Stations				PETS		Mobile phone	
Vehicle Operators	LRV Intercom			Radio			
Operations Control Center		PA	Radio		Radio, PBX, ETEL	PBX	
On-Duty Transit Personnel		PA		Radio, PBX, ETEL	Radio		PA
Emergency Responders In Stations		FACP VES or PA		ETEL, PBX			FACP VES or PA
Patrons in Elevators				Cab PBX			

601.5.4 Vehicle

601.5.4.1 Design fire heat release rate must be used for fire modelling.

601.5.5 Track

601.5.5.1 Emergency walkways must be coordinated with duct banks, OCS poles, maintenance walkways, exits, and points of safety.

601.5.5.2 Access gates must be coordinated street and fire department access.

601.5.5.3 Track crossing including protective gates, guards, lights and signs must be coordinated with station means of egress.

601.5.5.4 Standpipe Systems must be coordinated with stanchion, fence, bridges for support, thrust forces and seismic forces, and the LRV dynamic envelope.

601.5.5.5 Embedded track must be coordinated with trainway and station exit access.

601.5.5.6 Special trackwork at passenger crossings must be coordinated with trainway and station exit access.

601.5.6 Fire/Life Safety

601.5.6.1 Fire/life safety systems must interface with each other.

601.5.7 Structures

601.5.7.1 Structure must be coordinated with fire department access, emergency walkways and dry standpipe systems.

601.5.8 Architecture

601.5.8.1 Stations must account for fire access and means of egress requirements including number of required exits, travel distance, capacity of the means of egress, and point of safety.

601.5.9 Civil

601.5.9.1 Roadways must be provided to meet fire department emergency access requirements.

601.5.9.2 Emergency walkways must be coordinated with the trainway design and pathways to a point of safety.

601.5.9.3 Intrusion Protection must be coordinated with emergency access locations.

601.5.9.4 Fire mains and underground portions of standpipe systems must be coordinated with track and building footprints.

601.5.10 MEP

601.5.10.1 FLS systems, fire department access, and means of egress must be coordinated with other MEP systems, elevators, and escalators.

601.5.10.2 Station visual alarm locations must be coordinate with VMS boards, walls, ceilings, and architectural features to avoid visual obstruction.

601.5.10.3 Clean agent suppression systems must be coordinated with architectural and HVAC systems for gas containment retention time.

601.5.11 Technology

601.5.11.1 FACP, PA and VMS emergency messages must be coordinated with PIMS.

601.5.11.2 FLS system must be integrated with BMS systems.

601.5.11.3 FLS systems must be integrated with EVS systems for light rail stations.

601.5.11.4 FLS systems must support FireWorks for light rail stations.

601.5.12 Security

601.5.12.1 Intrusion detection systems, when required, must be coordinated with fire department access locations.

601.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

601.6.1 Fire/Life Safety Elements

601.6.1.1 The following section is intended to outline general FLS requirements. The sections to follow outline additional requirements specific to buildings, structures, and sites.

601.6.1.2 Emergency Access

601.6.1.2.1 Emergency access must extend from the public way to the developed facility.

Commentary: Emergency access elements include fire apparatus access roads, signage, painted curbs, fire apparatus access gates, manual (personnel) gates, Knox boxes, emergency access pathways, and fixed or other ladders.

601.6.1.2.2 Fire Access and Fire Apparatus Access Roads

601.6.1.2.2.1 Provide fire access in accordance with local transportation requirements (for public streets), the IFC (for private fire apparatus access roads), and local requirements. Roads must meet width, clear height, turning radius, and loading requirements. Vault lids in fire access roads must be support fire truck and outrigger loading.

601.6.1.2.2.2 No parking signage must be provided to ensure fire access is not obstructed.

601.6.1.2.2.3 See Set series 900 Civil for additional roadway requirements.

601.6.1.2.3 Access Identification

601.6.1.2.3.1 A physical address number, meeting the IFC and local rules, must be provided for all buildings. The address number must be visible from the fire department access road. Follow standard convention for addressing and obtain the address number from the AHJ. Stations may require two addresses; for those cases, identify the primary address for public wayfinding and automatic fire department response.

Commentary: Coordinate with the fire department for a final review of the physical address sign. Evaluate landscape design for visual obstruction.

601.6.1.2.3.2 At-grade and elevated guideway emergency access signage is to be in accordance with Sound Transit Standard Drawings.

601.6.1.2.4 Painted Curbs

601.6.1.2.4.1 Painted curbs (red, or in another color as approved by the AHJ) must be provided to complement “No Parking” signs to maintain fire access.

601.6.1.2.5 Fire Apparatus Access Road Gates

601.6.1.2.5.1 Click-2-Enter Fire Department access, or equal, automatic opening gates systems that use a specific radio frequency must be provided for security gates of private yards (e.g., OMFs) only when required by the local AHJ. Coordinate with Set 1203 Access Control System when the entry is serving both Fire Department and Sound Transit Operations access.

601.6.1.2.5.2 Manual gates must be provided where security is required across fire apparatus access roads. Gates must open to provide the minimum width per the IFC. See Set 302 Telephony for additional requirements for trainway crossings.

601.6.1.2.5.3 Hi-rail access gates must serve as emergency access for the fire department when required by the AHJ.

601.6.1.2.5.4 Automatic opening gates must not be provided for Fire Department access across the trainway unless required by the AHJ. When required the gate opening must be integrated in the train signal and control system.

601.6.1.2.6 Manual (personnel) gates

601.6.1.2.6.1 Manual gates must be 48 inches wide (44 inches clear when open), corrosion resistant, and capable of being secured as outlined in 6.1.2.7.

601.6.1.2.6.2 See Set 801 Architectural Materials and Set 903 Fencing for additional requirements for fences and gates.

601.6.1.2.7 Security

601.6.1.2.7.1 Gates must be capable of being secured with a padlock. A Knox box with key or Knox padlock must be provided when required by the AHJ. Provide a gatekeep locking system with two padlocks (one for ST Operations and another for Fire Department) when the gate also provides access for maintenance personnel.

601.6.1.2.8 Emergency Responder Access Pathway

601.6.1.2.8.1 Emergency access pathways must be minimum 48 inches wide all-weather surface with stairs (meeting IBC step rise and run provision) and ramps not to exceed a slope of 8:1 unless a steeper ramp is acceptable to the AHJ. See Set 1007 for Electrical Lighting requirements.

Commentary: The access pathways are typical to tunnel portals and other fire department access points along the trainway in between stations but could also include pathways to an FDC for example. Confirm requirements with the AHJ.

601.6.1.2.9 Emergency Responder Fixed Ladders and Ships Ladders

601.6.1.2.9.1 Fixed ladders must be in accordance with WAC 296-876 and ANSI A14.3 (Revision 2008 or newer), and ships ladders must comply with OSHA 1910.25.

601.6.1.2.10 Access to fixed ladders must be secured to prevent unauthorized use.

Commentary: Use of fixed ladders and ships ladders is uncommon but may be the only option in some cases. Designers should consider other options first before considering fixed ladders and ship ladders.

601.6.1.3 Construction Type/finishes/furnishing

601.6.1.3.1 Buildings and structures must meet the IBC and NFPA 130 requirements for type of construction, when applicable.

601.6.1.3.2 Commuter Rail station and light rail stations and trainways must be noncombustible construction as defined by the IBC.

601.6.1.3.3 Buildings and structures located below the trainway must be of noncombustible construction per NFPA 130.

601.6.1.3.3.1 Where the guideway extends over an existing combustible building, a fire hazard analysis must be performed that demonstrates acceptable risk to trainway assets and operating LRVs as determined by the Sound Transit Safety & Security Certification Review Subcommittee (SSCRS).

601.6.1.3.4 Finishes must meet the IBC and NFPA 130 where applicable.

601.6.1.3.5 Artwork must be noncombustible, limited combustible, or of a size/nature that does not present a hazard. Alternatively, a fire hazard analysis must be developed. See Set 808 for additional information.

601.6.1.3.6 Secure furniture and trash/recycle containers located in public areas must be secured in place so they cannot move or obstruct circulation and egress.

601.6.1.3.7 Stations furniture in public areas must be non-combustible or, when tested in accordance with ASTM E1537, have a peak heat release rate not exceeding 80 KW and total energy release of a single item during the first 10 minutes of the test not exceeding 25 mega joules.

601.6.1.4 Fire Separations

601.6.1.4.1 To maintain continuity, fire rated assemblies must not be supported from non-rated floor assemblies or non-rated structural members unless permitted by the IBC.

601.6.1.5 FCC/FCR/ERER

601.6.1.5.1 The FCC/FCR must be accessed directly from a public area near the main facility entrance unless an alternate location is approved by the AHJ. The access door must be capable of being automatically unlocked.

601.6.1.5.2 FCCs must meet IBC 911 and NFPA 130 requirements and include storage locations for drawings, binders, and reference materials for use by emergency responders. Equipment must include the fire alarm panel, ETEL, emergency ventilation control panel (EVCP), PBX phone, elevator control/annunciator, emergency radio monitoring panel, FCC room clean agent releasing panel, clean agent tank, traction power emergency trip station, SCADA workstations TCS, BMS, and EVS, fire alarm graphics (FireWorks) workstation, PA control/microphone, and other equipment as outlined in Systems Standard Drawing EFP101.

601.6.1.5.3 FCRs must be dedicated rooms with no other function. Equipment must include the fire alarm panel (and associated subpanels, traction power Transit emergency trip station, PA control/microphone, BMS Cimplicity (local) workstation, emergency radio monitoring panel, ETEL, PBX phone, and a flat surface for the BMS workstation and two-way radio charger. The room must include a working surface and storage locations for drawings, binders, and reference materials for use by emergency responders. See System Standard Drawing EFP100.

601.6.1.5.4 ERERs must meet the following requirements:

601.6.1.5.4.1 The room must be within 100 feet travel distance to the platform and preferably at the platform level.

601.6.1.5.4.2 If the path to the platform involves an elevator, the elevator must be sized accordingly.

601.6.1.5.4.3 The room must be at least 80 square feet and arranged to store and access three carts (24 inches by 60 inches) individually without moving carts. The door must be at least 42 inches wide and swing out.

601.6.1.5.4.4 The room must be a dedicated room without plumbing, electrical, or other access panels that could be obstructed by storage. See Systems Standard Drawing STD-EFP102 for layout examples.

601.6.1.6 Means of Egress

601.6.1.6.1 Means of egress must meet the requirements of the IBC and NFPA 130 as amended by the State of Washington and local AHJs. Construct facilities to IBC standards for accessible means of egress and associated accessibility standards including ANSI A117.1. Requirements are building/structure type specific. See site/location section for application.

Commentary: Means of egress calculations must be completed during preliminary design and preliminary approval obtained from Sound Transit and the AHJ as outlined in Engineering Procedure EP-03.

601.6.1.6.2 Coordinate means of egress design with security design.

601.6.1.6.3 See Set 700 Structural for seismic importance factor requirements.

601.6.1.6.4 One- and two-step stairs are not permitted. See Set 805 for additional requirements.

601.6.1.6.5 A platform end gate must meet NFPA 130 and the following:

601.6.1.6.5.1 Not more than 39 inches high, provides a clear width of 28 inches, opens away from the track and in the direction of egress.,

601.6.1.6.5.1.1 Exceptions: Platform end gates for at-grade stations must be at least 18 inches wide and may be non-latching.

601.6.1.6.5.2 Self-closing and positive latching and require no more than 30 pounds force to initiate movement and 15-pound force to open. The closer must overcome force from tunnel piston effect wind, and atmospheric wind.

601.6.1.6.5.3 Equipped with panic hardware with the panic bar located at or near the top of the gate and at least 34 inches above the walkway.

601.6.1.6.5.4 A sign that reads, “DANGER - Authorized Personnel Only,” or equal. Provide other signage per the IBC, NFPA 130, and Set 806 Signage.

601.6.1.6.5.5 See Standard Drawing STD-ATD325.

601.6.1.6.6 Confined spaces including access points must be identified during preliminary design and listed in a drawing schedule and meet the requirements of WAC 296-809. See Set 001 General for additional requirements.

601.6.1.6.6.1 Signage to identify the confined spaces that require authorized access must be provided.

601.6.1.6.7 Area of refuge, area of rescue assistance, exterior area of rescue assistance including signage must be provided where required per IBC 1009.

601.6.1.6.8 Provide evacuation maps that comply with IFC 404 when required by the AHJ.

Commentary: Evacuation maps are not usually required for public areas of open stations and back of house areas when access is limited to employees trained in emergency procedures and evacuation. Evacuation maps are often required for maintenance facilities, and other buildings where the facilities and location of the exits is not intuitive.

601.6.1.7 Exits/Point of Safety

601.6.1.7.1 Buildings must not use “point of safety” terminology or criteria. Use “exits” as defined by the IBC.

601.6.1.7.2 A point of safety as defined by NFPA 130 is applicable only to stations and trainways.

601.6.1.7.3 Station exits must lead to a point of safety as defined by NFPA 130 and one of the following:

601.6.1.7.3.1 An interior stair meeting the requirements of the IBC Chapter 10.

601.6.1.7.3.2 Safe dispersal area meeting the requirements of IBC 1028 and located at least 50 feet away from the station platform.

601.6.1.7.3.3 Public way or 50 feet beyond the architectural footprint of the station, whichever is less.

601.6.1.7.3.4 Concourse and other point of safety approved by the AHJ.

601.6.1.7.4 Surface exit hatches are not permitted.

601.6.1.7.5 Pedestrian safety gates at track crossing must meet the IBC (swing direction, width, opening force, accessibility, and other requirements) if the means of egress crosses the tracks.

601.6.1.8 Emergency walkways

601.6.1.8.1 Emergency walkways must meet the requirements of NFPA 130.

Commentary: The minimum width is defined in NFPA 130 (see NFPA 130 coffin illustration). Note that some local jurisdictions require more width than what is outlined in NFPA 130.

601.6.1.8.2 Emergency walkways may also serve as maintenance walkways and must meet worker safety requirements per WAC 296. See 522 Track Construction for requirements.

601.6.1.8.3 See Set 522 Track Construction for maximum ramp slope and step requirements.

601.6.1.8.4 The distance from the LRV floor and the top of the emergency walkway must be between 0 and 36 inches depending upon the application. See FLS sites and locations for additional requirements.

601.6.1.8.5 Walkway material must be non-combustible as outlined in NFPA 130.

601.6.1.8.6 Fiberglass reinforced polymer materials that have an ASTM E84 Class A flame spread rating and an ASTM D635 HB classification are considered by Sound Transit to meet NFPA 130 and acceptable for at-grade or elevated guideway application only but must be specifically approved by the local AHJ.

601.6.1.8.7 Exit stairs, exit ramps, and trainway appurtenances (e.g., catenary poles, light standards, passenger assistance intercoms, corrosion control units, fire standpipes) must not encroach on the emergency walkway clear width. See Set 520 Vehicle Clearance and Track Spacing for additional requirements.

601.6.1.8.8 Emergency walkways must have a uniform, nominally level, non-slip surface with a coefficient of friction of 0.5 or greater when wet for flat surfaces. Conduits and other materials that present a trip/slip hazard must not cross the walkway.

Commentary: National standards are limited for some materials. Credible manufacturer's product information will be accepted when third party evaluation is not available. Where concrete is used the surface must be broom finished, or equal, for slip resistance.

601.6.1.8.9 Grated emergency walkway surfaces must be close mesh with at least one dimension of the opening less than 5/8 inch.

Commentary: The grate must function well for the public and account for small-heeled shoes.

601.6.1.8.10 Emergency walkways must terminate at station platforms but, if necessary, may terminate at exit stairs meeting the requirements of the IBC.

601.6.1.8.11 Stairs providing means of egress from emergency walkways, including stairs that connect the emergency walkway to the end of a station platform, must be at least 36 inches wide.

601.6.1.8.12 Dead ends exceeding 75 feet are not permitted for enclosed trainways and must not exceed 400 feet for other trainways.

601.6.1.8.12.1 Exception: Dead ends not exceeding 800 feet for end-of-line open-air tail tracks.

601.6.1.8.13 See Set 520 Vehicle Clearance and Track Spacing and 522 Track Construction for additional requirements.

601.6.1.9 Guards/handrails

601.6.1.9.1 Guards must meet the requirements of the IBC where applicable.

601.6.1.9.2 Guards must meet the requirements of WAC 296-880-40005 to provide fall protection for employees on elevated guideways (for both emergency and maintenance walkways) and other elevated surfaces where required.

601.6.1.9.3 Guards must be provided for emergency walkways where required by NFPA 130 and WAC 296-880-40005. The guard must be 42 inches high measured from the top of the walking surface. See Sound Transit Set 522 Track Construction and Standard Drawings for opening protection and additional requirements.

601.6.1.9.4 Handrails must be provided where required per the IBC and NFPA 130.

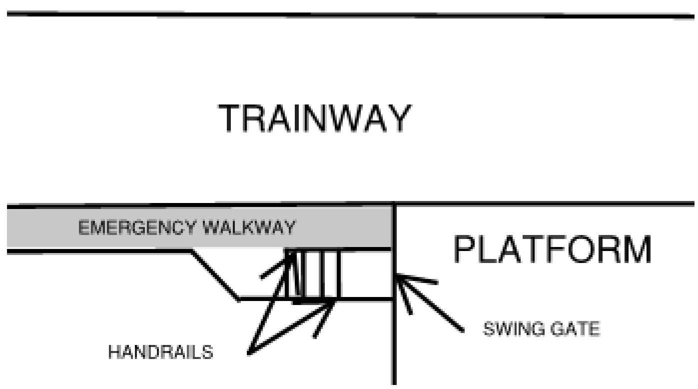
601.6.1.9.5 Handrails must meet the requirements of the IBC when required by the IBC or NFPA 130.

601.6.1.9.6 Where NFPA 130 does not provide requirements for handrail height, diameter, profile, and other topics, apply the requirements of the IBC.

601.6.1.9.7 Handrails must be provided on stairs and ramps, including those on the emergency walkway.

601.6.1.9.8 For the platform termination application, recess the stair or provide another design solution so that the stair and associated handrails do not conflict with the emergency walkway, which must be continuous to the platform (See Figure 601-2).

Figure 601-2: Example – Emergency Walkway Termination at Platform



601.6.1.10 Fire Alarm and Detection Systems

601.6.1.10.1 Technical Requirements:

601.6.1.10.1.1 Fire alarm technology platform and software must be backwards and forwards compatible with one generation of equipment.

601.6.1.10.1.2 Systems must be installed to comply with the IFC, NFPA 72, and NFPA 130 where applicable.

601.6.1.10.1.3 A fire alarm system must only serve a single building or facility unless specifically approved by the FLS Set 601 owner.

601.6.1.10.1.4 FLS control panels must be UL 864 listed for fire alarm, and UL 864 UUKL listed when smoke control is required.

601.6.1.10.1.5 FLS control panels must be modular in design and capable of communicating with subpanels to support a distributed panel design.

601.6.1.10.1.6 The main fire alarm panel must be in the fire command center or fire control room. In buildings without an FCC or FCR, locate the fire alarm control panel in an electrical room.

601.6.1.10.1.7 The main FLS control panels must include supervised bypass switches or buttons for confidence testing purposes.

601.6.1.10.1.8 Link station fire alarm systems must interface with the public address system, building management system, EVS and other systems to the LCC (see Standard Drawing STD-EFS204).

601.6.1.10.1.9 When a fire alarm system is required as outlined in Section 601.6.2 Fire/Life Safety Sites and Locations, the system manufacturer and model must be as follows:

601.6.1.10.1.9.1 Light Rail Stations: Edwards EST4 with FireWorks graphics workstation.

601.6.1.10.1.9.2 OMFs: Edwards EST4 or Edwards IO Series panel

601.6.1.10.1.9.3 Other Facilities: Edwards EST4, Edwards IO Series Panel, Simplex 4100ES, or Simplex 4010.

601.6.1.10.1.10 Fire alarm panels consisting of two or more enclosures must be provided with a square wire way (gutter) located above or below the FACP for wire/cable connections between the enclosures.

601.6.1.10.1.11 FLS control panels and subpanels must be in space that is either conditioned or a space that is designed to stay within temperature/humidity limits of the equipment.

601.6.1.10.1.12 Fire alarm control panels with FireWorks workstations must be networked to the LCC via the TCN.

601.6.1.10.1.13 Fire alarm systems must be monitored by a UL listed central station using mesh radio. Cellular and other approved monitoring technology is acceptable where a wireless mesh radio network is not available, or when there are practical difficulties.

601.6.1.10.1.13.1 Exceptions:

601.6.1.10.1.13.2 The LCC must serve as the monitoring station for light rail stations located in the City of Seattle.

Commentary: Seattle Fire Department accepts the LCC as equivalent to a proprietary central station for Sound Transit Link stations in the city of Seattle. UL Central Station monitoring is not required for stations located in Seattle.

601.6.1.10.1.13.3 Wayside TPSS and signal bungalow fire detection must be monitored by the LCC.

Commentary: UL central station monitoring is not needed unless required by the AHJ.

601.6.1.10.1.14 The fire alarm system monitoring communication device must be furnished and installed by the monitoring company.

601.6.1.10.1.15 The fire alarm control panel must provide clear visual annunciation via an alpha-numeric display of the activated initiating device location using clear room/area nomenclature consistent with facility signage.

601.6.1.10.1.15.1 A fire alarm system submittal that lists alphanumeric text display for addressable field devices and associated addressable points must be reviewed and approved by Sound Transit.

601.6.1.10.1.16 When required, a remote annunciator must be provided in an approved location.

601.6.1.10.1.17 Graphic wall-mounted annunciator panels are not to be provided unless required by the AHJ.

601.6.1.10.1.18 Smoke detector alarm verification must be set for 30 seconds unless not allowed by the AHJ.

601.6.1.10.1.19 Smoke and heat detection must be listed for the anticipated environment (temperature and humidity).

601.6.1.10.1.20 Provide smoke detection for early warning in electrical and UPS rooms, if conditioned.

601.6.1.10.2 Positive alarm sequence per NFPA 72 is not permitted.

601.6.1.10.3 Locate devices in accordance with the IFC, NFPA 72, and ANSI A17.1.

601.6.1.10.4 Audible alarm notification must be by horns with temporal tone unless EVACS system is required.

601.6.1.10.5 Visual alarms in outdoor locations must be designed for direct viewing rather than indirect viewing that relies on light reflection from surfaces, when practical.

Commentary: Locating visual alarms so they may be viewed directly while looking along the platform is preferred with additional strobes provided for other areas of the platform level. For outdoor station platforms visual alarm may be mounted on walls, post, pendant, or on the VMS support structure above the touch zone. For parking garage roofs direct viewing along walkways is ideal where practical, but colocating devices at light standards is acceptable when approved by the AHJ.

601.6.1.10.6 Visual alarm must be provided in public and common use areas per the IFC.

Commentary: Common use areas are those areas made available for two or more people per the IBC. For design purposes a furniture plan showing two or more people and rooms with an IBC occupant load of occupant load of 2 or more should be common use. As an example, small (<300 sf) electrically and mechanical rooms with low ambient noise do not require visual alarms but may require audible alarms if sound pressure cannot penetrate from an adjacent area.

601.6.1.10.7 A 24 Vdc exterior electric bell (or horn if required by the AHJ) must be located near the FDC when practical, otherwise locate it near the riser room. Activate the bell only for water flow alarm.

601.6.1.10.8 Avoid providing audible notification devices in restrooms and similar small rooms where sound pressure may be met through a device located in a nearby common area such as a corridor.

601.6.1.10.9 Where an EVACS is provided, using the fire alarm system or public address system, speakers must be located to provide a minimum sound pressure of 70 dBA, or greater depending upon ambient noise per the IFC and NFPA 72. Speakers must be located to achieve intelligibility per NFPA 72.

Commentary: Speakers placed to meet sound pressure requirements when set at ½ watt is recommended to help ensure the sound pressure is reasonably balanced. When EVACS is provided via fire alarm speakers (rather than the PA) emergency voice messages must be intelligible but measuring the intelligibility during commissioning is not required unless specifically required by the AHJ.

601.6.1.10.10 Fire alarm notification devices (speakers) must have multiple wattage taps to optimize sound pressure.

601.6.1.10.11 The design must provide speaker/horn type, mounting location, and layout.

601.6.1.10.12 Horns must not be provided in interior exit stairs and visual alarms must not be provided in exits as defined by the IBC.

601.6.1.10.13 Speakers, on a separate circuit for ad hoc voice message only, must be provided in interior exit stairs and elevator cars for enclosed stations with a vertical travel greater than 30 feet.

Commentary: This is common to enclosed exit stairs for tunnel stations.

601.6.1.10.14 A remote indicator must be provided for each fire alarm duct detector not visible from the floor.

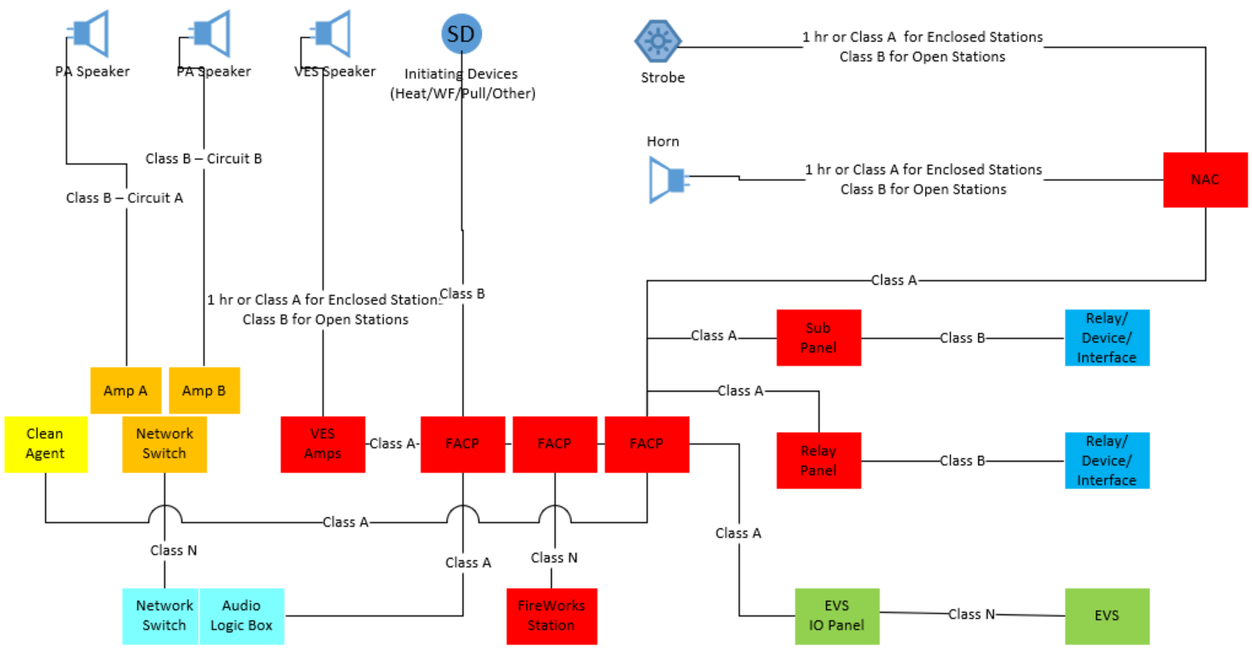
601.6.1.10.15 The fire alarm system panel and subpanels must be on a dedicated 110 Vac power circuit in accordance with NFPA 72 with internal panel backup batteries regardless of the presence of a generator or UPS.

601.6.1.10.16 Fire alarm system wiring pathways must be Class B per NFPA 72 unless otherwise required.

601.6.1.10.16.1 Exception: Wiring pathways between fire alarm control panels, subpanels, relay panels, PA interface, and fire suppression subpanels (i.e., pre-action and clean agent), typical of a distributed system design, must be wired Class A per NFPA 72. See Figure 601-3 for a Station application.

601.6.1.10.16.2 Exception: See Figure 601-3 for notification circuits for enclosed stations.

Figure 601-3: Fire Alarm Wiring Pathway Classifications



601.6.1.10.16.3 A detailed fire alarm system sequence of operation matrix must be developed. See Sound Transit Standard Drawing STD-EFS202 for guidance.

601.6.1.10.16.4 A block diagram indicating how the FACP interfaces with other systems must be provided. See Sound Transit Standard Drawings STD-EFS201 and STD-EFS204 for guidance.

601.6.1.10.16.5 Elevators must only recall when required for fire detection in lobbies, shaft, pit, and machine room, where allowed by the AHJ.

601.6.1.10.16.6 Fire alarm control unit components and calculations for circuit voltage drop must provide at least 25 percent over required capacity.

601.6.1.10.16.7 Battery power supplies must be sized to provide a minimum of 30 percent over the required capacity.

601.6.1.10.16.8 Fire alarm system junction boxes and cover plates must be red in color.

601.6.1.10.16.9 All wire and cable must be provided in the raceway that is dedicated to fire alarm. For additional requirements see Set series 1000 Mechanical-Electrical and Buildings Systems.

601.6.1.10.16.10 Fire alarm conductors must be color coded using a distinct color for each circuit type.

601.6.1.10.16.11 Fire alarm conductors must be pairs of distinct colors unless not permitted by the fire alarm manufacturer.

601.6.1.10.16.12 Fire alarm system cable and wire must meet temperature, damp/wet location, flame spread/smoke development, and fire resistance requirements as outlined in applicable codes and standards and Table 601-3.

Commentary: The product example columns are commentary.

Table 601-3: Fire Alarm System Conductors and Cable

Location and Application *Notes 3, 4*	**Min. Temp**	**Moisture**	**Flame Spread/Smoke release**	**Fire Resistance**	***Commentary: Product Examples***	
					Conductor (wire)	*Cable*
Enclosed Station (IFC, NFPA 70, 72, 130)						
Detection/Control Circuits (except smoke control)	90C	Wet	UL 1685 and NFPA 262, or FT4/IEEE 1202	Not required	*RHW-2- LSZH, XHHW-2- LSZH*	*Note 1*
Notification circuits (speakers/horns/strobes, and PA is used for EVACS)	90C	Wet	UL 1685 and NFPA 262, or FT4/IEEE 1202	1-hour (or redundant circuits in lieu of fire rating is an option when approved by the FLS 601 Set owner and the AHJ)	*For redundant pathway option: RHW-2- LSZH, XHHW-2- LSZH*	*For 1-hour option: CI Cable*
Smoke Control Systems (Note 2)	90C	Wet	UL 1685 and NFPA 262, or FT4/IEEE 1202	1-2 hours	*Note 1, 2*	*Notes 1, 2*
Open Station (IFC, NFPA 70, 72, 130)						
All Circuits	90C	Wet	Per NFPA 70, 130	Not required	*RHW-2, XHHW-2*	*Note 1*
Parking Garages (IFC, NFPA 70, 72)						
All Circuits	75C	Wet	Per NFPA 70	Not required	*RHW, THHW, XHHW*	*Note 1*
Other (OMF, BB, other) (IFC, NFPA 70, 72)						
All Circuits (Conditioned space/areas)	75C	Dry	Per NFPA 70	Not required	*RHW, THHN, THWN*	*FPLP*
All Circuits (Unconditioned space/areas)	75C	Wet	Per NFPA 70	Not required	*RHW, THHW, XHHW*	*Note 1*

Note 1: No examples provided.
Note 2: Smoke control system control wiring for smoke control systems must be protected with a 1 to 2-hour fire barrier, UL 2196 circuits, 2-inch concrete encasement, or electrical circuit protective systems with 1- to 2-hour fire resistance rating. Confirm minimum duration with AHJ.
Note 3: All wire must be solid copper conductor when available.
Note 4: All conductors and cable must meet fire alarm system manufacturer's requirements.

601.6.1.10.16.13 Power limited and non-power limited circuits must meet NEC separation requirements.

601.6.1.10.16.14 Signal/detection/data circuits must be 16, or 14 AWG. Notification and power circuits must be 16, 14, or 12 AWG.

601.6.1.10.16.15 Splicing, tee-tapping, star tapping, and wire nuts are not allowed. Field terminal cabinets, if provided, must be provided with terminal blocks/strips and wire labels indicating in, out, and circuit number. Panel and cabinet wiring must be installed in a neat and orderly manner.

601.6.1.10.16.16 Initiating devices, including programmable modules, must be provided with a field label indicating the device circuit and address.

601.6.1.10.16.17 Smoke and fire/smoke damper associated with environmental HVAC systems for Link stations must be monitored by the BMS for damper position.

Commentary: BMS position monitoring reduces time required for confidence testing as stations that operate 20 hours a day. See Set 1004 Buildings Monitoring and Control for specific requirements.

601.6.1.10.16.18 Environmental fans and terminal unit fans that have the capability to spread smoke beyond the room of origin must be controlled in accordance with State Mechanical Code Section 606.

601.6.1.10.16.19 Elevator fire recall, environmental HVAC fire/smoke dampers (except those associated with clean agent fire suppression), and fire doors hold-open devices must be controlled directly by the fire alarm control panel.

601.6.1.10.16.19.1 The EVS must be used to control station/tunnel emergency ventilation and stair/elevator smoke control (including associated dampers). An engineering analysis must be completed, and a report developed to demonstrate the EVS is equal to a UL 864 system for control of fire life safety equipment. AHJ concurrence must be obtained. See Figure 601-4.

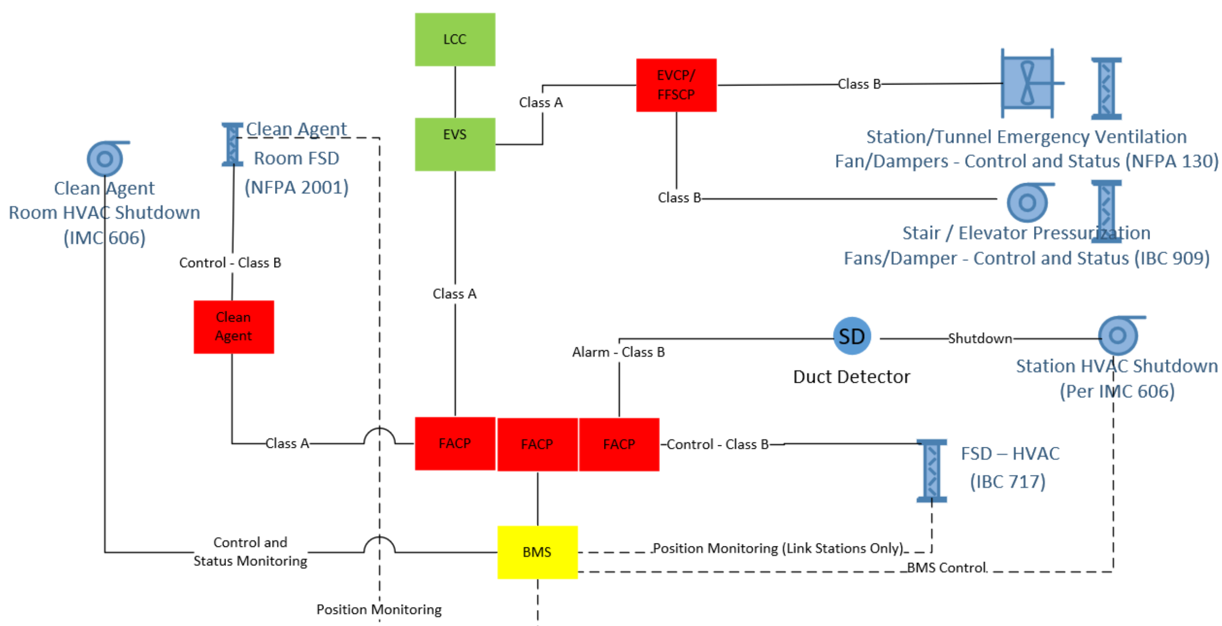
Commentary: BMS and EVS control systems are not typically UL 864 listed. Seattle Fire Department has previously approved for a highly robust PLC system (in lieu of a UL 864 UUKL FFSCP) that is not UL 864 listed.

601.6.1.10.16.20 The EVCP must include a feature to mimic a firefighter's smoke control panel and be programmed to perform a weekly self-test of the stair and elevator pressurization systems in accordance with IBC 909. Programming for the weekly self-test must reside in the FACP with EVS integration.

601.6.1.10.16.20.1 The weekly self-test must report abnormal conditions audibly, visibly, and via a printed report.

Commentary: Sound Transit will accept a saved PDF report in lieu of a physical printer and printed report if acceptable to the AHJ.

Figure 601-4: Fan and Damper Control



601.6.1.10.16.21 Where a protected premises (building) fire alarm panel is not required, elevator recall must be controlled by a UL 864 listed dedicated function fire alarm system as defined by NFPA 72. The same system must also monitor automatic sprinkler systems and emergency radio systems and other systems where provided.

601.6.1.11 Gas/Refrigerant Detection/Mitigation Systems

601.6.1.11.1 Gas detection systems must meet the requirements of IFC 916, IFC Chapter 12, and IMC 502.

601.6.1.11.2 Provide a controlled ventilation system using input from gas sensors to respond to a gas detection rather than providing continuous ventilation.

601.6.1.11.3 Gas detection systems must be monitored for alarm conditions by the building management system.

601.6.1.11.4 Gas detection system must be monitored for trouble by the building fire alarm system. See Figure 601-5.

601.6.1.11.5 Gas detection systems alarms must not be monitored by the fire alarm system unless specifically required by the AHJ.

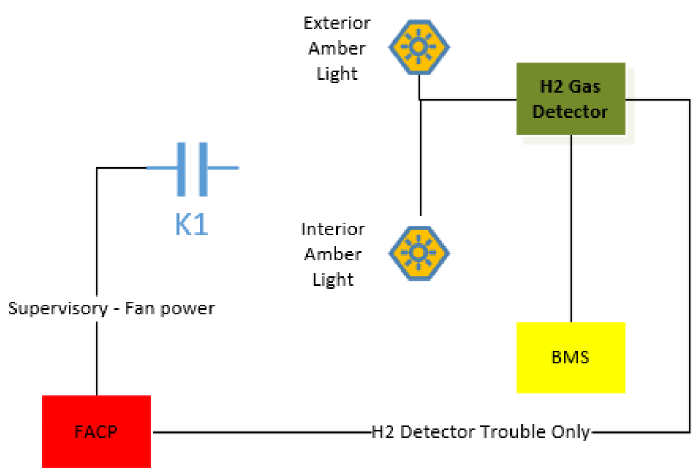
601.6.1.11.6 Gas detection systems must be provided with standby power for 2 hours when required by the IFC.

601.6.1.11.7 Amber visual notification devices and associated signs must be provided on both sides of the room entry door.

Power for fans on standby that respond to hydrogen gas (H2) detection must be monitored by the fire alarm system. See Set 1003 Mechanical – HVAC for location and other requirements. See Figure 601-5.

Commentary: Gas detection systems are typically required for hydrogen gas generated from lead-acid batteries associated with energy storage systems but may be necessary for other systems.

Figure 601-5: Hydrogen Gas Detection



601.6.1.11.8 Locations designated for food trucks must be evaluated to prevent fumes and vapors from entering building openings and HVAC intakes.

601.6.1.11.9 Refrigerant detection systems must be in accordance with IFC 605. Detectors must be connected to a UL 864 listed local detection and control panel (a subpanel to the building FACP) that provides audible alarm, visual alarm, ventilation control, and warning devices at the machinery room entry door. The local panel must be connected to and monitored by the building fire alarm system.

Commentary: Refrigerant detection systems are not common to Sound Transit facilities but may be necessary for some operations & maintenance facilities. See sustainability requirements for information on acceptable types of refrigerants.

601.6.1.11.10 An engineering analysis must be conducted to identify hazardous electrical locations per the NEC on permit drawings. MEP consultants must coordinate with the architect to illustrate or reference the classified areas on the architectural code sheets.

601.6.1.12 Emergency communications

601.6.1.12.1 Emergency communication systems must meet the IBC, IFC, NEC, NFPA 72, NFPA 130, NFPA 1221, ANSI A17.1 and other standards when required. An evaluation of applicable codes and standards must be included as an element of a code study.

601.6.1.12.2 Emergency communication system must meet survivability requirements of NFPA 72.

Commentary: Table 601-4 is intended to serve as a guide to help ensure all applicable codes are identified and followed. Confirm requirements with the AHJ.

Table 601-4: Emergency Communication System Codes

System	Function	Applicable Code/Standards
Public Address System	One-way communication within station	NFPA 130, IFC, NEC, NFPA 72,
Fire Alarm System EVACS	One-way communication within station	IFC, NEC, NFPA 72, NFPA 130
Variable Message Sign	One-way communication within station	NEC, NFPA 72, NFPA 130
Area of Refuge PETS	Two-way communication with LCC	IBC, NEC, NFPA 72, NFPA 130
PETS – other than area of refuge	Two-way communication with LCC	NFPA 130, NEC, NFPA 72
Garage Customer Emergency Phones (CES)	Two-way communication with SOC (SECURITY OPERATIONS CENTER)	NEC, NFPA 72
Elevator Lobby Phones (PETS/CES)	Two-way communication with LCC, SOC or central station	IBC, NEC, NFPA 72, NFPA 130
ETELS	Two-way communication with other ETELS and the LCC	NFPA 130, NEC, NFPA 72,
Elevator Cab Intercom	Two-way communication with Lobby	ASME A17.1
Elevator Cab Phone	Two-way communication with SOC or LCC and central station	IFC, NEC, NFPA 72, NFPA 130
Public Exchange Phones	Two-way communication with any other PBX Phone	IBC, Operational Communication Set 300
Emergency Radio Enhancement (BDA/DAS)	Two-way communication within building or station	IFC, NEC, NFPA 72, NFPA 130, NFPA 1221
SCADA Network Supporting Emergency Communication Systems	Infrastructure for monitoring and control of data within a station, station to station and LCC	IFC, NEC, NFPA 72, NFPA 130

601.6.1.12.3 PA system used for fire alarm EVACS (FACP/PA hybrid design) must meet NFPA 72 and NFPA 130 requirements for fire alarm systems and emergency communications systems.

601.6.1.12.4 See Set 302 Telephony, for requirements for ETELS, CES, PETS, and other phone systems.

601.6.1.12.5 Station platform VMSs (aka textual visual appliances per NFPA 72) must meet ANSI A117.1, NFPA 72 and PIMS Set 1102. Emergency power for 2 hours must be provided as outlined in NFPA 72. Emergency messages must be static; scrolling messages are not allowed.

601.6.1.12.6 VMSs must be secondary to fire alarm visual alarms (strobes) but may be primary visual notification when strobe lights are expected to be less effective due to location, high outdoor ambient light, and/or canopies with glazing. AHJ approval must be obtained for VMS as primary visual notification.

601.6.1.12.7 All building/structure communication systems except PBX phones must continue to operate upon loss of primary facility power. See categorization of power loads in Set series 1000 Mechanical-Electrical and Buildings Systems for requirements.

601.6.1.12.8 Emergency communications system must meet NFPA 72, and NFPA 130 requirements for survivability.

601.6.1.13 Means of Egress Illumination and Exit Signs

601.6.1.13.1 Means of egress illumination and exit signs must meet the IBC 1013 and NFPA 130. See Set 1007 Electrical Lighting for additional requirements.

601.6.1.14 Fire Hydrants:

601.6.1.14.1 Public and private hydrants must be installed in accordance with the IFC, local amendments to the IFC, and local municipal code.

601.6.1.14.2 When a portion of a station, building or facility is over 400 feet from a public hydrant on-site private fire hydrants must be provided along fire access roads at a spacing not to exceed 350 feet to serving buildings and train yards.

601.6.1.14.3 Water supply must provide at least 1,500 gallons at 20 pounds per square inch residual pressure. A flow test within five years or hydraulic analysis must be performed to confirm the minimum flow is met.

601.6.1.14.4 Fire hydrants must be installed with a service gate valve on the horizontal underground pipe serving the hydrant. The gate valve must be UL listed and have a 2-inch-square operating nut accessible through a protective cover (aka curb box valve).

601.6.1.14.5 Hydrants must be separated from any fixed object by 4 feet, except hydrant guard posts. Guard posts must be provided around hydrants not protected by curbs.

601.6.1.14.6 Guard posts must be steel filled with concrete, or concrete (minimum 8-inch diameter). Posts must be 3 feet from the center of the hydrant and not in a direct line with discharge ports.

601.6.1.14.7 Hydrants must be in plain view of 50 feet in the line of fire vehicle approach. Landscaping near fire hydrants, FDC, and post indicator valves must not obstruct access to, or visibility from, the fire apparatus access road.

601.6.1.14.8 Hydrants must be installed in accordance with NFPA 24.

601.6.1.14.9 New hydrants must be flow tested with result verified to meet flow requirements.

601.6.1.15 Automatic Sprinkler Systems:

601.6.1.15.1 Automatic sprinkler systems must meet the IBC, IFC, NFPA 13, NFPA 130, and be UL listed and FM approved.

601.6.1.15.2 See Set 720 Building Structures for seismic importance factor requirements.

601.6.1.15.3 Design drawings must be sealed by a licensed professional engineer. Drawings must establish the engineer's objectives including scope of work, applicable codes, occupancy, hazard classification, and the type of systems to be installed.

601.6.1.15.4 The licensed engineer must review shop drawings and calculations prepared by a qualified engineering technician (NICET or equal) for compliance with the engineer's design and specification.

601.6.1.15.5 The licensed engineer and technician together must provide construction monitoring services.

601.6.1.15.6 Installing contractors must have at least one permanent employee with a Washington State Level 3 Certificate of Competency.

601.6.1.15.7 Sprinkler fitters must meet the conditions of WAC 212-80.

601.6.1.15.8 See Set 801 Architectural Materials, Elements, and Furnishings for painting of pipe and others architectural requirements.

601.6.1.15.9 Backflow preventer must be in the sprinkler riser room. Horizontal, vertical, or N-pattern oriented backflow devices are permitted. Locating the backflow preventer in a vault is permitted when space constraints are documented.

601.6.1.15.10 Backflow preventers must be accessible for testing and maintenance from the room floor without a portable ladder.

601.6.1.15.11 Sprinkler heads must not be located directly over the dedicated electrical space of electrical panels as defined by the NEC.

601.6.1.15.12 Vault valves must be provided with a chain and lock but need not but supervised by the fire alarm system unless required by the AHJ.

601.6.1.15.13 When provided, post indicator valves must be locked and supervised by the fire alarm system where provided.

601.6.1.15.14 Pre-action systems must not be used unless specifically approved by the FLS 601 Set owner

601.6.1.15.15 Antifreeze systems are not allowed.

601.6.1.15.16 Heat trace/insulation system must not be used except where a lead-in or water service to a heated location is not practical.

601.6.1.15.17 Heat trace systems must be UL 512A listed.

601.6.1.15.18 Where more than one dry-pipe system is in a riser room, a single tank-mounted compressor must serve all dry-pipe valves.

601.6.1.15.19 Tank-mounted compressors must be provided for dry-pipe systems.

601.6.1.15.19.1 Exception: Tank-less riser-mounted compressors for rooms/areas with only one dry-pipe system where there is lack of space for a tank-mounted air compressor.

601.6.1.15.20 Tank-mounted compressors must be limited to serve up to eight dry-pipe systems or 5,000 gallons total.

601.6.1.15.21 Compressors must be rated fire protection (UL 1450 VDUR), rated below 65 dBA when operating, and powered by a hard-wired dedicated circuit with a local disconnect switch per NEC 430.102(B). See the Set series 1000 Mechanical-Electrical and Buildings Systems for motor requirements.

601.6.1.15.22 Main drains for sprinkler systems must discharge to the sanitary sewer and be designed for a flow main drain test per NFPA 25 without resulting in internal flooding or landscape erosion. See Set 1002 Mechanical-Plumbing for additional requirements.

601.6.1.15.23 Main drains must be ganged in riser rooms with multiple systems.

Commentary: This provision is to allow for annual full-flow 2-inch drain tests, which can discharge up to 300 gallons per minute.

601.6.1.15.24 Wet pipe sprinkler systems automatic air vent to help reduce internal pipe corrosion must be accessible.

601.6.1.15.25 Low point drains and inspector’s test connections must be in non-public areas or provided with locks.

601.6.1.15.26 Unless prohibited by the local AHJ, dry-pipe system low point auxiliary drains (drum drips) located in areas accessible to the public must be located at 8 feet above the floor to prevent tampering and to reduce patron injury from obstruction in the circulating path. Drum drips must be equipped with ball valves and a plug at the drain opening. Alternately, locate drum drips at 3 to 5 feet above the floor and provide locking ball valves and padlocks with ST Operations standard key.

Commentary: NFPA 13 requires these devices to be accessible. The design team must obtain concurrence from the AHJ that access using a small portable ladder is permissible.

601.6.1.15.27 In rooms protected by clean agent fire suppression and separated from other areas with 2-hour fire rated construction automatic sprinkler protection must not be provided unless required by the AHJ. AHJ concurrence must be obtained by the design team.

601.6.1.15.28 Dry-pipe and pre-action systems must be constructed of schedule 40 hot-dipped galvanized steel pipe with cut-groove or threaded hot-dipped galvanized couplings and fittings. Hangers and bracing must be electro- or hot dip galvanized. Flange connections must be used where necessary for dissimilar metals.

601.6.1.15.28.1 Alternately, dry-pipe and pre-action systems must be constructed of schedule 40 black steel pipe with painted exterior and cut-groove or threaded ductile iron couplings and fittings and a corrosion prevention system acceptable to the Set 601 Fire/Life Safety owner. Hangers and bracing must be electro-galvanized. Flange connections must be used where necessary for dissimilar metals.

601.6.1.15.29 Shop or field cuts following galvanic coating are not allowed for galvanized steel pipe except for mechanical tees when permitted by the specification.

601.6.1.15.30 Wet-pipe systems must be constructed of schedule 10, or heavier, steel pipe with ductile iron or cast-iron roll-groove, cut-groove or threaded couplings and fittings.

601.6.1.15.31 Wet-pipe systems, (including pipe, couplings, fittings, supports and braces) exposed to direct- or wind-blown weather must be externally galvanized.

601.6.1.15.32 Fire pumps must be in accordance with the IFC, NFPA 20, and NFPA 110.

601.6.1.15.33 Fire pumps must be horizontal split-case or vertical in-line centrifugal fire pump with electric motor driver.

601.6.1.15.34 Design teams must perform a preliminary hydraulic calculation and develop a written report when it is unclear if a pump will be required. This analysis must be performed by a qualify licensed engineer.

Commentary: Due to initial capital cost and long-term operation and maintenance cost Sound Transit prefers to avoid fire pumps when possible.

601.6.1.15.35 A tap ahead of the main electrical service or a separate electrical service (rather than a fixed standby generator) must be used for areas where utility power has been determined to be reliable by the AHJ.

601.6.1.15.36 A test header with external hose connections must be provided for annual full-flow fire pump testing. Test loops are not allowed.

601.6.1.15.37 The fire alarm control panel must monitor the fire pump and include valve supervision, controller connected to alternate source, controller off/manual, controller trouble, and pump running indication.

601.6.1.16 Fire Department Connections

601.6.1.16.1 FDCs must be installed in accordance with the IFC, NFPA 13, NFPA 14, NFPA 20, and NFPA 130.

601.6.1.16.2 FDCs must be within 100 feet of a fire hydrant or closer if required by the AHJ.

Commentary: Sound Transit prefers hydrants to be located on the same side of the street for major arterials (four roadway lanes wide or greater).

601.6.1.16.3 FDCs manifolds must be brass, painted ductile iron, or Schedule 40 (or greater) hot-dipped galvanized steel with 2.5-inch brass snoots, or aluminum Storz connection depending upon local requirements.

601.6.1.16.3.1 Brass Manifolds: Brass body manifolds are preferred but must be installed in a manner that is not subject to theft. Mechanical couplings/fittings must be at least 10 feet above grade to help prevent theft. Alternately, specify painted ductile iron manifolds. Brass snoots must be painted red and secured with lock-tight or other means to prevent theft. The FDC body must be connected by threaded piping.

601.6.1.16.4 FDC hose plugs must be 2.5-inch threaded red plastic with corrosion-resistant metal chains unless Knox locking plugs, or other plug types, are required by the AHJ.

601.6.1.16.5 For Storz FDCs, an aluminum cap and identification plate must be provided.

601.6.1.16.6 Brass plugs, non-threaded plastic caps/plates, and steel caps/plates are theft prone and high maintenance and must not be provided.

601.6.1.16.7 Piping between the FDC and the check valve must be schedule 40 hot-dipped galvanized steel or cement lined ductile iron.

601.6.1.16.8 Automatic drains must be provided at low points associated with fire department connections. For FDC serving underground pipe, an automatic drain valve with gravel basin sized for the applicable pipe segment must be provided.

601.6.1.16.9 See architectural requirements for location and finish of FDCs.

601.6.1.16.10 FDC signs must meet the IFC, NFPA 13, and NFPA 14. Signs must be durable and steel or aluminum with UV resistant paint. Signs must have white letters and a red background and be securely fastened to a flat surface where practical and use durable corrosion resistant pipe clamps elsewhere. Signs are subject to AHJ review and approval.

Figure 601-6: Sign Examples – Guideway Dry Standpipe Multi-zone

GUIDEWAY MANUAL DRY STANDPIPE
SOUTH to WILBURTON STATION
HOSE VALVE 1-21: PUMP AT 185 PSI
HOSE VALVE 21-40: PUMP AT 225 PSI
E12-FDC-01

Figure 601-7: Sign Examples – Guideway Dry Standpipe Single-zone

GUIDEWAY MANUAL DRY STANDPIPE
NORTH TO S. DEAN STREET
PUMP AT 225 PSI
E01-FDC-02

Figure 601-8: Sign Examples – Garage and Station Sprinklers/Standpipes

STATION **MANUAL DRY STANDPIPE AND AUTOSPKR** **N09-FDC-01**

601.6.1.16.11 FDCs must be mounted within 18 to 48 inches of the walking surface. The entire connection component of the FDC must be within 18 to 48 inches of the walking surface. Provide cane detection if the FDC protrudes more than 4 inches when required by ICC A117.1.

Commentary: Protruding objects that are less than 27 inches AFF can be detected by cane by persons with visual disabilities. Locating the FDC above 27 inch requires a means of detection that does not affect fire department access and use.

601.6.1.17 Standpipes

601.6.1.17.1 Standpipes must be in accordance with the IFC, NFPA 13, NFPA 14, and NFPA 24.

601.6.1.17.2 For buildings and stations standpipes must be designed for a maximum operating pressure of 175 pounds per square inch. Pressure reducing hose valves and devices must not be used unless necessary due to building height.

601.6.1.17.3 Installing contractors must possess a Washington State Level 3 License or NICET Level 3 certification.

601.6.1.17.4 Shop drawings and final calculations must be developed by NICET Certified sprinkler contractor. Shop drawings and calculations must be stamped by a certified technician.

601.6.1.17.5 Standpipes must be above ground type except for track locations where the standpipe may be buried. An underground standpipe located under a building slab or station platform is not permitted.

601.6.1.17.6 All standpipe control valves, except sectional valves in tunnels and along elevated guideways, must be electronically supervised. Unsupervised sectional valves must be locked.

601.6.1.17.7 Dry standpipes systems must be provided with 2-inch main drains and drain completely in less than 30 minutes.

601.6.1.17.8 Main drains, auxiliary drains, and automatic drains must be in accordance with NFPA 14.

601.6.1.17.9 Automatic drains, when used as the only means to drain a trapped segment of pipe, must be limited to 10-gallon capacity and applications where the weight-induced water pressure does not exceed the limit of the automatic drain (typically 7 to 12 psi)..

601.6.1.17.10 Manual drain valves accessible to the public must be lockable.

601.6.1.17.11 An isolation valve must be provided at the base of each standpipe in accordance with NFPA 14.

601.6.1.17.12 Expansion devices at structural expansion joints must be provided along the guideway.

601.6.1.17.13 Axial (in-line) expansion joints made up of multiple flexible couplings installed in series with short nipples are permitted when supported by a hanger assembly.

601.6.1.17.14 Expansion joint must not trap water within the expansion joint itself or in adjacent piping.

601.6.1.17.15 Dry standpipe systems must be corrosion resistant and constructed of schedule 40 hot-dipped galvanized steel pipe with cut-groove or threaded hot-dipped galvanized couplings and fittings. Flange connections must be used where necessary for dissimilar metals and other needs.

601.6.1.17.16 Hangers, bracing, and supports use in unconditioned space must be hot-dipped galvanized.

601.6.1.17.17 Standpipe systems must be fully tested and include flow testing, per NFPA 14.

601.6.1.17.17.1 Contractors must provide a temporary pump for this test and fill the system at the design fill rate and flow at the design flow rate.

Commentary. Sound Transit requires flow testing even in cases where the AHJ may waive the test. The Sound Transit naming and numbering standard must be followed for fire hose valves tags.

601.6.1.17.18 Fire hose valve caps must be 2.5-inch threaded red plastic with corrosion-resistant metal chain unless Knox locking plugs are required by the AHJ. Brass caps are theft prone and not allowed.

601.6.1.17.19 Additional Requirements for Tunnel and Elevated Guideway Standpipe.

601.6.1.17.19.1 Tunnel and guideway standpipe systems are complex and must be designed by a licensed fire protection engineer working with a licensed structural engineer as engineers of record to develop design drawings and specification. A design that includes key design parameters and equipment must be included in the drawings and associated specification.

601.6.1.17.19.2 The licensed engineers must produce a basis of design and stamped IFC drawings.

601.6.1.17.19.3 A formal letter of concurrence with the AHJs must account for access locations, fire flows (volume and residual pressure), flow location (midsegment or end), maximum inlet pressure, hydraulic fill time assumptions, hose valve arrangement, segment lengths, fire access points, and approval of non-listed components for example.

601.6.1.17.19.4 Shop drawings and calculations must be completed and stamped by the engineering technician.

601.6.1.17.19.5 The designer must confirm the design conforms to key parameters through submittal review (i.e., shop drawing, calculations, and products) and perform field inspections to verify the system was installed in accordance with approved drawings. A specification specific to tunnel and elevated guideway standpipe systems must be developed.

601.6.1.17.19.6 The design must account for the following. These elements of the design must not be delegated to an engineering technician (e.g., NICET certified designers). An alternate design proposed by the engineering technician that deviates substantially from the engineer-of-record (EOR) design is not permitted.

601.6.1.17.19.6.1 Fire department access

601.6.1.17.19.6.2 FDC locations

601.6.1.17.19.6.3 Hydrant locations

601.6.1.17.19.6.4 Fire flow criteria.

601.6.1.17.19.6.5 Hydraulic design

601.6.1.17.19.6.6 Fill time

601.6.1.17.19.6.7 Drainage

601.6.1.17.19.6.8 Vent size/location

601.6.1.17.19.6.9 Component pressure limitations

601.6.1.17.19.6.10 Fire department apparatus flow/pressure constraints

601.6.1.17.19.6.11 Thermal expansion

601.6.1.17.19.6.12 Water hammer

601.6.1.17.19.6.13 Thrust forces

601.6.1.17.19.6.14 Environmental induced corrosion

601.6.1.17.19.6.15 Dissimilar metal related corrosion

601.6.1.17.19.6.16 Seismic restraint

601.6.1.17.19.6.17 Train clearance envelope

601.6.1.17.19.6.18 Emergency walkway width

601.6.1.17.19.6.19 Trainway curvature

601.6.1.17.19.6.20 Fire hose valves

601.6.1.17.19.6.21 Supports

601.6.1.17.19.6.22 Axial and lateral movement at structural expansion joints

601.6.1.17.19.6.23 UL listed components

601.6.1.17.19.6.24 Product availability

601.6.1.17.19.6.25 Buy America requirements.

601.6.1.17.19.7 The system must be design for a maximum operating pressure of 300 pounds per square inch.

601.6.1.17.19.8 Thermal expansion must be based upon ASHRAE Climate Design Condition data for 50-year extreme temperature for Seattle, King County Airport and Paine Field, and heat gain through solar radiation. For exposed standpipes a temperature range of 10 to 140 degrees Fahrenheit or greater must be used.

Commentary: guideway standpipe systems are directly exposed to the sun and will gain heat through solar radiation.

601.6.1.17.19.9 The designer must also account for reduction in coupling capacity when using couplings for angular deflection in addition to linear thermal movement.

601.6.1.17.19.10 When required for hydraulics, welded schedule 10 stainless steel pipe or roll groove stainless steel couplings must be used instead of schedule 40 hot-dipped galvanized steel pipe. Flange connections must be used where necessary for dissimilar metals.

601.6.1.17.20 Hose valves must be provided every 200 feet along the guideway, or as required by the AHJ.

601.6.1.17.21 Angle fire hose valves connected to the top of the horizontal standpipe must be provided.

601.6.1.17.22 Hose valve must be the non-pressure reducing type.

601.6.1.17.23 Hydraulic demand must be 250 gallons per minute from each of the three most hydraulically remote hose valves with 100 pounds per square inch residual pressure at the hose valve per NFPA 14 unless otherwise required by the AHJ.

Commentary: To clarify, the remote hose vales are to be at the far end of the standpipe segment. With formal written approval from the AHJ hydraulic calculations may be to the hydraulic midpoint rather than the far end of the standpipe.

601.6.1.17.24 Standpipes must be fed from two directions.

601.6.1.17.24.1 Exception: Dead ends for tail track up to 800 feet long may be fed from one FDC when approved by the AHJ.

601.6.1.17.25 Calculations must be performed in both directions to determine inlet pressure and flow for each FDC.

601.6.1.17.26 To calculate the system fill time, 1,000 gallons per minute must be used unless a different fill rate is required by the AHJ.

601.6.1.17.27 Air release/vacuum valves must be provided in accordance with NFPA 130. Valves must be sized and located through engineering analysis so that there is negligible back pressure when the system is being filled.

Commentary: A best practice is to locate and size release valves so fill time is not reduced but to provide some back pressure to reduce water hammer.

601.6.1.17.28 A normally open sectional valve must be provided every 800 feet per NFPA 130 unless documented in a formal agreement they are not required. A lock and chain, but no tamper switch or fire alarm monitoring, must be provided.

601.6.1.17.29 Air release vacuum valves must be UL listed, or FM approved for fire service, or specifically approved by the AHJ. The following products are acceptable to Sound Transit, but AHJ concurrence must be obtained:

601.6.1.17.29.1 Claval 35t

601.6.1.17.29.2 Valmatic 100s

Commentary: These air release/vacuum valves are not UL listed or FM approved for fire service. AHJ approval must be obtained to use them. Products must be durable.

601.6.1.18 Underground Fire Service Mains

601.6.1.18.1 The following applies to belowground piping for fire protection and standpipe systems:

601.6.1.18.1.1 Below grade piping must be installed according to the IFC and NFPA 24.

601.6.1.18.1.2 Installing contractors must have at least one permanent employee with a Washington State Level 3 or Level U License.

601.6.1.18.1.3 Piping must be flushed in accordance with NFPA 24 prior to connection to aboveground piping.

601.6.1.18.1.4 At least one form of restraint must be provided; thrust blocks and restrained joint systems are acceptable.

601.6.1.18.2 Below grade and buried piping, located within 50 feet or under the trainway, must be cement-lined ductile iron and protected for corrosion using factory applied zinc exterior coating with a biocide enhanced polyethylene encasement, or equal.

601.6.1.18.3 Below grade and buried piping located beyond the trainway must be cement-lined ductile iron with polyethylene encasement, or equal, as appropriate for the local conditions to meet the required life cycle.

601.6.1.18.4 Piping passing under the trainway must be provided in a sleeve with support spacers and mechanical sleeve seals at sleeve openings.

601.6.1.18.5 See Set 902 Utilities for additional requirements.

601.6.1.19 Portable Fire Extinguishers:

601.6.1.19.1 The following fire extinguisher types are applicable to Sound Transit Facilities

Table 601-5: Types of Fire Extinguishers

ST Fire Extinguisher Designation	Fire Extinguisher Type	Agent Weight (approximate, varies by manufacturer)	Agent	Rating (minimum)
1	Dry Chemical Stored Pressure	5	Ammonium Phosphate	2A10BC
2	Dry Chemical Stored Pressure	6	Ammonium Phosphate	3A40BC
3	Dry Chemical Stored Pressure	10	Ammonium Phosphate	4A80BC
4	Carbon Dioxide	10	Carbon Dioxide	10BC

601.6.1.19.2 Fire extinguishers must meet the IFC, NFPA 10, NFPA 130 and ANSI A17.1.

601.6.1.19.3 Fire extinguisher location must be based upon fire extinguisher type and travel distance. Layout must apply travel distances considering walls, door, and obstructions (rather than drawing circles).

601.6.1.19.4 , Fire extinguishers must be accessible without accessing a secure room.

Commentary: Placing fire extinguishers in common spaces (hallways for example) can serve many small rooms.

601.6.1.19.5 Dry chemical and carbon dioxide fire extinguishers are to be of rugged design with a minimum five-year manufacturer's warranty. All other fire extinguishers are to be of a rugged design with a one-year manufacturer's warranty.

601.6.1.19.6 Dry chemical fire extinguishers must be of drawn-steel cylinders, durable high-gloss powder paint, red, with hose and nozzle, brass or aluminum valve body and stainless steel or aluminum handle and lever.

601.6.1.19.7 Carbon dioxide fire extinguishers must be of aluminum cylinders containers, durable high-gloss powder paint, red, with hose and horn, metal valve body and stainless steel or aluminum handle and lever.

601.6.1.19.8 Fire extinguishers are to be mounted in surface or recessed cabinets where required in public spaces and surface mounted in other locations. See standard drawings for details.

601.6.1.19.9 Fire extinguishers cabinets must be powder coat finish, durable steel cabinet, steel door with acrylic viewing window, and continuous hinge, and tamper resistance door.

601.6.1.19.10 Fire extinguisher cabinets must have a five-year warranty.

601.6.1.19.11 Fire rated cabinets must be specified for recessed application in a fire rated wall, when required.

601.6.1.19.12 Portable fire extinguishers must meet the requirements of the IFC, NFPA 10 and be UL listed.

601.6.1.19.13 Durable fire extinguisher signs must be provided where the extinguisher is not readily visible.

Commentary: A "Fire Extinguisher" sign placed on the wall above the fire extinguisher cabinets if often necessary in parking garages and in locations where the unit is visually obstructed by equipment and furnishings.

601.6.1.20 Clean Agent Systems

601.6.1.20.1 The vender must be a locally authorized dealer with a proven record of performance and capable of providing emergency services 24 hours a day 7 days a week.

601.6.1.20.2 Clean agent systems for protected areas must meet the requirements of the IFC, NFPA 2001, and FM Data Sheet 4-9 for a total flooding system.

601.6.1.20.3 Clean agents must be either 3M Novec 1230 (C6-perflouroketone) or equal as approved by the Fire/Life Safety Set 601 owner.

601.6.1.20.4 Where space is limited in the protected room, agent bottle(s) must be in an adjacent secured room, if available. Locate and arrange agent cylinder for easy access and replacement.

601.6.1.20.5 The clean agent releasing panel must be UL 864 listed and FM approved addressable releasing panel with 90-hour standby power supply with a minimum 10-minute alarm and activation current.

601.6.1.20.6 Clean agent systems must be designed to function (agent release and room containment) without relying on the fire alarm system, building management system or other systems.

601.6.1.20.7 The clean agent releasing panel must be located in the protected room, outside of the room adjacent to the door, or in an adjacent room.

601.6.1.20.8 A single clean agent releasing system may protect up to two contiguous rooms.

601.6.1.20.9 When two rooms are protected with one clean agent system, a single zone must be used if the rooms communicate, otherwise provide two zones.

601.6.1.20.10 If more than two rooms require protection, or the rooms are not contiguous, separate clean agent systems must be provided.

601.6.1.20.11 Wiring must be Class B per NFPA 72 using 16 AWG or larger solid copper wire.

601.6.1.20.12 Fire detection will utilize cross-zoned photoelectric smoke detectors with the first detector activation as a pre-alarm condition. Any two activated detectors must initiate the release sequence. The sequence of operation must be in accordance with control drawings.

601.6.1.20.13 Doors, dampers, and other controlled equipment necessary to enclose the area subject to total flooding must be controlled directly from the clean agent releasing panel.

601.6.1.20.13.1 Exception: Local HVAC shutdown that may be controlled indirectly via the BMS as allowed by the IMC for small systems.

601.6.1.20.14 A keyed maintenance lockout switch must be provided adjacent to each releasing panel that opens the agent releasing circuit.

Commentary: This is to accommodate prevent accidental agent release. Panel based bypass button and switches are not a substitute for this keyed switch.

601.6.1.20.15 Manual release and abort stations must be located together but separated by at least 18 inches from room light switches and other unrelated control interfaces to help prevent accidental agent release.

601.6.1.20.16 The abort switch must be dead-man style stop requiring constant manual pressure and not reset time delay.

601.6.1.20.17 Smoke dampers must close upon first detection.

601.6.1.20.18 Smoke dampers must be provided at walls, floors, ceilings, and roofs to seal off the room, or rooms, where the clean agent system is intended to protect.

601.6.1.20.19 Dampers used to seal the room must be UL 555 S listed with a Class II leakage rate that fail closed upon loss of power.

601.6.1.20.20 If fire dampers are required combination fire smoke dampers may be provided but the fire damper retaining angles flange (not the annular space within the wall) must be sealed with caulk to reduce the leakage rate around the fire/smoke damper assembly.

601.6.1.20.21 Doors must be normally closed, self-closing, and provided with smoke gaskets and a sweep to seal tight when closed.

601.6.1.20.22 A room pressurization integrity test using a door fan system specifically design for the purpose must be performed in accordance with NFPA 2001.

601.6.1.20.23 The room must be sealed to at wall-floor interface, wall-ceiling interface, conduits/electrical boxes, and other wall, floor, and ceiling penetrations. This work must be accounted for in the design and an inspection performed to confirm quality as the facility is constructed and at a time when visual inspection is possible. Increasing the volume of agent or other mitigation for an inadequate sealed room is not permitted.

601.6.1.20.24 Calculation to show design concentration is met must be provided.

601.6.1.20.25 Room pressure during agent release must be calculated to determine if a relief vent is needed.

601.6.1.20.26 The entire system must include a warranty of at least two years.

601.6.1.20.27 Visual notification devices must have a blue lens.

601.6.1.21 Emergency ventilation/smoke control

601.6.1.21.1 emergency ventilation and smoke control must be designed to meet NFPA 130, and the IBC where applicable.

Commentary: The IBC and NFPA 130 are both applicable to stations. NFPA 130 is applicable to enclosed trainways but in some jurisdictions elements of the IBC may also apply. Confer with the local AHJ and obtain confirmation on this subject during preliminary design.

601.6.2 Fire/Life Safety Sites and Locations

601.6.2.1 Elevated, At-grade and other Limited Access Guideway

601.6.2.1.1 This section outlines specific requirements associated with elevated, at-grade, and other limited access guideways. Section 601.6.1 Fire/Life Safety Elements outlines general requirements that also apply.

601.6.2.1.2 Emergency Access / Site

601.6.2.1.2.1 Provide emergency access in accordance with NFPA 130 and 601.6.1.

601.6.2.1.2.2 Emergency access must be through stations, gates located adjacent at-grade points, stairs/ramps, streets using fixed ladder or ladder truck from streets, or as required by the AHJ. Designer must coordinate with Sound Transit and the AHJ and develop a letter of concurrence to formally define emergency access points.

601.6.2.1.2.3 Emergency access using gates must include an emergency access pathway continuous from the street to the trainway. See Section 601.6.1 for specific requirements.

601.6.2.1.3 Openings in the guardrail for fire department access to the elevated guideway—via ladder truck, for example—must be at least 48 inches wide and protected with hot dipped galvanized steel chain or stainless-steel cable that meets WAC 296-880-40005 requirements for fall protection. See Standard Drawing STD-SWD104 for additional requirements.

601.6.2.1.4 Permanent structures are not permitted within the easement area unless justified with a fire hazard analysis. The storage of hazardous materials is not permitted within the easement area. No use is allowed within feet of columns and girders. See Standard Drawings for additional information.

601.6.2.1.5 Construction Type/Finishes/Furnishings

601.6.2.1.5.1 Elevated guideways must be of noncombustible materials as outlined in NFPA 130. Combustible materials must conform to IBC Chapter 6.

601.6.2.1.5.2 Elevated walkway material must be non-combustible as required by NFPA 130. Fiberglass reinforced polymer materials that have an ASTM E84 Class A flame spread rating and an ASTM D635 HB classification are acceptable and considered by Sound Transit to meet NFPA 130 for open walkway surface material (non-tunnel) but must be specifically approved by the local AHJ. See Track Set 522 for additional requirements.

601.6.2.1.6 Fire Separations

601.6.2.1.6.1 See NFPA 130 for requirements.

601.6.2.1.7 FCCs/FCRs/ERERs (Not Used)

601.6.2.1.8 Means of Egress

601.6.2.1.8.1 See NFPA 130 for requirements.

601.6.2.1.8.2 A platform end gate must be provided where the emergency walkway connects to the platform. See 606.6.1.6.5.

601.6.2.1.8.3 Stairs connecting the emergency walkway to the station must be at least 36 inches wide and provided with a guard and handrail on both sides per the IBC.

601.6.2.1.9 Exits/Point of Safety

601.6.2.1.9.1 Emergency walkways must terminate at outlined in NFPA 130 at the station platform, exit stair, other approved exit, or point of safety. See 601.6.1.

601.6.2.1.10 Emergency Walkways

601.6.2.1.10.1 Elevated guideways must be provided with an emergency walkway that serves both tracks and meets the requirements of NFPA 130.See 601.6.1 for additional requirements.

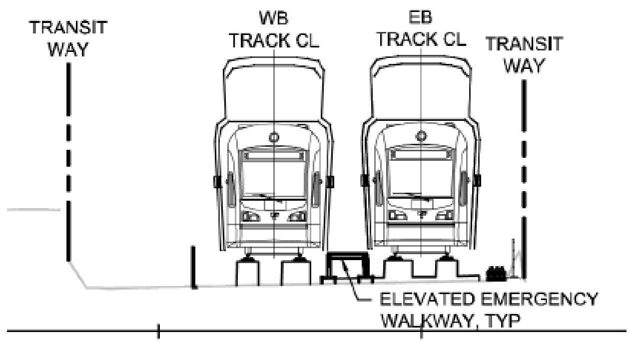
601.6.2.1.10.2 The minimum unobstructed width of egress within or directly adjacent to the trainway, as measured to the static light rail envelope, must be in accordance with NFPA 130.

601.6.2.1.10.3 Pedestrian swing gates for trainway crossings, when provided, must meet the requirements for platform end gates. See 601.6.1.6.5.

601.6.2.1.10.4 For at-grade trainways located on roadways includes floating bridges the distance from the LRV floor to the adjacent walking surface must be less than 36 inches. When the distance exceeds 36 inches, a raised emergency walkway must be provided to reduce the vertical distance from the LRV floor to the emergency walkway to 7 inches. See Figure 601-9.

Commentary: Passengers may exit the train to grade and walk to the nearest station or be transferred to another train, if necessary. For ballasted at-grade trainways the distance from the LRV floor to the top of the track ballast is approximately 20 inches. Where plinths or other structures are formed on top of roadways or guideways the distance from the LRV floor to the walking surface may exceed a practical vertical distance for unassisted egress from the train. Design that exceeds 36 inches make it impractical for passengers to safely exit and must be avoided or mitigated with a raised emergency walkway or other means.

Figure 601-9: Emergency Walkway



601.6.2.1.10.5 The portion of the ballasted trainway that serves as the emergency egress pathway must be at least 30 inches wide, nominally flat, and suitable for walking to function effectively as an emergency walkway. See Set 522 for ballast material.

601.6.2.1.11 Guardrails/handrails

601.6.2.1.11.1 Guards along the elevated guideway must be provided where required by NFPA 130 and WAC 296-880-40005. The guard must be 42 inches high measured from the walking surface. See Track Set 522 and Standard Drawings STD-SWD100 for additional requirements.

601.6.2.1.11.2 Guards must be provided at stairs with an unprotected edge when the distance from the top landing is more than 30 inches measured vertically to the surface below.

Commentary: Evaluate this condition where the emergency walkway terminates at the station platform and other locations as needed.

601.6.2.1.11.3 Handrails must be provided on both sides of stairs.

601.6.2.1.12 Fire Alarm/Detection (Not Used)

601.6.2.1.13 Gas/Refrigeration Detection (Not Used)

601.6.2.1.14 Emergency Communications

601.6.2.1.14.1 See Section 601.6.1 Fire/Life Safety Elements and Set 302 Telephony for additional requirements.

601.6.2.1.15 Means of Egress Illumination and Exit Signs

601.6.2.1.15.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.1.16 Fire Hydrants

601.6.2.1.16.1 Existing hydrants along limited access highways that will be obstructed by the guideway must be mitigated to the satisfaction of the AHJ. Do not provide fire hose valves on Sound Transit standpipe systems to serve limited access highway fires.

Commentary: Sound Transit prefers not to be responsible for maintenance of fire hydrants that are provided for public roadway fire protection.

601.6.2.1.16.2 Hydrants must be provided where required to serve guideway standpipe systems.

601.6.2.1.17 Automatic Sprinkler Systems (Not Used)

601.6.2.1.18 Fire Department Connection

601.6.2.1.18.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.1.18.2 FDC signs must include inlet pressure for each zone where more than one pumping zone is provided. Fire hose valve identification numbers must be listed and grouped by pressure zone.

601.6.2.1.19 Standpipes

601.6.2.1.19.1 Elevated, at-grade, and other limited-access guideway standpipes must not be provided unless required by the local AHJ.

Commentary: Design teams must confer with the AHJ to determine the requirement for standpipes on elevated guideways. Designers should be prepared to discuss: (1) areas that are only slightly elevated and can be served from grade, and (2) remote/elevated areas between stations that would take considerable time to access where standpipes would potentially add little value. The LRV fire duration is estimated to be about 20 minutes based upon the heat release rate curve in 601.6.5.20.4.2. An LRV fire may approach burnout before manual firefighting operations can commence considering response time, standpipe fill time, guideway access/travel time, and fire hose set up time. Sound Transit anticipates the priority will be for the fire department to assist with evacuation.

601.6.2.1.19.2 See 601.1 for requirements.

601.6.2.1.19.3 FDCs must be provided at both ends of the horizontal standpipes longer than 800 feet and located such that no segment has a dead end longer than 800 feet.

601.6.2.1.19.4 Elevated guideway segments must be filled within 10 minutes and meet hydraulic demand. To meet the 10-minute fill time, dry standpipes must be filled from one location unless otherwise approved by the AHJ.

Commentary: The fill time and hydraulic demand establishes a practical limit for dry standpipes to about 6,000 feet in length depending upon topography, guideway height, pipe type, pipe diameter, hydraulic demand, and design criteria.

601.6.2.1.19.5 The designer must confirm in writing fire pumper truck pressure and flow capabilities.

601.6.2.1.20 Underground Fire Service Mains

601.6.2.1.20.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.1.21 Portable Fire Extinguishers (Not Used)

601.6.2.1.22 Clean Agent Fire Suppression (Not Used)

601.6.2.1.23 Emergency Ventilation/Smoke Control (Not Used)

601.6.2.2 Tunnel (Enclosed) Guideway

601.6.2.2.1 This section outlines specific requirements associated with tunnels and enclosed guideways. Section 601.6.1 Fire/Life Safety Elements outlines general requirements that also apply.

601.6.2.2.2 Emergency Access

601.6.2.2.2.1 Emergency access to enclosed trainways (tunnels) and tunnel portals must be through passenger stations, gates/pathways located adjacent to portals, stairs/ramps, or as required by the AHJ.

601.6.2.2.2.2 Emergency access gates must be located near portals for ease of access to tunnels, as determined by the AHJ.

601.6.2.2.2.3 Emergency access must include an emergency access pathway with stairs and ramps that is continuous from the street/access point to the trainway. Ramps and Stairs must meet Washington Industrial Safety and Health Act requirements or be acceptable to the AHJ.

601.6.2.2.2.4 Ramps must not exceed 8:1; gravel is acceptable.

601.6.2.2.2.5 The stair risers must not exceed 9 inches and treads must not be less than 11 inches.

601.6.2.2.2.6 Stair landings must be provided at direction changes and every 12 feet vertically.

601.6.2.2.2.7 Designers must confer with the AHJ to obtain concurrence for tunnel and tunnel portal access design.

601.6.2.2.2.8 The need for fire fighter access doors between tunnels shorter than 2,500 feet must be evaluated for effective fire response and firefighting operations when required by the AHJ.

601.6.2.2.3 Construction Type/Finishes/Furnishings

601.6.2.2.3.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.2.4 Fire Separations

601.6.2.2.4.1 See NFPA 130 for requirements.

601.6.2.2.5 FCCS/FCRs/ERERs

601.6.2.2.5.1 An FCC must be provided at an adjacent station, or adjacent ancillary facility, to serve the enclosed trainway.

601.6.2.2.6 Means of Egress

601.6.2.2.6.1 Means of egress for the trainway must be provided via the emergency walkway to stations, cross passages, and other exits. See NFPA 130 for requirements.

601.6.2.2.6.2 Cross passage exit to the opposing tunnel must not to be used in lieu of emergency exit stairs except where egress to the surface is not practical.

601.6.2.2.6.3 Cross passage exits must be as follows:

601.6.2.2.6.3.1 Doors must swing into the passageway from the tunnel.

Commentary: A fire door is usually provided at each end of the cross passage and both swing into the passageway.

601.6.2.2.6.3.2 Pivoted or side-hinged swinging type (36 inches width minimum) with a clear width of at least 32 inches when the door is open to 90 degrees.

601.6.2.2.6.3.3 Fire rated in accordance with NFPA 130 (90 minutes).

601.6.2.2.6.3.4 Smoke gaskets must not be provided unless required by the AHJ.

601.6.2.2.6.3.5 Provided with a door closer and open with no more than 50 pounds force applied at the latch side of the door.

601.6.2.2.6.3.6 Structurally designed to account for fatigue associated with the tunnel piston effect of moving trains.

601.6.2.2.6.4 A platform end-gates must be provided where the emergency walkway connects to the platform. See 601.6.1.6.5.

601.6.2.2.7 Exits/Point of Safety

601.6.2.2.7.1 Emergency walkways must terminate at outlined in NFPA 130 at the station platform, exit stair, exit access corridor, other approved exit, or point of safety. See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.2.8 Emergency Walkways

601.6.2.2.8.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.2.8.2 The minimum unobstructed width within or directly adjacent to the trainway, as measured to the static light rail envelope, must be in accordance with NFPA 130.

601.6.2.2.8.3 The vertical distance from the LRV floor to the top of the walkway surface must be between 0 and 7 inches with the walkway even with or lower the LRV floor.

Commentary: This distance is not outlined in NFPA 130. In the event of an LRV fire in a tunnel environment passengers must be able to evacuate the train to the emergency walkway quickly without tripping. A level surface like the station platform or a small step down is ideal but one step down not to exceed 7 inches is acceptable.

601.6.2.2.8.4 The emergency walkway must not be in front of vertically oriented emergency ventilation track dampers where the air velocity exceeds 2,200 feet per minute as outlined in NFPA 130.

601.6.2.2.9 Guardrails/handrails

601.6.2.2.9.1 Handrails must be provided along the emergency walkway in accordance with NFPA 130. A handrail is not required to be continuous where the emergency walkway transitions to a wider area where passengers are not required to walk near the unprotected edge.

601.6.2.2.9.2 Handrails must be provided on both sides of stairs.

601.6.2.2.9.3 A guardrail must be provided in between tracks at side-platform stations to serve as a barrier to keep passengers from crossing the tracks where crossing would otherwise be possible.

601.6.2.2.10 Fire Alarm/Detection (Not Used)

601.6.2.2.11 Gas/Refrigerant Detection/Mitigation/Mitigation Systems

601.6.2.2.11.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.2.12 Emergency Communications

601.6.2.2.12.1 Emergency access points to enclosed trainways must be provided with security and communications elements and be clearly signed. See Set 302 Telephony and Set 303 Radio for additional requirements.

601.6.2.2.12.2 Survivability: Communication system must meet survivability requirements of NFPA 72 and NFPA 130.

601.6.2.2.12.3 Emergency communication systems conductors and cable must be protected from fire for at least 1 hour or have diversity in system routing, and meet flame spread and smoke development requirements in accordance with NFPA 130.

601.6.2.2.13 Means of Egress Illumination and Exit Signs

601.6.2.2.13.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.2.13.2 Illuminated exit signs at cross passages, stairs, and other exits must be double-faced and visible while approaching the cross passage and exit from the emergency walkway.

Commentary: Orienting signs in this manner is preferred but it may present a conflict with the train dynamic envelope. Coordinate with Track design and optimize the design as practical.

601.6.2.2.14 Fire Hydrants

601.6.2.2.14.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.2.15 Automatic Sprinkler Systems (Not Used)

601.6.2.2.16 Fire Department Connections

601.6.2.2.16.1 Tunnel dry standpipe FDCs must be co-located with station FDCs unless otherwise required by the AHJ.

Commentary: The preferred layout is a pair of FDCs (one tunnel standpipe and one combined station standpipe/sprinkler FDC) at one end of the station and another pair at the other end of the station.

601.6.2.2.16.2 Tunnel dry manual standpipes system FDC signs must include inlet pump pressure for each zone where more than one pumping zone is provided.

601.6.2.2.16.3 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.2.17 Standpipes

601.6.2.2.17.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.2.17.2 A manual wet standpipe must be provided with heat tracing near stations and portals where required. Designers must perform an engineering analysis to confirm the system will not freeze during normal operations and periodic EVS testing.

601.6.2.2.17.2.1 Exception: When the tunnel is subject to freezing provide a dry manual standpipe.

601.6.2.2.17.2.2 A semi-automatic manual standpipe system equipped with a deluge valve or valves controlled by EVS must be provided to automatically fill the system (via EVCP/FACP control) while the fire department is responding.

Commentary: Some large systems cannot be filled within the 10-minute fill-time requirement of NFPA 130 and a deluge valve is intended to mitigate but not necessarily fill the entire system in 10 minutes which, depending upon the system volume, may be impractical.

Consult the AHJ to determine their response time capabilities and filling requirements.

601.6.2.2.17.3 A single standpipe system dual fed and cross connected at each end must be provided between stations, and between stations and portals, for dual-bore or separated tunnels. Additional cross connections (through cross passages for example) must not be provided unless necessary to meet hydraulic demand.

601.6.2.2.17.4 Isolation valves accessible from grade without a ladder must be provided on standpipe connections between tunnel bores and at 800 feet intervals in accordance with NFPA 130.

Commentary: Tunnel standpipes have been cross connected at every cross passage in past projects which adds cost and provides little value. While standpipe systems must be dual fed with an FDC provided at each end of the segment numerous cross connections are not required but permitted if necessary for system hydraulics. Isolation valves must be accessible so sections can be isolated if the system is damaged by train derailment.

601.6.2.2.17.5 Provide fire hose valves in accordance with 601.6.1 plus one fire hose valve in each cross passage when required by the AHJ.

601.6.2.2.18 Underground Fire Service Mains

601.6.2.2.18.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.2.19 Portable Fire Extinguishers

601.6.2.2.19.1 Type 1 portable fire extinguishers must be provided in cross passages.

601.6.2.2.20 Clean Agent Suppression Systems (Not Used)

601.6.2.2.21 Emergency Ventilation/Smoke Control

601.6.2.2.21.1 See Stations (Light Rail) section for information on tunnel ventilation requirements.

601.6.2.3 Stations (Light Rail)

601.6.2.3.1 This section outlines specific requirements associated with light rail stations which include a variety of occupancies, including Groups A-3, B, and S-2. Section 601.6.1 Fire/Life Safety Elements outlines general requirements that also apply.

601.6.2.3.2 Emergency Access

601.6.2.3.2.1.1 Stations must provide emergency access roads in accordance with the IFC.

601.6.2.3.2.1.2 Access must be coordinated with location of fire department connections, fire hydrants, and the location of the fire command center or fire control center. See 601.6.1 for general requirements.

601.6.2.3.2.1.3 Permanent and removeable bollards, concrete demarcations, and other facilities must be provided to define firefighter access roads that extend into station circulation areas.

601.6.2.3.3 Construction Type/Finishes/Furnishings

601.6.2.3.3.1 Stations must be of noncombustible construction as outlined in the IBC. Combustible materials must conform to IBC Chapter 6. See Set series 800 Architecture for additional requirements.

601.6.2.3.3.2 Heavy timber roofs, where allowed by the IBC for noncombustible construction, are permitted. See Set 801 Architectural Materials, Elements, and Furnishings for additional requirements and conditions for approval.

601.6.2.3.3.3 “No storage” signs must be provided for station rooms and areas not intended for storage, including accessible areas under stairs.

601.6.2.3.3.4 Commentary: Examples include Kiosks, electrical rooms, and space under stairs.

601.6.2.3.3.5 Artwork must be noncombustible, limited combustible, or of a size/nature that does not present a hazard. Alternatively, a fire hazard analysis must be developed. See Set 808 Start Program for additional information.

601.6.2.3.3.6 Stations must be classified as open or enclosed in accordance with NFPA 130. Classify stations as open stations whenever possible and obtain concurrence with the AHJ. This may require an engineering analysis in some cases.

Commentary: Enclosed stations classification applies to tunnel stations and other stations where tenability of the platform, and means of egress, could be affected by a station or LRV fire. An open station with a roof that extends over the trainway and provided with wall enclosures, for example, could potentially be classified as an enclosed station. An engineering analysis may be needed to classify such a station as an open station. Enclosed ancillary space associated with open stations and other space not accessible to the public and station means of egress are not usually classified as an enclosed station area, but this must be verified with the AHJ. Note, enclosed stations have higher standards for electric wiring, emergency power, and emergency ventilation.

601.6.2.3.4 Fire Separations

601.6.2.3.4.1 Rooms and areas must be separated with fire rated construction as required by the IBC and NFPA 130.

601.6.2.3.4.2 Rooms and vaults must be separated from other spaces with fire rated construction when required by the IBC, IFC, NFPA 130, NEC, ANSI/ASME A17.1 and Table 601-6:

Table 601-6: Room Fire Ratings

Room	Rating (hours)
Traction Power Substations	3
High voltage rooms (600 V or greater)	3
Fire Command Centers, Communication Rooms, Signal Rooms, Emergency Ventilation Rooms	2
Other station critical rooms identified by ST	2
Ancillary rooms/areas separation from the public areas. Examples include electrical, mechanical, elevator, automatic sprinkler riser, signal, fan, storage, and similar rooms.	As required by code[1]
Commentary: These rooms could potentially be separated as a block of rooms from the public areas (concourse, platform, and lobby) of the station. See the IFC or energy storage systems.	
Non-system rooms/areas. Examples include mercantile, assembly, and other uses operated by ST or leased to others.	As required by code
Energy Storage System Rooms (also known as UPS rooms) with IFC threshold quantities located in non-dedicated buildings.	2
Commentary: Lithium-Ion ESS are not currently permitted by ST. Consultants must inquire with ST before spending time on a proposal for lithium-Ion or similar technologies with known fire risk. All IFC Chapter 12 requirement must be met.	
Exterior walls at the plaza (grade) level adjacent to public areas must not be fire rated unless required by the code or the AHJ.	As required by code
Commentary: Rating exterior walls may be necessary in some cases depending on property lines, assumed property lines, and occupancy separation for example but it is not common.	
The supporting structure for fire rated construction, including floor and roof assemblies, must be supported with fire rated construction per IBC Chapter 7.	As required by code
Commentary: Open stations are often Type IIB construction. If separation is required from ancillary and other non-public areas, the separating walls, floors, and other assemblies must be supported with fire rated structure. This is sometimes overlooked by designers and plans examiners but is picked up during construction by inspectors.	
Fire rated elevator shafts must be rated to meet the requirements of IBC Chapter 7 and IBC Chapter 30.	As required by code
Commentary: Elevator shafts are often required to be fire-rated per the IBC Chapter 30 and IBC Chapter 7. CEPTED goals may call for glass elevator doors that preclude a fire rating. Sound Transit has successfully negotiated Alternate Materials and Method Request (AMMR) with the AHJ to allow non-rated elevator doors. The design team must identify this early in the design and seek AHJ approval.	

1. NFPA 130 has been amended at the State level to refer to the IBC for separation of ancillary rooms/areas and no longer refers to NFPA 101. IBC 508 and 509 must be applied. Note that EVSs and emergency communication system survivability requirements may also require fire-rated rooms for continuity.

601.6.2.3.5 FCCs/FCRs/ERERs

601.6.2.3.5.1 Enclosed station and stations with tunnels must be provided with a FCC.

601.6.2.3.5.2 Grade separated (elevated or retained cut) open stations must be provided with a FCR.

Commentary: At-grade stations do not have an FCC or an FCR.

601.6.2.3.5.3 An ERER to store emergency response equipment must be provided at the following locations. See 601.6.1 Fire/Life Safety Elements for additional information:

601.6.2.3.5.3.1 Underground stations

601.6.2.3.5.3.2 Grade-separated stations

601.6.2.3.5.3.3 Stations associated with tunnels

601.6.2.3.5.3.4 Unique stations/locations when required by the AHJ.

601.6.2.3.6 Means of Egress

601.6.2.3.6.1 See 601.6.1 Fire/Life Safety Elements for general requirements.

601.6.2.3.6.1 Ridership projections used for determining the platform occupant load must be based upon 20-year future ridership.

601.6.2.3.6.2 The platform occupant load must be the sum of the calculated train load of trains entering the station plus the entraining load of persons awaiting trains a specified time.

601.6.2.3.6.3 The calculated train load must be the number of passengers on trains simultaneously entering the station on all tracks in normal traffic direction during the peak 15-minute period.

601.6.2.3.6.4 A surge factor of 1.25 to 1.5 must be used to determine the peak 15 minutes peak train and entraining load within the peak one hour.

601.6.2.3.6.5 The peak headway train load must be a fully loaded train regardless of ridership estimates.

Commentary: NFPA 130 does not specifically require the peak headway train to be fully loaded but Sound Transit requires it to ensure egress capacity for growth and to align with our procedure to be able to fully evacuate a train at any station in the event of an LRV fire. The LRV load is based on the added weight loading of AW2 (four persons per square meter) for standing plus full seat loading regardless of ridership estimates. For Siemens and Kinkishario four-train consists, the calculated using this criteria load is 780 persons, but Sound Transit rounds up to 800 persons for a fully loaded four-train consist for calculating means of egress.

601.6.2.3.6.6 The non-peak headway train load must be based on ridership at the peak train period and is not expected to be a fully loaded train.

Commentary: The non-peak train (serving the opposite platform for center platform stations) must be loaded based upon ridership calculation and not loaded at 800 persons without clear justification.

601.6.2.3.6.7 The entraining load must be equal to the number of passengers that would accumulate on the platform in the time equivalent to two headways or 12 minutes during the peak 15-minute period, whichever is greater.

601.6.2.3.6.8 The number of passengers on the concourse must be calculated by applying 100 square feet per person gross as outlined in the IBC, or an alternative method when approved by the AHJ.

Commentary: Depending on the concourse's area, it may be more appropriate to determine its occupant load by calculating peak passenger inflow into the station.

601.6.2.3.6.9 Station platforms must meet the 4-minute platform and 6-minute station evacuation time provision of NFPA 130, or by justifying additional time through a performance-based means of egress analysis.

601.6.2.3.6.10 Performance-based means of egress analysis must include occupant load, pre-movement time, movement speed and time, and population parameters that reflect the diversity of ridership (adult, child, elderly, persons with disabilities, cohort groups).

601.6.2.3.6.11 The egress analysis must be performed while evaluating tenability during egress. The fire scenario must include at least two worst case design fires. CFD software approved for the application must be used.

601.6.2.3.6.12 Occupant load signs must be provided for the platform(s).

601.6.2.3.6.13 Means of egress calculation that disclose assumptions and parameters must be developed and included in the architectural code sheets of the permit drawings.

601.6.2.3.6.14 System demand for civic event centers must be accounted for in the determination of peak 15-minute period.

601.6.2.3.6.15 Surges from civic event centers that occur at the end of the event or other time that could result in a surge that exceeds station capacity (e.g., the daily peak) must be addressed with temporary controls restrict access to the station to prevent platform overcrowding. Space must be available for queuing outside of the station during the surge.

Commentary: This has typically been addressed using security and temporary administrative controls at the surface.

601.6.2.3.6.16 Some jurisdictions will require the platform occupant load to be calculated using an occupant load factor of 7 square feet per person or 15 square feet per person, for example, in addition to peak ridership method outlined in NFPA 130. As a result, the area of the platform must be considered.

Commentary: Large platforms can drive exit capacity beyond what would be required by NFPA 130. When applicable, designers must perform an analysis to determine the implication of platform area on the means of egress.

601.6.2.3.6.17 Areas of Rescue Assistance associated with accessible means of egress must be designated at the platform level elevator lobbies of enclosed stations. Areas of rescue assistance must be sized in accordance with IBC 1009. PETS at the elevator lobbies must serve as a two-way communication system. See Set 302 Telephony for PETS requirements.

Commentary: Enclosed stations with automatic sprinklers are not required by code to have areas of refuge but Sound Transit voluntarily designates space for areas of rescue assistance for enclosed stations to enhance safety for our passengers. The number of areas must be determined based upon 1 for every 200 platform occupants, or alternate criteria as approved by the AHJ.

601.6.2.3.6.18 For open stations, elevator lobbies must be designated as areas of refuge in accordance with IBC 1009 when required. See Set 302 Telephony for PETS requirements.

Commentary: Areas of refuge may be unenclosed for open stations location that are open to the outside per IBC 1009.6.4.

601.6.2.3.6.19 Elevators as a means of egress must meet NFPA 130, IBC 3008, and ASME A17.1 requirements for Occupant Evacuation Operations. Evacuation elevators must only be used when specifically approved by Sound Transit where egress by stair is impractical. Designers must identify code conflicts and develop a letter of concurrence or other formal agreement early in design.

601.6.2.3.6.20 An engineering analysis must be conducted for stations with a platform located more than 60 feet below the surface to confirm egress by stairs can be achieved within the NFPA 130 time limit while accounting for reduced travel speed (for travelling up the stairs) and potential obstruction from people resting within the stair enclosure.

Commentary: Occupant evacuation elevators should only be used for deep tunnel stations when the physical effort to reach the surface during an emergency may exceed passenger ability. The depth is undefined in NFPA 130. Most Sound Transit stations are less than 50 feet below grade and do not have occupant evacuation elevators. The 60 feet threshold is based upon the IBC for underground buildings.

601.6.2.3.6.21 Designers must obtain specific approval for Sound Transit to use escalators as a means of egress.

Commentary: To comply with the IBC, NFPA 130 and ANSI A17.1 requirements prohibiting automatic shutdown, only escalators that always operate in the direction of egress may be included in egress capacity.

This limitation combined with the NFPA requirement that one escalator must be considered out of service may limit the ability to use escalators as a means of egress.

601.6.2.3.6.22 Emergency exits must be meet the IBC and not secured in a manner that requires keys, special knowledge, or more than one action to open the door/gate to exit.

601.6.2.3.6.23 Bollards, or other facilities, to protect station approaches, entrances and exits from vehicles must be provided. See Set 801 Architectural Materials, Elements, and Furnishings for additional information.

601.6.2.3.7 Exits/Point of Safety

601.6.2.3.7.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.3.7.2 When more than two exits are required, exits must be separated from each other by at least 20 feet, unless approved by the AHJ.

Commentary: This provision defines the distance implied in IBC 1007 for separation of stairs when more than two exits are required. When not practical for enclosed stations, seek written concurrence with the AHJ. A point of safety must be used for calculating evacuation time. See 601.6.1 for areas that qualify as a point of safety.

601.6.2.3.8 Emergency Walkways

601.6.2.3.8.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.3.9 Guardrails/Handrails

601.6.2.3.9.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.3.10 Fire Alarm/Detection Systems

601.6.2.3.10.1 See Set 601.6.1 for general requirements.

Commentary: Transit stations require Public Address, and the fire code requires an EVACs (Emergency Voice Alarm Communication System) system. If permitted by the AHJ, it is Sound Transit's desire not to have both systems and use the Public Address system for emergency messages (EVACS). Obtaining AHJ permission will need to address the duration of emergency power as the fire code requires 24-hour emergency power and the communication system UPS system capacity is typically limited to about 2 hours. Sound Transit facilities will be closed to service if a power outage is anticipated to exhaust the UPS. The AHJ may find it acceptable to relax to the 24-hour duration of emergency power. Sound Transit has experience in negotiating with AHJs on this topic and will provide information and support to design teams to help expedite a decision so that the design can proceed.

601.6.2.3.10.2 A fire alarm system with EVACS must be provided for all enclosed station, grade-separated stations, and stations associated with tunnels. The EVACS component must be provided regardless of the occupant load.

601.6.2.3.10.3 *Commentary: The IFC does not require EVACS for assembly occupancies with an occupant load of less than 1,000 persons. For example, some stations have an occupant load as low as about 850 persons for a side platform. To ensure consistency, Sound Transit requires an emergency voice system for all enclosed and grade-separated stations.*

601.6.2.3.10.4 For enclosed stations with code-conforming emergency power, the fire alarm system must be integrated with the PA system to provide audible alarm notification and emergency voice messages in all public areas. Fire alarm horns must be used in back-of-house areas. See Appendix A.

601.6.2.3.10.5 For open stations where PA emergency power is provided by the Communications System UPS, the designer must seek AHJ approval for 2 hours of emergency power without load shedding (rather than 24 hours required by NFPA 72) and document the agreement with a letter of concurrence. Fire alarm horns must be used in back-of-house areas. When not approved by the AHJ, a UPS dedicated to the PA system to provide 24 hours of emergency power must be provided.

601.6.2.3.10.6 The hybrid fire alarm/PA hybrid interface must be reliable as determined through a failure mode effects analysis. The programing associated with emergency notification and voice messages must be password protected in the SCU (Station Control Unit) and other programmable equipment.

601.6.2.3.10.7 An engineering analysis and report for a hybrid fire alarm/PA system must be developed during preliminary design. The report must be presented to the AHJ for concurrence. The details of the PA system design and the interface (SCU, logic box) and the PA system must be addressed in the engineering analysis.

601.6.2.3.10.8 If the AHJ does not approve use of the hybrid fire alarm/PA system for EVACS, a fully redundant VES as a component of the fire alarm system must be provided for the station platform, concourse, and other public areas. Alarm activation must immediately override the PA system. See Set 301 Network Infrastructure and Control Drawings for integration and interface requirements.

601.6.2.3.10.9 Horns located in back-of house areas must not interfere with the intelligibility of the PA system serving the platform, concourse, and associated public areas where EVACS is required.

601.6.2.3.10.10 Audible and visual notification must be provided per NFPA 72 for the entire station.

601.6.2.3.10.11 Wall-mounted visual alarms are to be located at 96 inches to the top of the lens to be above the touch zone. See Set 801 Architectural Materials, Elements, and Furnishings for additional requirements.

601.6.2.3.10.12 VMSs must be provided in elevator lobbies designated as an area of refuge for occupant evacuation elevators per ANSI A17.1.

601.6.2.3.10.13 Provide heat detection in rooms not equipped with automatic sprinklers unless the room is provided with clean agent fire suppression system.

601.6.2.3.10.14 Manual pull stations must not be provided except for at the FACP unless required by the AHJ.

Commentary: The IFC and NFPA 72 require pull station for assembly occupancies. PETS located to serve areas of refuge and security purposes serve as an alternate to pull stations because the LCC can remotely activate the station fire alarm system. Designer to seek AHJ concurrence.

601.6.2.3.10.15 See the communication section for wire and cable survivability requirements.

601.6.2.3.11 Gas/Refrigerant Detection/Mitigation Systems

601.6.2.3.11.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.3.12 Emergency Communications

601.6.2.3.12.1 Emergency communication system cables and conductors must be listed for wet locations.

601.6.2.3.12.2 Emergency communication systems conductors and cables in enclosed stations must be protected from fire for at least 1 hour or have diversity in system routing and meet flame spread and smoke development requirements in accordance with NFPA 130.

601.6.2.3.12.3 Survivability: Communication system must meet survivability requirements as outlined in NFPA 72 and NFPA 130. See guidance Table 601-7.

Commentary: The following table is intended to help ensure design quality and consistency for communication system pathway survivability for stations. Confirm requirements with the AHJ.

Table 601-7: Communication System Survivability

System	*Function*	*Minimum Pathway Survivability Level*[1]		
		Open Stations[2]		*Enclosed Stations*[4]
		Fire Protection	*Partial/No Fire Protection*	*Fully Fire Protection*
Public Address/Fire Alarm EVACS	*One-way communication within the station*	*Level 0*[5]	*Level 0*[5]	*Level 0, (NFPA 72), 1 hour + raceway (NFPA 130)*
Variable Message Sign	*One-way communication within the station*	*Level 0*[5]	*Level 0*[5]	*Level 0,1 hour + raceway (NFPA 130)*
PETS – Area of Refuge and Elevator Lobby	*Two-way communication with LCC*	*Level 1*[6]	*Level 2*	*Level 1, (NFPA 72), 1 hour + raceway (NFPA 130)*
ETELS	*Two-way communication with other ETELS and the LCC*	*Level 1*	*Level2*	*Level 2, (NFPA 72), 1 hour + raceway (NFPA 130)*
Elevator Cab Telephone station.	*Two-way communication with SOC or central station*	*Level 0*	*Level 0*	*Level 0, NFPA 72 (1 hour + raceway (NFPA 130)*
Occupant Evacuation Elevator Lobby	*Two-way communication with LCC*	*NA*	*NA*	*Level 3, NFPA 72 (1 hour + raceway (NFPA 130)*
Emergency Radio Enhancement (BDA/DAS)	*Two-way communication within the station*	*Level 1*[3]	*Level 2*[3]	*Level 1*[3] *(NFPA 72), 1 hour + raceway (NFPA 130)*
SCADA Network Supporting Emergency Communication Systems	*Infrastructure for communication*	*See Set 301*	*See Set 301*	*See Set 322*
Other Communications system Not Classified as Emergency communications systems[7]				
PETS – General	*Two-way communication with LCC*	*NA*	*NA*	*NA*

1. *As defined by NFPA 72.*
2. *Assumes non-protected construction type (e.g., Type IIB)*
3. *See NFPA 72, NFPA 1221, and local rules for additional information*
4. *Apply most restrictive of NFPA 130 or NFPA 72 requirements for enclosed stations. Subject to AHJ approval, Class A or redundancy in circuits may be used to meet NFPA 130 for one-way communication systems.*
5. *Assumes relocation/partial evacuation is not used.*
6. *Level 0 requires no survivability and Level 1 is met with buildings that are fully sprinkler protected.*
7. *PETS at elevator lobbies and areas other than areas of refuge are not intended for firefighter use and not subject to NFPA 72 survivability requirements or NFPA 130 emergency communication requirements.*

601.6.2.3.12.4 Emergency communications systems are those systems defined by NFPA 72. See Table 601-8 and Section 601.6.1 Fire/Life Safety Elements for additional information and guidance.

601.6.2.3.12.5 The following communication systems must be provided for grade-separated stations:

Table 601-8: Communication Systems Required for Grade-separated Stations

System	Emergency Communication System	Other Communication System
Public Address System	X	
Fire Alarm System with EVACS unless a fully integrated and approved fire alarm/public	X	

System	Emergency Communication System	Other Communication System
address system is provided with the public address system speakers serving as NFPA 72 required EVACS.		
Variable Message Sign	X	
Area of Refuge PETS if areas of refuge are provided	X	
PETS – other than area of refuge		X
Elevator lobby phones, when required, which may be met by providing PETS when allowed by the AHJ	X	
ETELS	X	
Elevator Cab Phones	X	
Public Exchange Phones		X
Emergency Radio Enhancement (BDA/DAS)	X	
SCADA Network Supporting Emergency Communication Systems	X	

601.6.2.3.12.6 The following communication systems must be provided for at-grade stations:

Table 601-9: Communication Systems Required for At-grade Stations

System	Emergency Communication System	Other Communication System
Public Address System		X
Variable Message Sign		X
Area of Refuge PETS if areas of refuge are provided (uncommon)	X	
PETS – other than area of refuge		X
Elevator lobby phones, when required, which may be met by providing PETS when allowed by the AHJ	X	
ETELS (e.g., end of platform)	X	
Emergency Radio Enhancement (BDA/DAS) when provided (less common)	X	
SCADA Network Supporting Emergency Communication Systems	X	

601.6.2.3.12.7 See Operational Communication Set 300 for additional requirements.

601.6.2.3.13 Means of Egress Illumination and Exit Signs

601.6.2.3.13.1 An illuminated exit sign must be provided at the person door adjacent main entrance security grilles. See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.3.14 Fire Hydrants

601.6.2.3.14.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.3.15 Automatic Sprinkler Systems

601.6.2.3.15.1 At-grade station must not have automatic sprinkler system unless specifically required by the AHJ:

Commentary: Some municipalities have adopted progressive standards for fire protection based upon the facility size starting as low as 500 square feet for example. Sound Transit encourages design teams to discuss these requirements with the AHJ and determine if applicable. Non-combustible canopies and other projections often do not need to be considered when determining building area.

601.6.2.3.15.2 Grade-separated open stations must be provided an automatic sprinkler system in enclosed rooms regardless of code requirements with the following exceptions:

601.6.2.3.15.2.1 Communication room(s) and signal rooms when protected with clean agent fire suppression and separated from other spaces with 2-hour fire rated construction.

601.6.2.3.15.2.2 Other station critical rooms, as identified by the Set 601 Fire/Life Safety owner during preliminary design or outlined in a project requirement, when protected with clean agent fire suppression and separated from other spaces with 2-hour fire rated construction.

601.6.2.3.15.3 Designers must obtain a formal letter of concurrence to confirm the extent of automatic sprinkler protection for grade-separated open stations.

Commentary: Sound Transit prefers to omit fire protection from exterior stairs, exit access stairs, platform canopies, and other canopies/exterior projections where fire protection adds little value. When local code requires full protection, apply NFPA 13 exceptions for non-combustible canopies and projections to omit fire protection when possible. AHJ concurrence must be documented in a formal letter of concurrence.

601.6.2.3.15.4 To avoid the provision of small wet-pipe systems, heated ancillary rooms must be protected from a dry-pipe system with upright heads, pendant on return bends, or other means per NFPA 13 unless the AHJ requires separate systems for heated and unheated areas. For heated areas greater than 2,000 square feet, a separate wet-pipe systems must be provided.

601.6.2.3.15.5 Enclosed station must be provided with an automatic sprinkler system in accordance with NFPA 13 with the following exceptions:

601.6.2.3.15.5.1 Traction power substation (TPSS) is in a transformer vault designed according to the NFPA 70-450 Part III.

601.6.2.3.15.5.2 Other high-voltage equipment in a transformer vault designed according to the NFPA 70-450 Part III when approved by the AHJ.

601.6.2.3.15.5.3 Fire command centers, communication room(s), and signal rooms when protected with clean agent fire suppression and separated from other spaces with 2-hour fire rated construction.

601.6.2.3.15.5.4 The main electrical rooms separated from other areas with 2-hour fire rated construction.

601.6.2.3.15.5.5 Other operational critical rooms, as identified by Set 601 Fire/Life Safety owner during conceptual design or outlined in a project requirement, when protected with clean agent fire suppression and separated from other spaces with 2-hour fire rated construction, when approved by the AHJ.

Commentary: NFPA 130 does not require fire protection over the trainway. Automatic sprinkler protection is not expected to be effective for an LRV fire because many of the fire scenarios are shielded by the train (metal) envelope and floor. Do not provide fire protection over the trainway unless specifically required by the AHJ.

601.6.2.3.16 Fire Department Connections

601.6.2.3.16.1 For open stations, a single FDC for Class I standpipe and automatic sprinkler system must be provided.

601.6.2.3.16.2 For enclosed stations Class I standpipe system must be cross-connected and fed from two separated FDCs. Confer with the AHJ to determine placement of FDCs.

601.6.2.3.16.3 See 601.6.1 Fire/Life Safety Elements for additional requirements.

601.6.2.3.17 Standpipes

601.6.2.3.17.1 Station standpipes must be dry manual standpipes per the IFC and NFPA 14 unless wet standpipes are required by the AHJ.

601.6.2.3.17.2 Fire hose valves must be located at exit stairs, the platform, additional locations to serve ancillary area, and as required by the AHJ.

601.6.2.3.17.3 Fire hose valves must be provided at exit stairs on the platform level and along the platform located to be accessible for an LRV fire.

Commentary: The IFC, NFPA 130, and NFPA 14 do not require standpipes at open stations less than 30 feet above or below the level of fire department access. The provisions above are intended to exceed the code to enhance safety and provide fire protection for the LRV and to be consistent with past practice for open stations.

Commentary: Standpipes must not obstruct required width for egress or accessible means of egress, where applicable.

601.6.2.3.17.4 Public area fire hose valves must be in tamper resistance hose cabinets.

601.6.2.3.17.5 Do not provide standpipes for at-grade stations unless required by the AHJ.

601.6.2.3.17.6 See 601.6.1 for additional requirements.

601.6.2.3.18 Underground Fire Service Mains

601.6.2.3.18.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.3.19 Portable Fire Extinguishers

601.6.2.3.19.1 Type 1 fire extinguishers must be provided in stations to meet the IFC and NFPA 10.

601.6.2.3.19.2 Type 4 fire extinguisher must be provided in communications rooms, signal rooms, the fire command center and other rooms as required by the IFC and NFPA 10.

601.6.2.3.19.3 Fire extinguishers must not be provided in public areas of at-grade station unless required by the AHJ.

Commentary: At-grade station fire extinguishers are prone to theft and vandalism.

601.6.2.3.20 Clean Agent Systems

601.6.2.3.20.1 A clean agent fire suppression must be provided in the fire command center, main communication room, and the signal room in stations. See Section 601.6.1 Fire/Life Safety Elements for requirements.

Commentary: Do not provide clean agent fire suppression in fire control rooms, communication closets, electrical rooms/closets, UPS rooms, generator rooms, or any other rooms unless specifically identified by Sound Transit.

601.6.2.3.21 Emergency Ventilation/Smoke Control

601.6.2.3.21.1 General

601.6.2.3.21.1.1 Emergency ventilation must be provided for tunnels and enclosed stations in accordance with NFPA 130, and IBC Chapter 9 where applicable.

601.6.2.3.21.1.2 Station roofs, canopies, bridges, and walkways that extend over the trainway must be evaluated to determine if the station is classified as an open or enclosed station.

601.6.2.3.21.2 Design Strategy

601.6.2.3.21.2.1 The ventilation strategy must be based on tunnel length, configuration, and associated station design. The strategy must be determined during preliminary design to coordinate shaft requirements, station envelope, fan placement, damper placement, intake and discharge locations with station and tunnel design.

601.6.2.3.21.2.2 A pressure transient analysis associated with training travelling in a tunnel (piston effect) must be performed for enclosed stations to ensure that pressure spikes are mitigated through design.

601.6.2.3.21.2.3 Tunnel and station emergency ventilation must be met with one (most critical) fan out of service per NFPA 130.

601.6.2.3.21.2.4 See 601.7 Engineering Management for engineering analysis requirements associated with emergency ventilation systems.

601.6.2.3.21.3 Fire Scenarios

601.6.2.3.21.3.1 An engineering analysis must be conducted for tunnel train fire and enclosed station train fire scenarios.

601.6.2.3.21.3.2 The analysis must be limited to a single train per ventilation zone.

601.6.2.3.21.3.3 The worst-case scenario location of the fire in the station and each tunnel segment must be determined.

601.6.2.3.21.3.4 Other fire scenarios must be evaluated when necessary, depending upon fire loads and station configuration in accordance with NFPA 130 Appendix H.

601.6.2.3.21.4 Design Fires

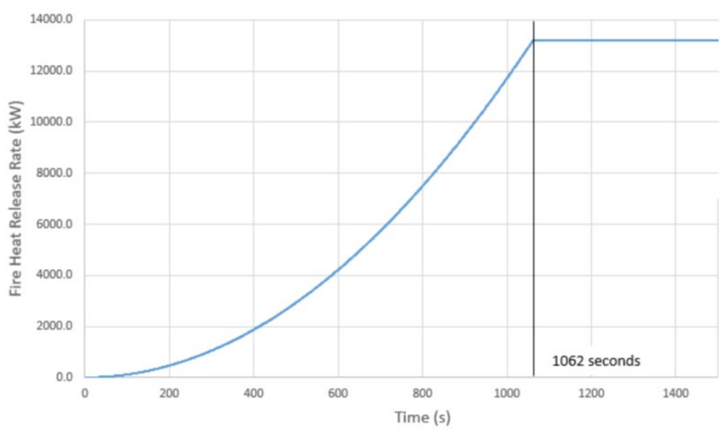
601.6.2.3.21.4.1 The fire scenarios to be assessed during the station and tunnel design must be in accordance with Table 601-10.

Table 601-10: Design Fire Summary for Stations and Tunnels – Life Safety

Fire Location	Fire Type	Maximum Fire Size MW	Notes
Tunnel	LRV	13.2	Peak heat release rate – steady state analysis only
Station	LRV	13.2 Medium Fire Growth Rate	Fire size relates to fire growth period assumed vs. time for exit

601.6.2.3.21.4.2 The station fire growth curve is presented in Figure 601-10 below.

Figure 601-10: Fire Heat Release Rate Over Time



Commentary: The fire growth rate for a fire on an LRV at a station is assumed to be consistent with a medium fire growth rate and a 13.2 MW peak heat release rate, achieving peak heat release rate at 1,062 seconds (about 17.5 minutes).

601.6.2.3.21.4.3 For tenability analysis, the peak heat release rate must be held (rather than decaying) beyond 1,062 seconds to be conservative for fire modelling.

601.6.2.3.21.5 Fire Parameters

601.6.2.3.21.5.1 The design FHRR parameters in Table 601-11 must be used for modelling unless modified by the EOR.

Table 601-11: FHRR Fire and Smoke Parameters

Parameter	Value	Units	Notes
Average Heat of Combustion	11,141	$kJ/kg_{fuel\ burnt}$	
Average Soot Yield	0.1245	$kg_{soot}/kg_{fuel\ burnt}$	
Average CO Yield	0.6665	$kg_{co}/kg_{fuel\ burnt}$	
Average Mass Extinction Coefficient	5,532.6	m^2/kg_{soot}	
Chemical Composition	$C_{6.7}H_{7.7}$		
Radiation	10-30%		1
HRR (Heat Release Rate) density	500	kw/m^2	
[1]10% radiation must be used for life-safety analysis, 30% radiation must be used for structural integrity analysis			

601.6.2.3.21.6 Reliability Analysis:

601.6.2.3.21.6.1 A reliability analysis for the EVS meeting the requirements of NFPA 130 must be prepared and submitted for approval by Sound Transit and the AHJ.

601.6.2.3.21.7 Integrated Design:

601.6.2.3.21.7.1 The EVS design must be integrated with the fire/life safety system, station elements and coordinated with train control.

601.6.2.3.21.8 Tenability

601.6.2.3.21.8.1 Ventilation must be designed so that smoke is captured, extracted, and dispersed without affecting tenability.

601.6.2.3.21.8.2 Tenability must be defined as follows unless amended by engineer or record or the AHJ, and the Set 601 Fire/Life Safety owner:

601.6.2.3.21.8.2.1 Smoke obscuration at 6.6 feet (2 meters) above the walking surface must be continuously maintained below the point at which a sign illuminated at 7.5 foot-candles is discernible at 100 feet (30 meters) and doors and walls are discernable at 33 feet (10 meters).

601.6.2.3.21.8.2.1.1 *Exception: In areas where occupants are queuing, reduced levels as outlined in NFPA 130 Appendix B are acceptable.*
Commentary: This parameter may be used as a proxy for preliminary modelling. The final modeling report must account for all tenability criteria.

601.6.2.3.21.8.2.1.2 *The temperature in a path of egress away from a train fire must be limited to 140°F (60°C) for 10 minutes. Contours of temperature must be shown at 6.6 feet (2 meters) above the platform and concourse.*

601.6.2.3.21.8.2.2 Carbon monoxide in air or other asphyxiates must not exceed a fractional equivalent dose of 0.3.

601.6.2.3.21.8.2.3 The maximum air velocity at the evacuation path measured at 4 feet (1.2 meters) above and in the middle of the evacuation path must be 2,200 feet per minute.

601.6.2.3.21.8.2.4 Fan sound pressure measured along the path of evacuation at any point 5 feet (1.5 meters) above the walking surface must not exceed 75 dBA for stations and 85 dBA at 20 feet of a noise source for tunnels. An upper limit of 95 dBA is permitted where the emergency walkway is within 20 feet of the noise source for tunnels. See Track Set 007 for additional noise requirements.

601.6.2.3.21.8.2.5 The tenability time in stations must exceed the time required for egress.

601.6.2.3.21.8.2.6 The tenability time for Areas of Rescue Assistance in enclosed stations must be at least 12 minutes.

601.6.2.3.21.8.2.7 Tunnels must remain tenable in one direction during a fire event in accordance with NFPA 130.

601.6.2.3.21.8.2.8 For tunnels the EVS must control back layering to the last train door at the adjacent non-incident car upstream of the incident fire car and maintain tenability upstream of the fire for at least the time of tenability.

601.6.2.3.21.9 Tunnel Emergency Ventilation

601.6.2.3.21.9.1 The design must be in accordance with NFPA 130.

601.6.2.3.21.9.2 Tunnel smoke control must apply a push/pull design approach using fully reversable fans located at stations and/or jet fans located within the tunnel.

601.6.2.3.21.9.2.1 Exception: Tunnel smoke control using the extraction method is acceptable with specific Sound Transit approval.

601.6.2.3.21.9.3 Tunnel smoke control must be manually activated by the LCC based upon information from the LRV operator and other available information.

601.6.2.3.21.9.4 For an LRV tunnel fire, the direction of egress must be determined based upon the fire location in or associated with the LRV as follows:

601.6.2.3.21.9.4.1 Front of train fire: Operator instructs passengers to evacuate opposite direction of travel.

601.6.2.3.21.9.4.2 Fire in middle of train or undetermined: Operator instructs passengers to evacuate in the direction of travel.

601.6.2.3.21.9.4.3 Rear of train fire: Operator instructs passengers to evacuate in the direction of travel.

601.6.2.3.21.9.5 For tunnels with cross passages and a mode where smoke is to be discharged from a tunnel portal, non-emergency bore/side fan(s) must be activated to prevent smoke from entering the non-incident bore/side.

Commentary: The emergency response mode must include activation of fan(s) to provide sufficient velocity in the non-incident bore to overcome prevailing winds.

601.6.2.3.21.9.6 Door opening forces for cross passage doors and tunnel exit doors must comply with the NFPA 130 for all ventilation scenarios (50 pounds to set in motion).

601.6.2.3.21.10 Station Emergency Ventilation

601.6.2.3.21.10.1 The EVS must be in accordance with NFPA 130, and IBC Chapter 9 where applicable.

601.6.2.3.21.10.2 Stations must use point extraction smoke control methods unless an alternate is approved by Sound Transit and the AHJ.

601.6.2.3.21.10.3 An engineering analysis and report, such as a rational analysis report as outlined in IBC 909, must be prepared for station smoke control. The report must account for station and tunnel emergency ventilation modes to ensure the station smoke control systems (including stair and elevator systems) perform.

601.6.2.3.21.10.4 The EVS must maintain tenability at the platform and means of egress.

Commentary: For station fire scenarios smoke exhaust must be located at the ceiling of the station ideally pulling from a smoke reservoir.

601.6.2.3.21.10.5 Stair Smoke Control

601.6.2.3.21.10.5.1 Interior stairs as defined by the IBC must remain tenable for egress per IBC 909.

601.6.2.3.21.10.5.2 Smokeproof enclosures must be provided for enclosed exit stairs serving a floor level of 30 or more feet below grade or when required by the AHJ unless proven unnecessary through engineering analysis.

601.6.2.3.21.10.5.3 The pressurization alternative per IBC 909 using a compensated design approach with a single barometric relief damper designed to discharge about 2,500 cubic feet per minute when the system is running, and all stair doors closed must be used.

601.6.2.3.21.10.5.4 Pressure sensors, modulating dampers, dynamic fan volume, and other design approaches are not permitted.

601.6.2.3.21.10.6 A single fan with top injection must be used for stairs up to 40 feet in height.

601.6.2.3.21.10.7 For stairs that exceed 40 feet in height, injection points at three-story intervals or in accordance with best design practice (i.e., Society of Fire Protection Engineers Smoke Control Handbook, NFPA 92) must be provided.

601.6.2.3.21.10.8 A motorized isolation dampers with end switches designed to that fails open upon loss of power must be provided at the supply fan, barometric relief damper, and elsewhere as needed for balancing.

601.6.2.3.21.10.9 Stair door opening forces for station exits must comply with the IBC for all ventilation scenarios (30/15 pounds to set in motion/open, respectively).

Commentary: Larger doors will increase the opening force. Use standard doors (36 inches x by 80 inches) or validate the design is viable through modeling and engineering analysis.

601.6.2.3.21.10.10 Vents and balancing dampers must be provided to relieve excess pressure across the stair doors for trainway fire modes if determined necessary through modelling.

601.6.2.3.21.10.11 The stair pressurization system must be constant volume but provided with variable speed capability for initial air balancing.

601.6.2.3.21.10.12 Power door openers must not be used to overcome door forces induced by emergency ventilation and smoke control fans.

601.6.2.3.21.11 Elevator Smoke Control

601.6.2.3.21.11.1 When required, smoke control per IBC 909 for elevator hoistway pressurization alternate must be provided.

Commentary: Tunnel and station emergency ventilation modes can induce significant pressure on elevator doors such that starting the hoistway pressurization fan at the same time can result in over-pressurization of the hoistway and jam the doors, preventing opening and closing and presenting a hazardous condition.

601.6.2.3.21.11.2 Smoke control system must employ the compensated design approach using a single barometric relief damper designed to discharge 2,500 cubic feet per minute when the system is running all elevator doors closed.

601.6.2.3.21.11.3 Pressure sensors, modulating dampers, dynamic fan volume, and other design approaches are not permitted.

601.6.2.3.21.11.4 A single fan must be used with a single injection point at the top of the shaft.

601.6.2.3.21.11.5 A motorized isolation dampers with position switches designed to fail open upon loss of power must be provided at the fan and barometric relief damper.

601.6.2.3.21.11.6 The hoistway pressurization system must be constant volume but provided with a VFD for initial air balancing.

601.6.2.3.21.11.7 Elevator car doors must operate during Fire Fighters Phase II operation and not be affected by station air pressure. Pressure must be within range, as defined by IBC 909, and verified through modelling.

Commentary: Some elevator doors (i.e., sliding telescoping) are more susceptible to jamming or sticking when the hoistway is pressurized. Coordinate design with architect and elevator consultant.

601.6.2.3.21.12 Modeling

601.6.2.3.21.12.1 For stairs and elevators smoke control system CONTAM, or equal, must be used to validate the design concept and size the fans and barometric relief dampers. A CONTAM analysis must be performed for all fire scenarios.

601.6.2.3.21.12.2 Determine when the stair and hoistway smoke control system must be activated for each fire scenario and develop a sequence of operations matrix for each station (see example Table 601-12):

Table 601-12: Fire Scenarios

	Fire Scenario			
Component	**Fire in Trainway – Station in Supply Mode**[1]	**Fire in Trainway – Station in Exhaust Mode**[1]	**Fire in Station – LRV/Platform Fire**[1]	**Fire in Station – Back of house Fire**[4]
Stair Smoke Control				
Stair pressurization Fan	On[2]	Off	Off	On
Isolation damper for pressurization fan	Open	Closed	Closed	Open
Isolation damper for barometric relief	Open	Closed	Closed	Open
Stair enclosure vent at platform level	Closed	Open	Open	Closed
Stair enclosure vent at surface	Closed	Open	Open	Closed
Elevator Smoke Control				
Elevator Pressurization Fan	On[3]	Off	Off	On
Isolation damper for elevator pressurization fan	Open	Closed	Closed	Open
Isolation damper for barometric relief	Open	Closed	Closed	Open
Station Smoke Extraction	Off	Off	Activated	Activated

1. Associated with LCC mode launch
2. Stair pressurization is not needed during tunnel fire; however, stair fans may need to operate to balance pressure so that door forces are within range and doors close to latch.
3. Elevator pressurization is not needed for a tunnel fire, but fans may need to operate to balance pressure and prevent elevator doors from jamming.
4. Automatic response, LCC intervention not required.

601.6.2.3.21.12.3 SES modeling must be performed for each tunnel zone with a four-train consist.

601.6.2.3.21.12.4 CFD modeling must be performed for station fire scenarios.

601.6.2.3.21.12.5 CFD modeling must assume actual train configuration and anticipated conditions with the train stopped and train doors open.

601.6.2.3.21.12.6 CFD modeling must assume fire protection, if present, does not operate.

601.6.2.3.21.12.7 An emergency response matrix, including the following, must be developed. The matrix must be used to coordinate emergency responses. Format must be consistent with existing Sound Transit ERMs. The ERM must be submitted to and approved by Sound Transit and the AHJ during preliminary design:

601.6.2.3.21.12.7.1 Fire zone

601.6.2.3.21.12.7.2 Train fire location

601.6.2.3.21.12.7.3 Tunnel ventilation direction

601.6.2.3.21.12.7.4 Evacuation direction

601.6.2.3.21.12.7.5 Mode number

601.6.2.3.21.12.7.6 Tunnel emergency ventilation fan response organized by tunnel segment

601.6.2.3.21.12.7.7 Tunnel standpipe deluge system response

601.6.2.3.21.12.7.8 Station fire alarm response (alarm notification, inputs and outputs)

601.6.2.3.21.12.7.9 *Commentary: Information to be high level; not to be confused with detailed station FACP matrix)*

601.6.2.3.21.12.7.10 BMS monitoring and control functions

601.6.2.3.21.12.7.11 Station emergency ventilation fan and damper response organized by station

601.6.2.3.21.12.7.12 Fire doors

601.6.2.3.21.12.7.13 Door locks

601.6.2.3.21.12.7.14 PA system message

601.6.2.3.21.12.7.15 VMS message

601.6.2.3.21.12.7.16 Other system control and supervision interfaces as needed to clarify design intent

601.6.2.3.21.13 Train Control System Integration

601.6.2.3.21.13.1 Train control system must limit the number of consists in a fire zone to one at a time.

601.6.2.3.21.13.1.1 Exception: With Sound Transit and AHJ approval, two consists are allowed in a single bore with a written procedure to back out a follow-on train.

Commentary: The procedure to back out a follow-on train is an administrative procedure involving the LCC and operator. A two-train exception requires Sound Transit and AHJ approval and should only be proposed for long tunnel segments where headways could result in two train in the same fire zone concurrently.

601.6.2.3.21.14 Traction Power

601.6.2.3.21.14.1 The traction power design and power shutdown zones must be coordinated with the fire zone and account for the fire department emergency response protocol. The traction power preliminary design must be provided to Sound Transit and the AHJ for review and approval

601.6.2.3.21.15 Local Control/Override

601.6.2.3.21.15.1 An emergency ventilation control panel to provide local control and annunciation of emergency ventilation modes must be provided at each fire command center.

601.6.2.3.21.16 Emergency Ventilation Equipment

601.6.2.3.21.16.1 Shafts

601.6.2.3.21.16.1.1 Ventilation shaft must meet the requirements of NFPA 130 and the following:

601.6.2.3.21.16.1.2 Ventilation shaft terminals must be located to prevent entraining to stair and elevator pressurization fans or affecting station entrances and exits.

601.6.2.3.21.16.1.3 Enclosed station entrances must be limited in size to reduce the short circuiting that may occur during tunnel ventilation modes with push-pull smoke control methods.

601.6.2.3.21.16.1.4 Separation distances outlined in IBC 909 and the IMC must be met.

601.6.2.3.21.16.1.5 Shafts must have laminar transitions to optimize pressure loss and mitigate noise production. Turning vanes must be used to reduce pressure losses.

601.6.2.3.21.16.1.6 The design pressures for the shaft and various elements (including dampers, attenuators, and transitions) must be based on calculations.

601.6.2.3.21.16.1.7 Emergency ventilation shafts must not be used for intake/exhaust of general HVAC.

601.6.2.3.21.16.1.8 Air injection and exhaust intake locations (often referred to as track dampers) must be located away from emergency walkways and means of egress so air velocity does not exceed tenability requirements.

601.6.2.3.21.16.2 Ventilation System Equipment Parameters

601.6.2.3.21.16.2.1 Station and tunnel emergency fans must meet the following criteria:

601.6.2.3.21.16.2.1.1 Axial-flow type with an internally mounted, direct-drive motor.

601.6.2.3.21.16.2.1.2 Fully reversible to supply or exhaust air to or from the trackway.

601.6.2.3.21.16.2.1.3 Manually adjustable-pitch blades to permit a change in pressure versus air flow capacity for either system balancing or for future system modification.

601.6.2.3.21.16.2.1.4 Minimum total fan efficiency of 60 percent in the forward (exhaust) flow mode.

601.6.2.3.21.16.2.1.5 Instrumentation to remotely monitor each motor temperature, temperature and vibration from each bearing, and airflow. Fan safety interlocks must be disabled when operating in emergency “run-to-fail” mode.

601.6.2.3.21.16.2.1.6 Fan motor starter location must be coordinated and integrated into the design.

601.6.2.3.21.16.3 HVAC functionality

601.6.2.3.21.16.3.1 Perform an engineering analysis to confirm piston effect is adequate for normal operations and mitigate with mechanical ventilation as needed.

601.6.2.3.21.16.3.2 Tunnel emergency ventilation systems are only to operate during an emergency except for a mode to provide cooling, worker safety ventilation, and environmental ventilation during periods of train congestion during single lining, high rail-vehicles use, and other tunnel maintenance and service.

601.6.2.3.21.16.4 Fan, Tunnel, and Bypass Dampers

601.6.2.3.21.16.4.1 Damper configuration must support normal operations, tunnel emergency operations and station emergency operations.

601.6.2.3.21.16.4.2 Fan dampers must be located between the fan and the track side of the ventilation shaft.

601.6.2.3.21.16.4.3 Bypass dampers must be located so that piston-effect air flow is routed through the ventilation shaft and not across the fan. Track dampers must be located so that air flow caused by emergency fan operations can be diverted to or from either tunnel bore.

601.6.2.3.21.16.4.4 Dampers must withstand pressures during normal and emergency operations and the static pressure caused by fan operation against a closed damper. Damper blades must be provided with seal for low leakage.

601.6.2.3.21.16.4.5 Damper actuators must account for reliability and maintainability. Actuators must be located outside of damper free opening area.

601.6.2.3.21.16.4.6 Each damper section will indicate the fully open position and the fully closed position.

601.6.2.3.21.16.4.7 Fan dampers and bypass dampers must be interlocked with their respective fans.

601.6.2.3.21.16.4.8 Fan dampers must fail open upon loss of power. Bypass dampers must fail closed upon loss of power.

601.6.2.3.21.16.4.9 Fans must be provided with sound attenuators on either or both inlet and discharge sides when required to meet noise criteria (see tenability criteria and Track Set 007). The length of sound attenuators must be based on the dynamic insertion loss levels to be provided to the mechanical designer.

601.6.2.3.21.16.4.10 EVS controls must be a coordinated design between Mechanical, Electrical and Systems. The design must provide local control for maintenance purposes that includes monitoring capabilities of fan and dampers. These monitored parameters must also be available at the LCC.

601.6.2.3.21.16.4.11 A coordinated EVS controls design must be developed for applicable stations and integrated with control from the FCC and LCC. Additional details on equipment and network requirements are included in Set 301 Network Infrastructure, Systems Set series 1000 Mechanical-Electrical and Building Systems, and Set Series 1100 Technology.

601.6.2.3.21.17 Testing

601.6.2.3.21.17.1 All fans, motors, dampers, actuators, and sound attenuators must be subject to factory testing to confirm they meet airflow, noise, vibration, power, and other requirements.

601.6.2.3.21.17.2 An emergency ventilation test plan that addresses station and interstation emergency ventilation must be developed by the contractor that accounts for airflow velocity in tunnel for tenability, egress pathway airflow velocity, fan noise, boundary conditions, control systems, station emergency ventilation, stair and elevator pressurization for all modes, testing of emergency power, and other conditions outlined in the engineering analysis and rational analysis.

601.6.2.3.21.17.3 Airflow velocity testing must be performed for tunnels and stations to validate results with criteria determined through SES and CFD modeling. The testing must approximate the actual test conditions (ambient conditions, trains in the model, doors open/closed).

601.6.2.3.21.17.4 Acceptance criteria must be defined in engineering analysis reports and approved by Sound Transit and the AHJ.

601.6.2.3.21.17.5 The test results must be reviewed for compliance with the contract and code requirements.

601.6.2.3.21.17.6 A smoke control special inspector must be retained when required by the AHJ. The special inspector must be retained during preliminary design and tasks to review the design prior to permitting.

601.6.2.3.21.18 Systems

601.6.2.3.21.18.1 EVS must be connected to the EFN . Both systems must meet the requirements of NFPA 72, including survivability, redundancy, and physical protection requirements for a FLS system. See Set 301 for additional requirement.

601.6.2.3.21.18.2 FLS system programming must have secondary password protection if any programmable equipment also serves non-FLS purposes.

601.6.2.3.21.18.3 FLS equipment must not be connected to or accessible from the public internet.

601.6.2.3.21.19 Power and Control

601.6.2.3.21.19.1 Power requirements must meet NFPA 130. See the Mechanical-Electrical and Buildings Systems Set 1000 for additional requirements.

601.6.2.3.21.19.2 Emergency power and control circuits must be designed for survivability for at least 1 hour.

601.6.2.3.21.20 Maintenance Access

601.6.2.3.21.20.1 Safe access from a floor or mezzanine must be provided for maintenance for station and tunnel emergency fans, fan motors, control panels, and associated equipment. Stair and elevator pressurization fans and dampers must be accessed from a roof that is accessible via stair or access hatch and fixed ladder with fall protection as required. See Set 804 Fall Protection.

601.6.2.3.21.20.2 When fans are in a station, they must be housed in rooms that allow access without entering the airstream.

601.6.2.3.21.20.3 Orientation and labeling of reversible fans must follow the convention that forward airflow represents exhausting of the tunnel and/or station.

601.6.2.3.21.20.4 An analysis to confirm tunnel fans and other large equipment can be removed and replaced without requiring major disassembly or removal of other equipment components, in a completed station must be conducted in accordance with Sound Transit ICIP procedure.

601.6.2.4 Operation Maintenance Facilities (Link) and Bus Maintenance Facilities

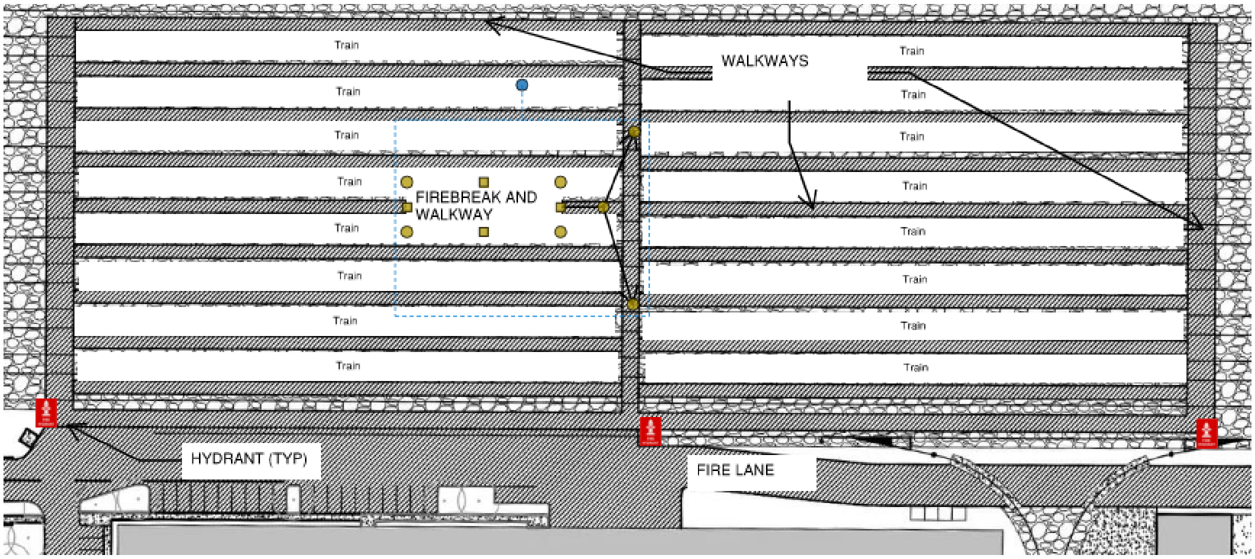
601.6.2.4.1 Operation Maintenance Facilities and Bus Maintenance Facilities may include several buildings and structures and a variety of occupancies, including Groups A-3, B, F-1, S-2, and U. This section outlines specific requirements for buildings and yards. See Section 601.6.1 Fire/Life Safety Elements for general requirements.

601.6.2.4.2 Emergency Access

601.6.2.4.2.1 Emergency access roads must be provided in accordance with the IFC. Access must be coordinated with location of FDCs, fire hydrants, and the location of the fire command center or fire control center.

601.6.2.4.2.2 The LRV storage yard must be broken up into at least two areas separated to serve as a firebreak. Walkways must be provided for firefighting access and LRV operators to access trains. The walkways must be visually discernable to LRV operators and the fire department. Fire hydrant(s) located along the fire lane near horizontal walkway access points, or equivalent as approved by the Fire/Life Safety Set 601 owner, must be provided. See Figure 601-11.

Figure 601-11: LRV Yard Fire Access



Commentary: This requirement does not have a clear code/standard basis and is intended as risk mitigation. The LRV parking plan must be coordinated with ST to account for the firebreak. The Fire Department must be conferred with to optimize the design for the site considering available space, fire lane locations, and manual firefighting capabilities.

601.6.2.4.2.3 Bus circulation roads may also serve as firefighter apparatus access roads when approved by the AHJ.

601.6.2.4.2.4 A Knox box must be at the primary fire department response point and elsewhere as required by the AHJ.

601.6.2.4.3 Construction Type/Finishes/Furnishings

601.6.2.4.3.1 Buildings and structures must be of noncombustible materials as outlined in the IBC. Combustible materials must conform to IBC Chapter 6.

601.6.2.4.4 Fire Separations

601.6.2.4.4.1 Rooms and areas must be separated with fire rated construction as required by the IBC.

601.6.2.4.4.2 Fire barriers must be provided to designate multiple control areas, as needed, so that hazardous materials do not exceed maximum allowable quantities.

601.6.2.4.4.3 Occupancy classification must be confirmed by developing a hazardous material inventory statement meeting the requirements of the IFC.

601.6.2.4.4.4 When provided, outdoor control areas must be separated from buildings with fire-rated construction or distance to meet code requirements and reduce risk to buildings.

601.6.2.4.5 FCCs/FCRs/ERERs

601.6.2.4.5.1 An FCC or FCR is not required.

601.6.2.4.6 Means of Egress

601.6.2.4.6.1 Means of egress must meet the IBC and applicable codes and standards.

601.6.2.4.7 Exits

601.6.2.4.7.1 Exits must discharge to a public way or safe dispersal area as defined by the IBC.

601.6.2.4.8 Emergency Walkways

601.6.2.4.8.1 Not applicable. For maintenance walkway requirements see Set series 500-Track.

Commentary: NFPA 130 requirement for an emergency walkway does not apply from where the rail spur originates at the revenue service trainway to, and within, the OMF yard.

601.6.2.4.9 Guardrails/Handrails

601.6.2.4.9.1 Handrails and guards must be provided per the IBC.

601.6.2.4.10 Fire Alarm and Detection System

601.6.2.4.10.1 When required by the IBC/IFC, a fire alarm system with horns and strobes must be provided.

601.6.2.4.10.2 The main fire control panel must be in an electrical room, or an alternate secured location determined by Sound Transit and acceptable to the AHJ.

601.6.2.4.10.3 A fire alarm annunciator panel must be provided at the main entry.

601.6.2.4.10.4 Smoke detectors must be provided in electrical rooms and communication rooms to detect incipient fire. Devices must be suitable for the environment.

601.6.2.4.11 Gas Detection Systems

601.6.2.4.11.1 A gas detection system must be provided when required by the IFC for battery rooms, UPS rooms, refrigeration machinery rooms, and other rooms.

601.6.2.4.12 Emergency Communication Systems

601.6.2.4.12.1 The following emergency communications systems must be provided for OMFs.

601.6.2.4.12.1.1 Two-way communication systems for areas of refuge, if provided.

601.6.2.4.12.1.2 Two-way communication system at elevator lobbies above and below grade must be provided in accordance with the IBC.

601.6.2.4.12.1.3 Two-way communication must be provided in elevator cars in accordance with the IBC.

601.6.2.4.12.1.4 Emergency radio enhancement system must be provided when required by the IFC and in Set 303 Radio.

601.6.2.4.12.1.5 Other emergency communication system must be provided as required by Set 302 Telephony.

601.6.2.4.13 Means of Egress Illumination and Exit Signs

601.6.2.4.13.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.4.14 Fire Hydrants

601.6.2.4.14.1 Fire hydrants must be provided along fire apparatus access roads and access aisles, as required by the AHJ, to protect LRV storage in the yards.

601.6.2.4.14.2 See 601.6.1 for additional requirements.

601.6.2.4.15 Automatic Sprinkler Systems

601.6.2.4.15.1 Automatic sprinklers must be provided when required by IBC/IFC. Provide an indoor fire pump and a generator (secured from the public) only if the public water supply pressure/volume is inadequate.

Commentary: The designer must evaluate the water supply and determine if a fire pump will be required. When possible, a hydrant flow test at the site, or as close as possible, must be conducted by the design team. When hydrant flow is not permitted by the AHJ other means to determine the water supply adequacy are acceptable. Information including test results must be included in the preliminary design.

601.6.2.4.15.2 Sprinkler riser must be in a secure room or rooms at the building's ground level.

601.6.2.4.15.3 Dry-pipe system volume must not exceed 750 gallons.

601.6.2.4.15.4 Central station monitoring must be provided via the fire alarm system.

601.6.2.4.16 Fire Department Connections

601.6.2.4.16.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.4.17 Standpipes

601.6.2.4.17.1 Standpipes must be provided when required by the IBC and IFC.

Commentary: Standpipe systems are not usually required for buildings with levels less than 30 feet above fire department access. Sound Transit has sometimes exceeded the code in past projects, but this practice will not be carried forward.

601.6.2.4.18 Underground Fire Mains

601.6.2.4.18.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.4.19 Portable Fire Extinguishers

601.6.2.4.19.1 Fire extinguishers must be provided in accordance with the IBC, IFC, NFPA 10, and the following:

601.6.2.4.19.2 Type 4 fire extinguisher must be provided in communications rooms, signal rooms, and other rooms as required by the IFC and NFPA 10.

601.6.2.4.19.3 Type 1 fire extinguisher must be provided in each elevator machine room.

601.6.2.4.19.4 Type 2 fire extinguishers must be provided in LRV serving bays.

601.6.2.4.19.5 Type 2 or Type 3 fire extinguishers must be provided within 30 feet or 50 feet, as required by the IFC, of hazardous material storage and use areas.

601.6.2.4.19.6 Type 1 fire extinguishers must be provided in all other areas of the building.

601.6.2.4.20 Clean Agent Systems

601.6.2.4.20.1 A clean agent system must be provided in main communication room, signal room, and other critical rooms as determined by the FLS 601 Set owner.

601.6.2.4.21 Emergency Ventilation/Smoke Control

601.6.2.4.21.1 Provide smoke control for stairs and elevators when required by the IBC.

601.6.2.5 Parking Garages

601.6.2.5.1 This section outlines specific requirements associated with parking garages. See Section 601.6.1 Fire/Life Safety Elements for general requirements.

601.6.2.5.2 Emergency Access

601.6.2.5.2.1 Parking garages must provide emergency access roads in accordance with the IFC.

601.6.2.5.2.2 Emergency access must be coordinated with the primary response location, FDCs, and fire hydrants.

Commentary: Some jurisdictions have local requirements regarding access to fire sprinkler riser and fire alarm panel and in some cases require an exterior door. This is not a Sound Transit requirement for parking garages.

601.6.2.5.3 Construction Type/Finishes/Furnishings

601.6.2.5.3.1 Garages must be of noncombustible materials as outlined in the IBC. Combustible materials must conform to IBC Chapter 6.

601.6.2.5.4 Fire Separations

601.6.2.5.4.1 Rooms and areas must be separated with fire rated construction as required by the IBC.

601.6.2.5.5 FCRs/FCCs/ERERs (Not Used)

601.6.2.5.6 Means of Egress

601.6.2.5.6.1 Means of egress including accessible means of egress must meet the IBC.

601.6.2.5.6.2 The elevator with standby power, as defined by the NEC, must serve an accessible means of egress where an accessible floor is four or more stories above or below the level of exit discharge.

601.6.2.5.7 Exits

601.6.2.5.7.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.5.8 Emergency Walkways (Not Used)

601.6.2.5.9 Guardrails/Handrails

601.6.2.5.9.1 Guardrails and handrails must meet the IBC.

601.6.2.5.10 Fire Alarm and Detection System

601.6.2.5.10.1 See Section 601.6.1 Fire/Life Safety Elements for general requirements.

601.6.2.5.10.2 A dedicated function fire alarm panel, as defined by NFPA 72, to recall elevators, monitor sprinkler and standpipe systems, monitor emergency radio communication system, and to detect fire in specific rooms as outlined herein must be provided. A single system that provides the required detection, alarm, and control functions must be provided if acceptable to the AHJ. Otherwise, independent systems as required by the AHJ must be provided.

601.6.2.5.10.3 An IFC and NFPA 72 compliant building-wide fire alarm system, including notification appliances (i.e., horns and strobes) must only be provided when required by the local AHJ.

Commentary: The State IBC does not require fire alarm systems (with notification devices) in open parking garages. However, some municipalities require alarm system based upon building size (i.e., all buildings greater than 5,000 square feet). When such a rule has been locally adopted, provide a full fire alarm system.

601.6.2.5.10.4 When garages and stations are co-located and both require a fire alarm system, each must have a dedicated fire alarm system.

601.6.2.5.10.5 The main fire control panel must be in the electrical room, or an alternate secured location determined by Sound Transit and acceptable to the AHJ. When practical, locate the panel near the fire department primary response point.

601.6.2.5.10.6 Field devices must be weatherproof.

601.6.2.5.10.7 When a fire alarm is required, provide audible and visual notification throughout including rooftop parking areas. Rooftop visual alarms must be placed for direct viewing.

Commentary: Bright daylight (especially when the canopy is glass) will significantly diminish reflective light. NFPA 72 prescriptive placement using squares based upon candela rating and indirect viewing (reflective light) is not applicable to outdoor locations per NFPA 72. With AHJ approval VMS may be used as primary visual notification at station platforms.

601.6.2.5.10.8 Cable and wire must be rated for wet conditions.

601.6.2.5.10.9 Smoke or heat detectors must be provided in electrical rooms, communication rooms, and closets, and elsewhere when required by code. Devices must be suitable for the environment.

601.6.2.5.11 Gas Detection Systems

601.6.2.5.11.1 A hydrogen gas detection system must be provided for UPS systems. See Set 1000 Mechanical-Electrical and Buildings Systems for additional requirements.

601.6.2.5.12 Emergency Communication Systems

601.6.2.5.12.1 A two-way CES communication system must be provided at elevator lobbies above and below grade in accordance with the IBC.

601.6.2.5.12.2 A two-way communication must be provided in elevator cars in accordance with the IBC. See Telephony Set 302 for additional information.

601.6.2.5.12.3 Emergency Radio Enhancement system must be provided when required by the IFC and in Set 303 Radio.

601.6.2.5.12.4 See 601.6.1 and the Set 302 Telephony for additional requirements.

601.6.2.5.13 Means of Egress Illumination and Exit Signs

601.6.2.5.13.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.5.14 Fire Hydrants

601.6.2.5.14.1 Fire hydrants must be provided to comply with the IFC and local amendments.

601.6.2.5.15 Automatic Sprinkler Systems

601.6.2.5.15.1 Automatic sprinklers must be provided throughout enclosed parking garages with a fire area that exceeds 12,000 square feet and open parking garages with a fire area that exceeds 48,000 square feet in accordance with the IBC/IFC and NFPA 13.

601.6.2.5.15.2 Provide an indoor fire pump and a generator (secured from the public) only if the public water supply pressure/volume is inadequate.

Commentary: The design must evaluate the water supply and determine if a fire pump will be required. When possible, a hydrant flow test at the site, or as close as possible, will be conducted by the Design Builder. When hydrant flow is not allowed by the AHJ, other means of determining flow data are acceptable. Information including test results must be included in the initial basis of design.

601.6.2.5.15.3 Sprinkler riser must be in a secure room or rooms at the building's ground level. Locate the sprinkler riser room near the fire department primary response point.

601.6.2.5.15.4 Dry-pipe system volume must not exceed 750 gallons.

601.6.2.5.15.4.1 Exception: Systems larger than 750 gallons are acceptable when water delivery time analysis has been conducted and approved by the FLS 600 Set owner.

601.6.2.5.15.5 Central station monitoring must be provided via the fire alarm system.

601.6.2.5.15.6 Provide automatic sprinklers in the communication room.

Commentary: Sound Transit specifies clean agent protection for Link communication rooms. This provision does not apply to communication rooms serving only parking garages.

601.6.2.5.16 Fire Department Connections

601.6.2.5.16.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.5.17 Standpipes

601.6.2.5.17.1 A Class I manual dry standpipe system with fire hose valves at stair landings and other locations as required by the AHJ must be provided when required by the IFC.

Commentary: For open parking garages the requirement for standpipe systems is typically determined by the floor height exceeding 30 feet above or below fire department access in accordance with IBC/IFC 905. Confirm with AHJ.

Commentary: Fire hose valves are usually required at every exit stair landing, but additional hose valves may be required by the AHJ to be within 150 feet to 200 feet from all areas per the IBC/IFC and NFPA 14. The distance must be measured based upon hose lay down. Do not evaluate using drawing circles.

601.6.2.5.17.2 A single FDC serve both the dry standpipe and the automatic sprinkler systems must be provided unless otherwise required by the AHJ.

601.6.2.5.18 Underground Fire Service Mains

601.6.2.5.18.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.5.19 Portable Fire extinguishers

601.6.2.5.19.1 Type 1 or Type 2 fire extinguishers in tamper resistant cabinets must be provided to meet the IFC.

601.6.2.5.19.2 Fire extinguisher cabinet must be red. Alternatively, red sign located above the fire extinguisher is acceptable.

601.6.2.5.20 Clean Agent Systems (Not Used)

601.6.2.5.21 Emergency Ventilation/Smoke Control

See Set 1003 Building Monitor and Control for mechanical ventilation requirements for areas not considered an open parking garage.

601.6.2.6 Bus Rapid Transit Stations

601.6.2.6.1 This section outlines specific requirements associated with bus rapid transit stations. These facilities typically have occupancy classification as follows; platforms (A-3), mechanical/electrical (S-2), and elevator lobbies under 750 square feet (B). See Section 601.6.1 Fire/Life Safety Elements general requirements that also apply.

601.6.2.6.2 Emergency Access

601.6.2.6.2.1 Provide emergency access roads in accordance with the IFC.

601.6.2.6.2.2 Access must be coordinated with the primary response location, fire department connections, and fire hydrants.

601.6.2.6.2.3 Emergency access to platforms may be via the highway served by the station.

601.6.2.6.2.4 A Knox box must be at the primary fire department response point and elsewhere as required by the AHJ.

601.6.2.6.3 Construction Type/Finishes/Furnishings

601.6.2.6.3.1 Stations must be of non-combustible construction (Type I or II) as defined by the IBC. Combustible materials must conform to IBC Chapter 6.

601.6.2.6.4 Fire Separations

601.6.2.6.4.1 Rooms and areas must be separated with fire rated construction as required by the IBC. See 608.1.1 for additional requirements.

601.6.2.6.5 FCCs/FCRs/ERERs (Not Used)

601.6.2.6.6 Means of Egress

601.6.2.6.6.1 Means of egress must meet IBC requirements. When two means of egress are required from the platform, exiting must be to the public way (dedicated bus lane) or a safe dispersal area. Confirm with the AHJ.

601.6.2.6.6.2 Accessible means of egress must meet the IBC. When two accessible means of egress are required from the platform, a safe dispersal area must be separated from the platform by 50 feet, or equivalent. Designer must obtain concurrence in writing with the AHJ.

Commentary: See IBC provisions for area of rescue assistance for criteria that could potentially be used (with AHJ concurrence) if a 50-foot separation cannot be met.

601.6.2.6.7 Exits

601.6.2.6.7.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.6.8 Emergency Walkways (Not Used)

601.6.2.6.9 Guardrails/Handrails

601.6.2.6.9.1 Guardrails and handrails must meet the IBC.

601.6.2.6.10 Fire Alarm and Detection System

601.6.2.6.10.1 A dedicated function fire alarm system must be provided for elevator recall, monitor emergency radio communication system, monitor other systems as required, and to detect fire in specific rooms as outlined herein. A single system or multiple systems may be provided depending upon the station size and configuration.

601.6.2.6.10.2 An IFC and NFPA 72 compliant building-wide fire alarm system including notification appliances (i.e., horns and strobes) must only be provided when required by the local AHJ.

601.6.2.6.10.3 The main fire control panel must be in the electrical room, or an alternate secured location. Locate the panel near the fire department primary response point.

601.6.2.6.10.4 Field devices must be weatherproof.

601.6.2.6.10.5 Cable and wire must be rated for wet conditions.

601.6.2.6.11 Gas Detection Systems

601.6.2.6.11.1 See Section 601.6.1 Fire/life Safety Elements for general requirements.

601.6.2.6.12 Emergency Communication Systems

601.6.2.6.12.1 A two-way customer emergency station (CES) communication system must be provided at elevator lobbies above and below grade in accordance with the IBC.

601.6.2.6.12.2 A two-way communication system must be provided in elevator cars in accordance with the IBC. See Operational Communications and Architectural sections for additional information.

601.6.2.6.12.3 See Section 601.6.1 Fire/Life Safety Elements and the Telephony Set 301 for additional requirements.

601.6.2.6.13 Means of Egress Illumination and Exit Signs

601.6.2.6.13.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.6.14 Fire Hydrants

601.6.2.6.14.1 Fire hydrants must be provided to comply with the IFC and local amendments.

601.6.2.6.15 Automatic Sprinkler Systems

601.6.2.6.15.1 Automatic sprinklers must be provided when required by the IBC/IFC or local rules. See series 800 Architectural for painting of pipe and others architectural considerations.

Commentary: Automatic sprinkler systems are not common to Bus Rapid Transit Stations.

601.6.2.6.16 Fire Department Connections

601.6.2.6.16.1 See Section 601.6.1 Fire/Life Safety Elements for requirements if FDCs are provided.

601.6.2.6.17 Standpipes

601.6.2.6.17.1 When required, provide a Class I manual dry standpipe system with fire hose valves in accordance with the IFC and NFPA 14.

Commentary: Standpipes for fire protection are not common to Bus Rapid Transit stations.

601.6.2.6.18 Underground Fire Service Mains

601.6.2.6.18.1 See 606.6.1 for requirements.

601.6.2.6.19 Portable Fire extinguishers

601.6.2.6.19.1 Provide Type 1 fire extinguishers to achieve full coverage in back-of-house areas but omit from public areas.

Commentary: Sound Transit prefers to omit fire extinguishers from at-grade bus and light rail station, Sounder, Bus Rapid Transit, and similar locations due to vandalism and theft. Seek concurrence with AHJ for omission where omission is not clearly allowed by code.

601.6.2.6.20 Clean Agent Systems (Not Used)

601.6.2.6.21 Emergency Ventilation/Smoke Control (Not Used)

601.6.2.7 Commuter Rail (Sounder) Stations

601.6.2.7.1 This section outlines specific requirements associated with Commuter Rail Stations. See Section 601.6.1 Fire/Life Safety Elements general requirements that also apply.

601.6.2.7.2 Emergency Access

601.6.2.7.2.1 Provide emergency access roads in accordance with the IFC.

601.6.2.7.2.2 Access must be coordinated with the primary response location, fire department connections, and fire hydrants.

601.6.2.7.2.3 A Knox box must be at the primary fire department response point and elsewhere as required by the AHJ.

601.6.2.7.3 Construction Type/Finishes/Furnishings

601.6.2.7.3.1 Stations must be of non-combustible construction (Type I or II) as defined by the IBC Chapter 6. Combustible materials must conform to IBC Chapter 6.

601.6.2.7.4 Fire Separations

601.6.2.7.4.1 Provide fire rated construction as required by the IBC and NFPA 130. See 608.1.1 for additional requirements.

601.6.2.7.5 FCCs/FCRs/ERERs (Not Used)

601.6.2.7.6 Means of Egress

601.6.2.7.6.1 See Section 601.6.1 Fire/Life Safety Elements for general requirements.

601.6.2.7.6.2 Means of egress must be designed to NFPA 130 and IBC requirements including local amendments.

601.6.2.7.6.3 Station platforms must be designed to meet the 4-minute platform and 6-minute station evacuation time provision of NFPA 130, or by justifying additional time through a performance-based means of egress analysis.

Commentary: Applying the IBC to calculate capacity of means of egress for the station platform is not required unless specifically required by the local AHJ.

601.6.2.7.6.4 Ridership projections used for determining the platform occupant load will be based upon 10- or 20-year future ridership.

601.6.2.7.6.5 The platform occupant load must be the sum of the calculated train load of trains entering the station plus the entraining load of persons awaiting trains a specified time.

601.6.2.7.6.6 Occupant load signs must be provided for the platform(s) that reflect the design occupant load.

601.6.2.7.6.7 Means of egress calculation that disclose all assumptions and parameters and are intuitive to Sound Transit and the AHJ must be developed and included in the architectural code sheets of the permit drawings.

601.6.2.7.6.8 Physical barriers along trainway near stations and garages must be provided to prevent crossing except at designated crossing locations. See Set 102 At-grade Crossings for additional requirements.

601.6.2.7.6.9 Bollards or equal barriers must be provided to prevent exits from being obstructed. See series 800 Architectural for additional information.

601.6.2.7.6.10 Accessible means of egress must meet the IBC.

601.6.2.7.7 Exits

601.6.2.7.7.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.7.8 Emergency Walkways (Not Used)

601.6.2.7.9 Guardrails/Handrails

601.6.2.7.9.1 Guardrails and handrails must meet the IBC.

601.6.2.7.10 Fire Alarm and Detection System

601.6.2.7.10.1 A dedicated function fire alarm system for elevator recall, to monitor sprinkler and standpipe systems, monitor emergency radio communication system, and to detect fire in specific rooms as outlined herein must be provided. A single system which provides the required detection, alarm, and control functions must be provided if acceptable to the AHJ. Otherwise, independent systems as required by the AHJ must be provided.

601.6.2.7.10.2 An IFC and NFPA 72 compliant building-wide fire alarm system including notification appliances (i.e., horns and strobes) must only be provided when required by the local AHJ.

Commentary: A fire alarm system has not been required for at-grade Sounder stations but could be required by the AHJ where the platform is separate from grade or provided with a large canopy and secured with a fence or barrier for example.

601.6.2.7.10.3 The fire control panel must be located in an electrical room, or an alternate secured location determined by Sound Transit and acceptable to the AHJ. When practical, locate the panel near the fire department primary response point.

601.6.2.7.10.4 Field devices must be weatherproof.

601.6.2.7.10.5 Cable and wire must be rated for wet conditions.

601.6.2.7.11 Gas Detection Systems

601.6.2.7.11.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.7.12 Emergency Communication Systems

601.6.2.7.12.1 Two-way CES must be provided at elevator lobbies above and below grade in accordance with the IBC and Set 302 Telephony.

601.6.2.7.12.2 A two-way communication system must be provided in elevator cars in accordance with the IBC. See 601.6.1 Fire/Life Safety Elements and Set 302 Telephony for additional requirements.

601.6.2.7.13 Emergency Lighting

601.6.2.7.13.1 See Set series 1000 Mechanical-Electrical and Buildings Systems for requirements.

601.6.2.7.14 Fire Hydrants

601.6.2.7.14.1 Fire hydrants must be provided to comply with the IFC and local amendments.

601.6.2.7.15 Automatic Sprinkler Systems

601.6.2.7.15.1 Automatic sprinklers must be provided when required by the IBC/IFC or local rules. See Set series 800 Architectural for painting of pipe and others architectural considerations.

601.6.2.7.16 Fire Department Connections

601.6.2.7.16.1 See Section 601.6.1 Fire/Life Safety Elements if FDCs are provided.

601.6.2.7.17 Standpipes

601.6.2.7.17.1 When required, a Class I manual dry standpipe system with fire hose valves in accordance with the IFC and NFPA 14 must be provided.

Commentary: Standpipes for fire protection are not common to Commuter Rail Stations.

601.6.2.7.18 Underground Fire Service Mains

601.6.2.7.18.1 See Section 601.6.1 Fire/Life Safety Elements for requirements.

601.6.2.7.19 Portable Fire Extinguishers

601.6.2.7.19.1 Type 1 fire extinguishers must be provided to achieve full coverage in back-of-house areas but omit from public areas.

Commentary: Sound Transit prefers to omit fire extinguishers from at-grade bus and light rail station, Commuter Rail, BRT, and similar locations due to vandalism and theft. Seek concurrence with AHJ for omission.

601.6.2.7.20 Clean Agent Systems (Not Used)

601.6.2.7.21 Emergency Ventilation/Smoke Control (Not Used)

601.6.2.8 Wayside TPSS and Signal Bungalows (including prefabricated facilities)

601.6.2.8.1 This section outlines specific requirements associated with traction power substations (TPSS), signal bungalows/houses and communication bungalows not attached to or located in a station. See Section 601.6.1 Fire/Life safety Elements general requirements that also apply.

601.6.2.8.2 Emergency Access

601.6.2.8.2.1 Emergency access roads must meet the IFC.

601.6.2.8.2.2 A Knox box must be at the primary fire department response point and elsewhere as required by the AHJ.

601.6.2.8.2.3 Construction Type/Finishes/Furnishings

601.6.2.8.2.3.1 Construction must be noncombustible as outlined in the IBC. Factory-built structures meeting WAC 296-150F are acceptable.

601.6.2.8.3 Fire Separations (Not Used)

601.6.2.8.4 FCCs/FCRs/ERERs (Not Used)

601.6.2.8.5 Means of Egress

601.6.2.8.5.1 Means of egress must meet the IBC.

601.6.2.8.5.2 A landing meeting the requirements of the IBC must be provided at the entry door(s).

601.6.2.8.5.3 Where access to the crawl space is provided by a floor access hatch a fixed ladder with extension rail/pole and access hatch meeting WAC 296-876 with protection of the floor opening using a guard meeting WAC 296-880-40015 must be provided.

601.6.2.8.5.4 The crawl space must be characterized with respect to confined space requirements and built to the applicable codes and standards. See Set 001 General for requirements.

601.6.2.8.5.5 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.8.6 Exits

601.6.2.8.6.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.8.7 Emergency Walkways (Not Used)

601.6.2.8.8 Guardrails/Handrails

601.6.2.8.8.1 Guardrails and handrails must meet the IBC.

601.6.2.8.9 Fire Alarm and Detection System

601.6.2.8.9.1 Smoke and heat detection meeting the spacing requirements of NFPA 72 and powered and monitored by the LCMS PLC must be provided.

601.6.2.8.9.2 Fire detection must be monitored by the LCC.

Commentary: This is not a fire alarm system. Provide no panel, notification devices or manual pull stations)

601.6.2.8.9.3 The LCMS must be programmed as follows:

601.6.2.8.9.3.1 Smoke detection provide notification to the LCC (TPSS and SB/SH)

601.6.2.8.9.3.2 Heat detection provides notification to the LCC (TPSS and SB/SH)

601.6.2.8.9.3.3 Heat and smoke detection combined trips the TPSS DC power. (TPSS only)

601.6.2.8.10 Gas Detection Systems

601.6.2.8.10.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.8.11 Emergency Communication Systems

601.6.2.8.11.1 An ETEL must be provided at or near the entrance to the building. See Section 601.6.1 Fire/Life Safety Elements and the Operational Communications Set series 300 for additional requirements.

601.6.2.8.12 Means of Egress Illumination and Exit Signs

601.6.2.8.12.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.8.13 Fire Hydrants

601.6.2.8.13.1 See Section 601.6.1 Fire/Life Safety Elements.

601.6.2.8.14 Automatic Sprinkler Systems (Not Used)

601.6.2.8.15 Fire Department Connections (Not Used)

601.6.2.8.16 Standpipes (Not Used)

601.6.2.8.17 Underground Fire Service Mains (Not Used)

601.6.2.8.18 Portable Fire extinguishers

601.6.2.8.18.1 A Type 4 fire extinguishers must be provided. See Section 601.6.1 Fire/Life Safety Elements for additional information.

601.6.2.8.19 Clean Agent (Not Used)

601.6.2.8.20 Emergency Ventilation/Smoke Control (Not Used)

601.7 Engineering Management Requirements

601.7.1 Interface and Integration Management

601.7.1.1 Account for all interfaces to provide a fully integrated design. Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructible documentation and functional designs must be followed.

601.7.1.2 Develop block diagrams, sequences of operation, interface tables, and points lists must be developed to clarify design and design intent. Sound Transit guidance drawing tailored to the project must be used.

601.7.1.3 Space needs for equipment in FCCs and FCRs must be accounted for. Scaled drawings must be developed to validate design and layout.

601.7.1.4 A separate sequence of operation matrix must be provided for fire alarm and clean agent systems.

601.7.1.5 See Sets 301, 302, 303, 304, 320, 322, 323, 324, 335, and 1205 for interface and integration requirements.

601.7.1.6 Each major link extension project must provide staff support for a committee regarding FLS to review and discuss design changes, and advise on construction, testing, training, and certification requirements in accordance with Federal Transit Administration C 5800 requirements.

601.7.2 Design Management

601.7.2.1 A basis of design study and report must be provided for tunnel and station EVS must be developed in accordance with Engineering Procedure EP-03. See 601.6.5.20 for CFD and SES modelling, engineering analysis, and report requirements.

601.7.2.2 A reliability analysis and report for EVS must be developed to meet NFPA 130 Chapter 7 requirements. The analysis must include electrical, mechanical, and control systems.

601.7.2.3 A functionality, reliability and control engineering analysis and report must be developed in accordance with EP-03 that addresses NFPA 130 Chapter 11 requirements including hybrid Fire Alarm/PA systems for alarm notification and emergency voice messages, when provided.

601.7.2.4 A code study must be prepared at preliminary design in accordance with EP-03. The study must identify applicable codes including IBC Chapters 3-11, 30, 31, IFC 4-12, NFPA 130, state amendments, and local amendments and municipal codes.

601.7.2.5 A means of egress analysis, and associated CFD tenability study when required, must be prepared for light rail (Link) and commuter rail (Sounder) stations during preliminary design and presented to the AHJ during a preapplication meeting during preliminary design. See 601.6.5.5, 601.6.9.6, and 601.6.5.5.11.

601.7.2.6 Letters of concurrence or other formal agreements must be developed during preliminary design as outlined in EP-03 to clarify code application and interpretations where the codes and standards are not clear or when the design does not meet the code prescriptively. Examples of where formal agreements (e.g., Letter of Concurrence) must be pursued are referenced throughout this set and summarized in Table 601-13.

Table 601-13: Formal Agreements

Set Section	Set Title
601.6.1.10.17.19.1	EVS Control of Station Emergency Ventilation
601.6.1.15.27	Dry-Pipe System Sprinkler Auxiliary Drains
601.6.1.15.28	Clean Agent in Lieu of Automatic Sprinkler
601.6.1.17.20.3	Trainway Horizontal Standpipes Design Criteria
601.6.1.17.29	Standpipe Sectional Valves
601.6.1.17.30	Non-UL Listed Air Release/Vacuum Valves
601.6.2.1.2	Trainway Emergency Access Points
601.6.2.2.2	Emergency Access to Tunnels and Portals
601.6.2.3.3.6	Open Station Definition Validation
601.6.2.3.4.2 (Table 601-6)	Non-Rated Elevator Doors
601.6.2.3.6.19	Evacuation Elevators
601.6.2.3.6.21	Escalators as a Means of Egress
601.6.2.3.7.2	Separation of Exits
601.6.2.3.10.3 – 601.6.2.3.10.7	Fire Alarm/PA Hybrid Design for Alarm/EVACS
601.6.2.3.10.13	Omit Manual Pull Stations at Light Rail Stations
601.6.2.3.15.3	Fire Protection for Open Stations
601.6.2.3.19.3	Omit Portable Fire Extinguishers for At-Grade Stations
601.6.2.10.6	Means of Egress for Bus Rapid Transit Stations

601.7.2.6.1 Draft agreements and LOCs (Letter of Concurrence) must be discussed and agreed to with Sound Transit, including the Set 601 Fire/Life safety owner, prior to seeking approval from the AHJ.

601.7.2.7 Subsystem element engineering analysis and preliminary engineering must be effectively planned, completed, and integrated into the final design.

601.7.3 Manufacturing and Construction Management

601.7.3.1 Fire protection and life safety system construction submittals (e.g., fire protection and fire alarm shop drawings and calculations) to the AHJ must follow EOR review and approval.

601.7.3.2 Construction of fire protection systems and life safety systems must not begin until shop drawings and calculation are approved by the EOR and the AHJ.

601.7.3.3 AHJ inspection for fire protection and life safety systems must be conducted and follow local requirements. Issues that cannot be resolved without delay or additional cost to Sound Transit must be reported to ST.

Commentary: Sound Transit has experience in the resolution of inspection comments from various agencies. Sound Transit encourages contractors to collaborate with Sound Transit SMEs (Subject Matter Expert) to resolve correction notices.

601.7.3.4 Fire protection and life safety systems shop drawings, product information, calculations, and other materials must be submitted for review and approval by the EOR. See Sound Transit Construction Management Plan or Division 1 specifications.

601.7.4 Installation Management

601.7.4.1 Fire alarm systems must be monitored by a central station when final approval for the fire safety systems is issued by the fire department. After final approval fire life safety system impairments must be managed in accordance with the IFC.

Light rail stations are often completed months ahead of revenue service. Fire alarm monitoring is typically required by the AHJ as a condition of obtaining final fire department approval. Sound Transit also requires monitoring to mitigate risk and meet insurance requirements when applicable.

601.7.5 Inspection and Testing Management

601.7.5.1 Design must adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

601.7.5.2 Fire protection and life safety systems for Link stations and trainways must be commissioned in accordance with NFPA 3, or equal. Test records must be developed and provided to Sound Transit.

601.7.5.3 Test failures must be retested and a record provided that documents the correction. A log of inspection and test failures must be maintained.

601.7.5.4 Integrated fire protection/life safety system testing for Link stations and trainways must verify the operation and functions perform as intended in accordance with NFPA 4, or equal.

601.7.5.5 Personnel responsible for performing commissioning activities must be qualified as defined by the IBC, IFC, NFPA 3 and other applicable NFPA standards.

601.7.5.6 AHJ inspections of fire and life safety systems and equipment must be completed with documentation of corrections and final approval provided to ST.

601.7.6 Training, Pre-Revenue Operations, Required Materials

601.7.6.1 Fire department familiarization, training, and drills must be provided for Link stations and trainways, and other facilities when required, prior to revenue service. This training is provided by Sound Transit but must be accounted for in the schedule and accommodated by the contractor.

601.7.6.2 The following materials must be developed, reviewed, and approved by ST, and provided at the FCC/FCR for fire department emergency reference:

601.7.6.2.1 Station fire response drawings

601.7.6.2.2 Guideway fire response drawings

601.7.6.2.3 Fire valve list

601.7.6.2.4 FACP operating procedure

601.7.6.2.5 FireWorks viewing instruction

601.7.6.2.6 Elevator level diagram

601.7.6.2.7 Certificate of occupancy

601.7.6.2.8 Photo labeled display of FCC equipment

601.7.6.2.9 Event mode matrix

601.7.6.2.10 EVCP viewing instruction

601.7.6.2.11 Traction power disconnect diagrams

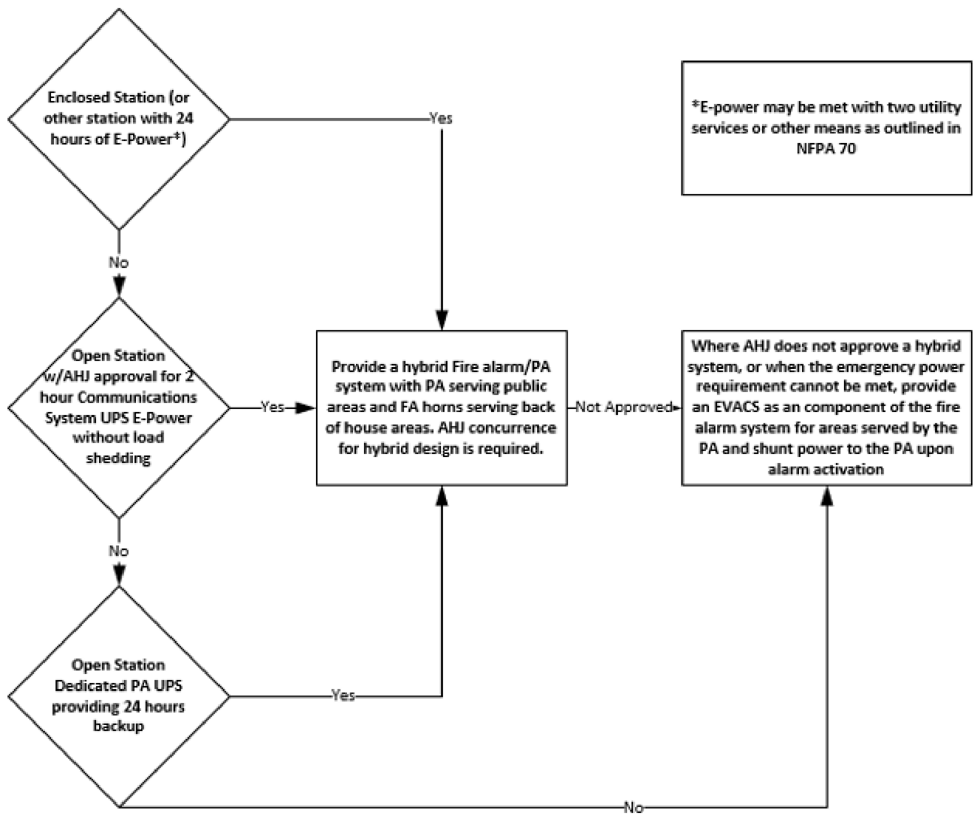
601.7.7 Certification Management

601.7.7.1 Certificates of occupancy, operating licenses and permits that have been issued by the AHJ must be delivered to Sound Transit prior to revenue service.

601.7.7.2 Sound Transit safety certification of fire protection and life safety systems must be prior to revenue service.

601.7.7.3 When facilities are constructed in WSDOT right of way or other locations where a building permit is not required, self-certification must be conducted by qualified third party.

601.8 APPENDIX A – STATION PA-EVACS DECISION FLOW CHART



END SET - 601

701 GEOTECHNICAL ENGINEERING

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TABLES

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SET - 701 GEOTECHNICAL ENGINEERING

701.1 INTRODUCTION

701.1.1 Document Scope

701.1.1.1 This Set establishes the design criteria for Geotechnical Engineering of Light Rail, Commuter Rail, Building, BRT, and Tunnel. This document supplements Set 720 Building Structures, Set 721 Bridges and Elevated Structures, and Set 722 Tunnel Structures. Except where modified or supplemented by this set, the structural design must meet the requirements of Set 720 Building Structures, Set 721 Bridges and Elevated Structures, and Set 722 Tunnel Structures. For special design conditions that are not specifically covered by these criteria, the DOR must bring them to the attention of Sound Transit to determine the technical source for the design criteria.

701.1.1.2 System Interface Requirement Sets: Stray Current Corrosion Control (222), Building Structures (720), Bridge and Elevated Structures (721), Tunnel Structures (722), Vehicle Clearances and Track Spacing (520), Track Construction (522) and Storm Drainage (901).

701.1.1.3 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 701 owner to determine the technical source for the design criteria.

701.1.2 Regulations, Codes, Standards, and Guidelines

Latest code version must govern. If the code version is different from what is referenced in this set, the DOR must consult with the Requirements Set 701 owner for further clarification.

701.1.2.1 International Regulations, Codes, Standards, and Guidelines (Not Used)

701.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

701.1.2.2.1 American Association of State Highway and Transportation Officials (AASHTO) Guide Specifications for LRFD Bridge Design Specifications.

701.1.2.2.2 American Association of State Highway and Transportation Officials (AASHTO) Guide Specifications for LRFD Seismic Bridge Design.

701.1.2.2.3 American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals.

701.1.2.2.4 American Association of State Highway and Transportation Officials (AASHTO) Road Tunnel Design and Construction Guide Specification

701.1.2.2.5 American Railway Engineering and Maintenance-of-Way Association (AREMA).

701.1.2.2.6 American Society of Civil Engineers (ASCE) Geotechnical Baseline Reports for Construction.

701.1.2.2.7 American Society of Civil Engineers (ASCE). “Assessment of the Liquefaction Susceptibility of Fine-Grained Soils, ASCE Journal of Geotechnical and Geoenvironmental Engineering." Bray, J.D., and Sancio, R.B., 2006, Vol. 132, No. 9, pp. 1165-1172.

701.1.2.2.8 Federal Highway Administration (FHWA-IF). Geotechnical Engineering Circular No. 4, Ground Anchors and Anchored Systems. Publication No. FHWA-IF-99-015.

701.1.2.2.9 Federal Highway Administration and the National Highway Institute (FHWA-NHI). Soil Nail Walls Reference Manual. Publication No. FHWA-NHI-14-007.

701.1.2.2.10 Federal Highway Administration (FHWA-SA). Geotechnical Engineering Circular No. 6, Shallow Foundations. Publication No. FHWA-SA-02-054.

701.1.2.2.11 Federal Highway Administration and the National Highway Institute (FHWA-NHI). Design and Construction of Driven Pile Foundations Reference Manual. Volumes I and II. Publication Nos. FHWA-NHI-05-042 and FHWA-NHI-05-043.

701.1.2.2.12 Federal Highway Administration and the National Highway Institute (FHWA-NHI). Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volumes I and II. Publications Nos. FHWA-NHI-10-024 and FHWA-NHI-10-025.

701.1.2.2.13 Federal Highway Administration and the National Highway Institute (FHWA-NHI). Drilled Shafts: Construction Procedures and LRFD Design Methods (FHWA-NHI-10-016).

701.1.2.2.14 Federal Highway Administration and the National Highway Institute (FHWA-NHI). LRFD Seismic Analysis and Design of Transportation Geotechnical Features and Structural Foundations. Publication No. FHWA-NHI-11-032.

701.1.2.2.15 Federal Highway Administration and the National Highway Institute (FHWA-NHI). Selection of Spread Footings on Soils to Support Highway Bridge Structures. Publication No. FHWA-RC/TD-10-001.

701.1.2.2.16 Federal Highway Administration and the National Highway Institute (FHWA-NHI). Soils and Foundation Volumes I and II. Publication Nos. FHWA-NHI-06-088 and FHWA-NHI-06-089.

701.1.2.2.17 Federal Highway Administration and the National Highway Institute (FHWA-NHI). Subsurface Investigations – Geotechnical Site Characterization. Publication No. FHWA-NHI-01-031.

701.1.2.2.18 Federal Highway Administration and the National Highway Institute (FHWA-NHI). Technical Manual for Design and Construction of Road Tunnels – Civil Elements (FHWA-NHI-10-034).

701.1.2.2.19 National Cooperative Highway Research Program (NCHRP). Seismic Analysis and Design of Retaining Walls, Buried Structures, Slopes, and Embankment: NCHRP Report 611, 2008 Transportation Research Board.

701.1.2.2.20 Naval Facilities Engineering Systems Command (NAVFAC). Design Manual: Soil Mechanics, Foundations and Earth Structures, DM 7.

701.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

701.1.2.3.1 Washington Administrative Code (WAC).

701.1.2.3.2 Washington State Department of Transportation (WSDOT) Bridge Design Manual (BDM).

701.1.2.3.3 WSDOT Geotechnical Design Manual (GDM).

701.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

701.1.2.4.1 "Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils," Journal of Geotechnical and Geoenvironmental Engineering, ASCE, V. 127, No. 10, p 817-833. Youd, T.L., Idriss, I.M. Andrus, R.D. Arango, I., Castro, G., Christian, J.T., Dobry, R.,Youd, T.L., Idriss, I.M. Andrus, R.D. Arango, I., Castro, G., Christian, J.T., Dobry, R.,Liam Finn, W.D.L., Harder, L.F., Jr., Hynes, M.E., Ishihara, K., Koester, J.P., Liao, S.S.C., Marcuson, W.F., III, Martin, G.R., Mitchell, J.K., Moriwaki, Y., Power, M.S., Robertson, P.K., Seed, R.B., Stokoe, K.H., II, 2001.

701.1.2.5 Other Jurisdictions (Not Used)

701.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines (Not Used)

701.1.3 Abbreviations and Acronyms

701.1.3.1 AASHTO –American Association of State Highway and Transportation Officials

701.1.3.2 ACI-American Concrete Institute

701.1.3.3 AHJ–authority having jurisdiction

701.1.3.4 BDM–bridge design manual

701.1.3.5 BRT–bus rapid transit

701.1.3.6 DNR–Department of Natural Resources

701.1.3.7 DOR–designer of record

701.1.3.8 GBR–geotechnical baseline report

701.1.3.9 GDM–geotechnical design manual

701.1.3.10 GDR–geotechnical data report

701.1.3.11 GFW–guideway foundation wall

701.1.3.12 GIMP–geotechnical instrumentation monitoring plan

701.1.3.13 GIP–geotechnical special inspection plan

701.1.3.14 GRR–geotechnical recommendation report

701.1.3.15 GSIP–geotechnical site investigation plan

701.1.3.16 ODE–operating design earthquake

701.1.3.17 MDE–maximum design earthquake

701.1.3.18 MSE–mechanically stabilized earth

701.1.4 Definitions and Classifications (Not Used)

701.1.5 References (Not Used)

701.2 STAKEHOLDER NEEDS (NOT USED)

701.2.1 Passenger Experience (Not Used)

701.2.2 Operational Needs

701.2.2.1 Limit seismic deformations for retaining walls supporting, protecting, or impacting track after ODE to minimize interruption of train service.

701.2.2.2 Limit seismic deformations for at-grade track after ODE to minimize interruption of train service.

701.2.2.3 Limit settlement after construction for retaining walls supporting, protecting, or impacting track to ensure train operation.

701.2.2.4 Limit settlement under normal service for at-grade track to ensure train operation.

701.2.2.5 Durability of MSE wall with steel reinforcement.

701.2.3 Maintenance Needs (Not Used)

701.2.4 Safety Needs

701.2.4.1 Design retaining walls to No Collapse and Life Safety under extreme seismic event.

701.2.4.2 Slope stability under normal service, seismic and rain conditions.

701.2.5 Security Needs (Not Used)

701.2.6 Reliability, Availability and Maintainability Needs (Not Used)

701.2.7 Environmental and Sustainability Needs (Not Used)

701.3 SYSTEM REQUIREMENTS

701.3.1 General Requirements

701.3.1.1 The DOR must follow design policy, performance, and risk acceptance of WSDOT BDM, GDM, and local AHJ requirements for building structures, except the requirements explicitly stated in this Set.

701.3.1.2 BRT Design

701.3.1.2.1 Sound Transit two-level earthquake, the ODE, and the MDE do not apply to BRT design. The BRT project building seismic design must follow Set 720 Building Structures. The BRT project bridge design seismic parameters must follow WSDOT BDM and GDM.

701.3.1.2.2 The BRT project geotechnical design must follow everything else in Set 701.

701.3.2 Site Investigation and Laboratory Testing

701.3.2.1 The DOR must follow the requirements in this Set and AHJ's applicable codes (for building structures) to prepare and implement a site investigation and geotechnical laboratory testing program to meet the minimum requirements for subsurface investigations, laboratory testing, and selection of design properties.

701.3.2.2 Minimum Requirements of Field Exploration

701.3.2.2.1 Retaining Walls

701.3.2.2.1.1 If the DOR identifies the need for soil nail walls, the DOR must follow FHWA-NHI-14-007 Soil Nail Walls Reference Manual and WSDOT GDM 15-3.4.1 for field investigation regarding exploration type, depth, and spacing in soil nail wall design. The DOR must follow WSDOT GDM 15-3.4.2.1 and excavate at least one test pit to evaluate stand-up time of the excavation surface.

701.3.2.2.1.2 For other retaining wall types, the DOR must space borings less than 200 feet apart alternating from in front of the wall to behind the wall. The DOR must provide at least one boring for each wall. For special wall types like anchored walls, the DOR must conduct additional borings.

701.3.2.2.1.3 The Boring depth must follow AASHTO LRFD Bridge Design Specifications Table 10.4.2-1.

701.3.2.2.2 The Bridge and Elevated Guideway Structure

701.3.2.2.2.1 For elevated guideway and bridge deep foundation design, the DOR must conduct at least one boring within the footprint of the deep foundation (one shaft or a group of shafts) that supports one bridge pier or one abutment.

701.3.2.2.2.2 The depth of exploration for elevated guideway and bridge deep foundations must extend below the anticipated shaft or pile tip elevation for at least 20 feet or two times of the minimum pile group dimension, whichever is deeper.

701.3.2.2.2.3 For shallow foundation design, follow AASHTO LRFD Bridge Design Specifications (2020) Table 10.4.2-1.

701.3.2.2.3 For tunnel design, the space of borings must be less than 300 feet, and in accordance with AASHTO Road Tunnel Design and Construction Guide Specification Table 5.4.4.1 Guidelines for Vertical/Inclined Boreholes Spacing, whichever is less.

701.3.2.2.4 Building Foundation

701.3.2.2.4.1 For building foundation design, the DOR must conduct at least one boring for built-over areas up to and including 750 square feet. Two borings for built-over areas greater than 750 square feet, but less than 5,000 square feet, and at least one additional boring for each additional 2,500 square feet. The DOR must conduct at least one boring for each additional 5,000 square feet, of built-over areas more than 20,000 square feet.

701.3.2.2.4.2 For the deep foundation of building structures, the depth of exploration must follow Section 701.3.2.2.2.2.

701.3.2.2.5 For at grade track, refer to the American Railway Engineering and Maintenance-of-Way Association (AREMA. 2019) 22.4.2 for the number and location of borings.

701.3.2.2.6 For all structure types, the DOR must conduct additional borings if erratic soil conditions are encountered.

Commentary: Apply engineering judgement to increase boring frequency and depth under necessary conditions.

701.3.2.2.7 Standard Penetration Test calibration must follow WSDOT GDM Chapter 3.5.

701.3.2.2.8 Follow WSDOT GDM Table 6-1 to conduct field investigation and testing for seismic design.

701.3.2.2.9 The DOR must approve the site investigation and laboratory testing program and submit to Sound Transit Geotechnical Engineer or its representative for review and approval prior to initiation of the site investigation.

701.3.2.2.10 The DOR must provide investigation and laboratory testing to support Low Impact Development following local AHJ requirements and Set 901 Storm Drainage.

701.3.2.2.11 The DOR must perform the soil sulfate content test to determine the sulfate exposure classes (S0, S1, S2, or S3) as defined in ACI 318 Table 19.3.1.1 Exposure Categories and Classes.

Commentary: This test is required for the structure DOR to determine the type of Type 1L cement in underground concrete structure mix design.

701.3.2.3 Soil Sample Storage

701.3.2.3.1 The DOR must store and keep all collected subsurface samples. The DOR must make the samples available for review by potential bidding construction or design-build contractors during the bidding phase of the project. The DOR must store the soil sample through the end of construction. Maintain the moisture content as close as possible to the natural conditions (higher than freezing temperature) and maintain the relative humidity for soil storage at 90 percent or higher to prevent moisture evaporation from the samples. A climate-controlled warehouse facility is not required.

701.3.2.3.2 After notice is received to proceed for the construction contract, the DOR must provide the opportunity for the Contractor to take possession of the samples from the Design consultant team. If the Contractor elects not to take possession of the samples, the DOR must be responsible for sample disposal after obtaining the written approval from the Sound Transit Geotechnical Engineer or its representative.

701.3.2.4 Governing Design Policies and Additional Resources

701.3.2.4.1 The following manuals are the primary sources of geotechnical field exploration for Sound Transit:

701.3.2.4.1.1 Sound Transit Design Requirements

701.3.2.4.1.2 Federal Highway Administration and the National Highway Institute (FHWA-NHI). Soil Nail Walls Reference Manual. Publication No. FHWA-NHI-14-007.

701.3.2.4.1.3 WSDOT (GDM), Chapters 3 and 6

701.3.2.4.1.4 AASHTO LRFD Bridge Design Specifications, Chapter 10.4

701.3.2.4.2 If the publication date is shown, that version must be used to supplement the geotechnical design policies in this Set 701. If the date is not shown, the most current version must be used. Other publications referenced in Set 701 must be used as directed.

701.3.3 Seismic Hazards Design

701.3.3.1 This Set provides criteria for geotechnical seismic hazard design of Light Rail, Commuter Rail, and Building.

701.3.3.2 Earthquake Hazard Design Policy, Performance, and Risk Acceptance

701.3.3.2.1 The DOR must follow Set 721 Bridges and Elevated Structures and Set 720 Building Structures for the earthquake hazard design policy, performance, and risk acceptance for the design of bridges and buildings.

701.3.3.2.2 Retaining walls that do not support, protect, or potentially impact the track must apply hazard design policy, performance, and risk acceptance based on code and AHJ requirements (e.g., International Building Code [IBC], AASHTO, WSDOT GDM). Check additional requirements in Set 720 Building Structures.

701.3.3.2.3 Performance and Risk Acceptance for Guideway Retaining Walls Supporting, Protecting, or Potentially Impacting Track

701.3.3.2.3.1 This section provides performance and risk acceptance criteria for retaining walls supporting, protecting, or potentially impacting the track operation. The walls defined in this section must design for two-level earthquake, the ODE and the MDE. For the ODE, the DOR must design the walls to respond with no damage or very minor structural damage that could be repaired during normal operating hours.

701.3.3.2.3.2 For the ODE, any residual deformation of walls due to total structural deformation, wall sliding, settlement, or overturning rotation must not encroach the Train Clearances (See Set 520 Vehicle Clearances and Track Spacing and Set 530 Track Clearance and Spacing), and meet Table 701-1, whichever is more stringent.

701.3.3.2.3.3 For the MDE, the DOR must design the walls to survive the deformation acting on the walls, to avoid major failure, and to ensure Life Safety.

701.3.3.2.3.4 For the ODE, the MDE, and post-liquefaction conditions, the Factor of Safety of global stability of the walls must be greater than or equal to 1.1. The DOR must follow WSDOT GDM Section 6-4.3.2, AASHTO LRFD Bridge Design Specifications 11.6.5.2, 11.6.5.3 and Appendix A11 for the analyses. Refer to Section 721.3.21.1.

Commentary: If it could not meet factor of safety criteria, the DOR could apply more complex analyses like the Newmark time history analysis and/or dynamic stress deformation models to estimate the amount of wall movement after approval from Sound Transit, considering train clearances and other performance criteria provided in 701.4.1.1 remain.

701.3.3.2.3.5 The following table shows the maximum permissible permanent deformation after the ODE based on track operation.

Table 701-1: Maximum Permissible Permanent Deformation for Walls Supporting Track after the ODE

	Wall Supporting Ballasted Track	Wall Supporting Non-Ballasted Track
Horizontal Deformation (inch)	6 (Note 1) (Note 2)	2 (Note 1)
Vertical Deformation (inch)	6 (Note 1) (Note 2)	2 (Note 1)

Notes:

1.The settlement is the total value from subgrade and wall.

2. The DOR must make sure the selected wall type could tolerate the maximum permissible permanent deformation. If not, more stringent permissible permanent deformation must apply.

Commentary: For the walls supporting the track, permissible permanent seismic deformations after ODE must be within practical limits to realign the track within normal operation hours after its occurrence. Provided that train clearances and other operational criteria are maintained, the practical deformation limit is dependent upon the type of track the walls support. These include either ballasted or concrete-slab supported (embedded or direct fixation) track.

701.3.3.2.3.6 The DOR must pay special attention to locations where the potential exists for uneven deformation and settlement, such as at bridge abutments and where transitioning from firm to weaker ground. Where anticipated deformations exceed these criteria in Table 701-1, the DOR must evaluate and mitigate deformations in the design.

701.3.3.2.4 The design must follow Table 701-2 for the maximum permissible permanent deformation for subgrade of at-grade track after ODE.

Table 701-2: Maximum Permissible Permanent Deformation for Subgrade of At-Grade Track after ODE

	Ballasted Track	Non-Ballasted Track
Horizontal Deformation (inch)	6	2
Vertical Deformation (inch)	6	2

Commentary: Tables 701-1 and 701-2 were established based subgrade settlement criteria in SET 522 TRACK CONSTRUCTION.

701.3.3.3 Design Earthquake Parameters

701.3.3.3.1 The DOR must apply the design ground motion parameters specified in this section for foundations and walls, unless the DOR is required to use non-linear time history analysis, then follow Section 721.3.21.9. Refer to Section 721.3.21.9.4.

701.3.3.3.2 The DO*R* must develop the five percent damped design response spectra for the ODE and the MDE by following the general procedures in WSDOT BDM using the ODE/MDE peak ground and spectral acceleration values based on the seismic hazard study conducted by the Unites States Geological Survey (USGS, 2014).
Commentary: It should be noted that adoption of USGS 2018 parameters is forthcoming based on updated standards to be released.

701.3.3.3.3 The DOR must assess the magnitudes of MDE and ODE using the seismic de-aggregation data, which is available at the USGS National Seismic Hazard website.

701.3.3.3.4 The DOR must classify the site in accordance with the Site Class Definitions in AASHTO Guide Specifications for LRFD Seismic Bridge Design for bridge and elevated guideway structures, or IBC for building structures.

701.3.3.3.5 The DOR must determine the ground motion parameters (PGA and spectral accelerations) for the Site Class B/C boundary using the USGS web-based hazard mapping tool (USGS, 2014). The DOR must define the site location in the USGS web-based seismic hazard tool based on the latitude and longitude coordinates.

701.3.3.3.6 The DOR must use either equivalent linear or nonlinear effective stress methods to conduct the site-specific response analyses.

Commentary: The DOR can use equivalent linear computer methods, like ProShake or SHAKE2000, to evaluate site-specific ground motion effects for sites that do not liquefy. The effective stress methods, using programs like DMOD or DESRA, are appropriate if liquefaction is expected to occur under the design ground motions. The DOR may perform one-dimensional site-specific ground motion response analyses in accordance with AASHTO LRFD Bridge Design Specifications (i.e., Chapter 3) and WSDOT GDM (i.e., Chapter 6). The DOR could perform two and/or three-dimensional site response analyses and/or dynamic soil-structure interaction modeling, if approved by the Sound Transit Geotechnical Engineer or its representative.

701.3.3.3.7 For bridge and elevated guideway foundations and retaining wall supporting, protecting, or potentially impacting tracks GFW, follow directions from WSDOT GDM (i.e., Section 6-3.2.2) and AASHTO LRFD (i.e., Section 3.10.2) to identify the conditions that require site-specific ground motion response analyses. If a magnitude 9 earthquake is not considered as one of the sources of ground motions in site-specific ground motion response analysis, the DOR must provide the justification to the Sound Transit geotechnical engineer or its representative for review. Refer to Section 721.3.21.9 for seismic time history analysis.

701.3.3.3.7.1 The DOR must conduct the site-specific response analysis for Site Class F for elevated structures defined in Set 721 Bridges and Elevated structures.

Commentary: For Conceptual and Preliminary Design of structures, the DOR may use local site effects of Site Class E to determine Site Class F design response spectra.

701.3.3.3.7.2 For GFW located within 6 miles of surface projection of known active faults, which can produce an earthquake with magnitude of 5 or greater, the DOR must address directivity and directionality as described in Section 3.4.3.1 of AASHTO LRFD Seismic Bridge Design, and WSDOT GDM Chapter 6.

701.3.3.3.7.3 For GFW on sites with significant change of bedrock topography, the DOR must evaluate basin effect to modify the ground motion.

701.3.3.3.8 For building structures covered in Set 720 Building Structures, the DOR must conduct the site-specific response analysis following Chapters 11 and 21 in ASCE 7, if required by ASCE 7 (AHJ will decide version of ASCE 7).

701.3.3.3.8.1 For Building Structures covered in Set 720 Building Structures, the DOR must follow ASCE 7 (i.e., Chapter 11.4.1) to evaluate near fault effect.

701.3.3.3.8.2 For Building Structures covered in Set 720 Building Structures on sites with significant change of bedrock topography, the DOR must evaluate basin effect to modify the ground motion.

Commentary: The DOR may consider Director’s Rule 20-2018 from City of Seattle.

701.3.3.4 Liquefaction

701.3.3.4.1 Maximum Considered Depth for Liquefaction

701.3.3.4.1.1 The DOR must analyze liquefaction potential at depths for deep foundation design.

701.3.3.4.1.2 The DOR must estimate the liquefaction potential at a site using the simplified procedure outlined in WSDOT GDM Section 6-4, unless the analysis violates the limitations of the simplified procedure described in WSDOT GDM Section 6-1.

701.3.3.4.1.3 When using the simplified method to perform liquefaction potential analysis, the depth must not exceed 80 feet. If simplified procedures or equivalent-linear total stress computer programs per WSDOT GDM Section 6-4 could not evaluate the situations properly, the DOR must perform nonlinear, effective stress models.

701.3.3.4.1.4 Where the factor of safety against liquefaction is less than 1.0, the DOR must use liquefied residual strengths. Where the factor of safety against liquefaction is greater than 1.0 and less than 1.2, the DOR must use cyclic softening and strength loss due to pore pressure buildup.

701.3.3.4.2 Liquefaction-induced Settlement for Bridge and Elevated Guideway Structures

701.3.3.4.3 The DOR must provide differential settlement criteria to ensure that the superstructure can tolerate the differential movement, and that design of the superstructure meets the Performance and Risk Acceptance Criteria in Set 721 Bridges and Elevated Structures.

Commentary: The DOR may apply more rigorous analytical methods, like Dynamic Soil Structure Interaction analysis, for the condition when liquefaction-induced total and differential settlement has significant impact to structural design.

701.3.3.5 Governing Design Policies and Additional Resources

701.3.3.5.1 The following manuals must be the primary sources of seismic design for bridges and elevated guideway structures and for retaining wall supporting and protecting or potentially impacting track:

701.3.3.5.1.1 Sound Transit Design Requirements

701.3.3.5.1.2 WSDOT Geotechnical Design Manual (GDM), Chapters 4, 6 and related sections.

701.3.3.5.1.3 AASHTO LRFD Seismic Bridge Design Specifications, Chapter 3, and related sections.

701.3.3.5.1.4 United States Geological Survey (USGS) website (USGS national hazard mapping project website).

701.3.3.6 Peer Review Procedure

701.3.3.6.1 A Peer Review must be performed if the DOR implements any of the following design procedures in the geotechnical seismic design.

701.3.3.6.1.1 Site-specific hazard analysis.

701.3.3.6.1.2 Total and effective stress site-specific response analysis.

701.3.3.6.1.3 Selection of seismic ground motions used for site-specific response.

701.3.3.6.1.4 Effective stress analysis to determine the number of cycles or elapsed time for the onset of liquefaction.

701.3.3.6.1.5 Dynamic soil structure interaction modeling for geotechnical seismic design.

701.3.3.6.1.6 Any other proposed analysis methods that are not addressed in the Mandatory Standards.

701.3.3.6.2 The Peer Reviewer must review the following aspects of the seismic design and analysis:

701.3.3.6.2.1 Geotechnical data collected and reasonableness of the assumptions made by the designer to develop the geologic and geotechnical models used in the analyses.

701.3.3.6.2.2 Soil and structure input parameters used by the designer in the ground response and soil-structure interaction response analyses.

701.3.3.6.2.3 Computer software analysis data for ground response and soil-structure interaction with respect to the ability of the software and constitutive models to incorporate non-linear soil effects, pre- and post-liquefaction stress-strain-strength relations, non-linear structure effects, and modeling methodology.

701.3.3.6.2.4 Interpreted results and conclusions.

701.3.3.6.2.5 Appropriate combination of seismic inertial loading, kinematic inertial effects, and liquefied/reduced soil strength.

701.3.3.6.3 The DOR must transmit the following information to Sound Transit as they are developed for all Peer Reviews:

701.3.3.6.3.1 The DOR must send documents to the Peer Reviewer for a Peer Review.

701.3.3.6.3.2 The Peer Reviewer's comments.

701.3.3.6.3.3 Comment responses and resolution of the Peer Reviewer's comments.

701.3.3.6.3.4 The DOR must provide Geotechnical recommendations carrying the Peer Reviewer's Professional Engineer's stamp and signature stating the Peer Reviewer's comments have been resolved. The Geotechnical Recommendations must list the documents reviewed by the Peer Reviewer and include the document date.

701.3.3.6.4 The DOR is responsible for addressing all comments made by the Peer Reviewer. The DOR must invite Sound Transit Geotechnical Engineer to attend all meetings between the designer and the Peer Reviewer. The DOR must resolve the Peer Review comments prior to the Geotechnical Recommendations being Released for Construction. The DOR must include the Geotechnical Recommendations from the Peer Reviewer as an appendix in all the Released for Construction Geotechnical Recommendations that were subject to the Peer Review.

701.3.3.6.5 The peer review team must be from the consultant company that is independent of the consultant the DOR works for. The peer review team lead must have at least 20 years of experience in the relevant field. The peer review team must be approved by the Sound Transit Geotechnical Engineer or its representative.

701.3.4 Foundation

701.3.4.1 Building Foundation

701.3.4.1.1 This section applies to the foundations supporting building and non-building structures defined in Set 720 Building Structures. The DOR must perform building foundation design using IBC Chapter 18, local amendments, and ASCE 7.

701.3.4.2 Bridge and Elevated Guideway Deep Foundation

701.3.4.2.1 This section applies to the deep foundation supporting structures that support, protect, or potentially impact the track. If the DOR increases the nominal end bearing resistance above the limit specified for bearing in soil in the AASHTO LRFD Bridge Design Specifications, the DOR must prepare a foundation test program plan for review. An increase above the AASHTO specified bearing limit requires approval by the Sound Transit Geotechnical Engineer or its representative to validate the value of bearing resistance selected for design.

701.3.4.2.2 The DOR must augment downdrag load factors for deep foundations presented in AASHTO Table 3.4.1-2 by Table 8-3 of the WSDOT GDM. The DOR must use downdrag load factor of 1.0 for Service and Extreme Limit States.

701.3.4.2.3 Governing Design Policies and Additional Resources

701.3.4.2.4 The following manuals must be the primary sources of guideway deep foundation for Sound Transit:

701.3.4.2.4.1 Sound Transit Design Requirements

701.3.4.2.4.2 WSDOT GDM.

701.3.4.2.4.3 AASHTO LRFD Bridge Design Specifications.

701.3.4.3 Design Tolerance of Shaft Foundations for Both Buildings and Bridges.

701.3.4.3.1 Design of drilled shaft foundations must allow for an accidental misplacement of the center of gravity of the substructure as outlined in Table 701-3.

Table 701-3: Design Tolerance of Shaft Foundations

Shaft Diameter (feet)	Tolerance (inches)
Less than or equal to 2	3
Greater than 2 and less than 5	4
5 or larger	6

701.3.4.4 Bridge and Elevated Guideway Structure Shallow Foundation

701.3.4.4.1 This section applies to the shallow foundation supporting structures that support, protect, or potentially impact the track.

701.3.4.4.2 Governing design policies and additional resources include the following manuals must be the primary sources of the guideway shallow foundation for Sound Transit:

701.3.4.4.2.1 Sound Transit Design Requirements

701.3.4.4.2.2 WSDOT GDM.

701.3.4.4.2.3 AASHTO LRFD Bridge Design Specifications.

701.3.5 Earth Retaining Structures Supporting, Protecting or Potentially Impacting Track

701.3.5.1 See Section 701.3.3 for seismic design requirements. See SET 001 GENERAL for retaining structures design life.

701.3.5.2 Limitation of Use of MSE wall for Commuter Rail.

701.3.5.2.1 The requirements in Section 701.3.5.2 only apply to Commuter Rail.

701.3.5.2.2 The DOR cannot design MSE wall to retain the railroad embankment.

701.3.5.2.3 For the MSE wall that protects or potentially impacts the commuter rail track, the following restrictions apply:

701.3.5.2.3.1 For locations less than 25 feet from the existing and future centerline of track, the design can't use MSE wall.

701.3.5.2.3.2 For locations greater than 25 feet and less than 50 feet from the existing and future centerline of tracks, a wall thickness of at least 2.5 feet is acceptable because it meets the AREMA "heavy construction" recommendations and are represented as having a 100-year design service life. The height of the 2.5-foot-thick section must be at least 6 feet above top of rail of the nearest existing or future track.

Commentary: Refer to Section 21.0 (Retaining Wall Project) in BNSF Railway Public Projects Manual

701.3.5.3 Corrosion Monitoring/Test Box for Mechanically Stabilized Earth (MSE) Walls Supporting Track

701.3.5.3.1 The DOR must design MSE walls in accordance with FHWA and AASHTO Standards.

701.3.5.3.2 Design of corrosion/degradation protection of steel reinforcement and reinforced fill soil of MSE walls must meet FHWA-NHI-10-024 and FHWA-NHI-10-025, FHWA-NHI-00-043, FHWA-NHI-09-087, and AASHTO LRFD Bridge Design Specifications Chapter 11.10.

Commentary: The DOR may apply the following mitigation measures:

701.3.5.3.2.1 Use selects backfill with resistivity material in place of native soils; the DOR must test the select backfill to ensure compliance with FHWA-NHI-09-087 Sections 2.3 and 2.5.

701.3.5.3.2.2 Refer to FHWA-NHI-10-024 Section 3.5.1 for galvanized coating for each earth reinforcing strip.

701.3.5.3.2.3 Refer to FHWA-NHI-10-024 Section 5.4 for coating the steel wall panel connection to reinforce strips during fabrication of the panels to prevent a corrosion cell at the soil-concrete interface.

701.3.5.3.2.4 Refer to FHWA-NHI-10-024 Section 5.4 to ensure discontinuity between adjacent MSE wall panel steel reinforcement during fabrication.

701.3.5.3.3 The DOR must install one monitoring/test box per MSE wall that is supporting Track. The DOR must locate the test station within 100 feet from either end of the wall where it is accessible to the maintenance crews without use of a ladder or lift. The DOR must install the Coupon Test corrosion test box or an approved equal. The DOR must follow additional requirement in Set 222 Stray Current Corrosion Control.

701.3.5.3.4 Governing Design Policies and Additional Resources

701.3.5.3.4.1 The following manuals must be the primary sources of corrosion monitoring system for mechanically stabilized earth walls for Sound Transit:

701.3.5.3.4.2 Sound Transit Design Requirements

701.3.5.3.4.3 FHWA-NHI-09-087, Corrosion Degradation of Soil Reinforcements for MSE Walls and Reinforced Soil Slopes.

701.3.5.3.4.4 FHWA-NHI-10-024 and FHWA-NHI-10-025, Design and Construction of Mechanically Stabilized Earth Walls and Reinforcement Soil Slopes, Volumes I and II.

701.3.5.3.4.5 AASHTO LRFD Bridge Design Specifications (i.e., Chapters 7 and 11).

701.3.5.3.4.6 FHWA-NHI-11-32 LRFD Seismic Analysis and Design of Transportation Geotechnical Features and Structural Foundations.

701.3.5.3.4.7 FHWA-NHI-00-043 Mechanically Stabilized Earth Walls and Reinforcement Soil Slopes, Design and Construction Guidelines.

701.3.5.4 Soil Nail Wall

701.3.5.4.1 The following manuals must be the primary sources of Soil Nail Wall design for Sound Transit:

701.3.5.4.2 Sound Transit Design Requirements

701.3.5.4.3 WSDOT Geotechnical Design Manual (GDM) (i.e., Chapter 15).

701.3.5.4.4 AASHTO LRFD Bridge Design Specifications (i.e., Chapter 11).

701.3.5.4.5 Federal Highway Administration and the National Highway Institute (FHWA-NHI). Soil Nail Walls Reference Manual. Publication No. FHWA-NHI-14-007.

701.3.5.5 Settlement Criteria for Retaining Wall.

701.3.5.5.1 Wall Supporting Guideway Track under Service Limit State.

The DOR must design to limit the settlement (primary and secondary) along track segments occurring after construction of the permanent way tracks as shown in Table 701-4, or WSDOT GDM Table 15-2, 15-3, and 15-4, whichever is more stringent.

701.3.5.5.2 For wall protecting or potentially impacting track operation, the DOR must follow settlement requirements in Table 15-2, 15-3 and 15-4 in WSDOT GDM.

701.3.6 Slope Stability

701.3.6.1 All permanent slopes that support, protect, or potentially impact the train operation must reach a factor of safety of 1.5 or greater under long-term static condition and 1.1 or greater under ODE, MDE, and post-liquefaction conditions. Other AHJs requirements must apply if more stringent.

701.3.6.2 The DOR must apply corresponding surcharge loads for slope stability analysis where structures, trains, or other non-earth material are present within a slope area. The DOR must take soil loads at their nominal values; no load factors are applied to soil in slope stability analysis.

Commentary: If the design can't meet the factor of safety criteria under ODE, MDE, and/or post-liquefaction conditions, the DOR may apply more complex analyses like the Newmark time history analysis and/or dynamic stress deformation models to estimate the amount of ground movement after approval from ST Geotechnical Engineer or its representative. DOR must follow WSDOT GDM Section 6-4.3.2, AASHTO LRFD Bridge Design Specifications (2020) 11.6.5.2, 11.6.5.3 and Appendix A11.

Commentary: WSDOT GDM Chapters 7, 8, 9.2.3.1, 10.3.1, 15, etc. are used to generate factor of safety criteria in this section. Life safety concern of ST tracks is also considered.

701.3.6.3 Refer to WSDOT GDM Chapter 20 for unstable slope (e.g., rock fall, landslides, debris flows, etc. due to heavy rain) management.

701.3.6.4 Sound Transit requires landslide monitoring in the historical landslide hazard area if the landslide has the potential to affect the train operation along ST Link and Commuter Rail alignments.
The DOR must review the ST Link and Commuter Rail alignments and the latest Landslide Hazard Map by Department of Natural Resources (DNR), WA. After review, the DOR must propose the Landslide Monitoring Area and the monitoring plan for approval from ST Geotechnical Engineer or their representative. Use the existing monitoring program for Commuter Rail - Seattle, Washington Landslide Monitoring Site (*https://www.usgs.gov/programs/landslide-hazards/science/seattle-washington-landslide-monitoring-site*) as the reference when generating the monitoring plan.

701.3.7 At-grade Track Settlement Criteria

701.3.7.1 The DOR must evaluate and integrate subgrade strength in the design of the track support system (e.g., ballast, subballast, concrete slab, or tie and fasteners) for at-grade track to ensure sufficient bearing resistance. The design must follow subgrade requirements for at-grade track in Set 522 Track Construction. Where the subgrade modulus is insufficient to meet track performance requirements, the DOR must require subgrade improvement.

701.3.7.2 The DOR must limit the settlement (primary and secondary) occurring after construction of the permanent way tracks along track segments as shown in Table 701-4.

Table 701-4: Settlement Criteria under Service Limit State—Residual Settlement after Placement of Tracks

Residual Settlement [1]	**Ballasted Track**
Differential Settlement [2]	1:1500 longitudinally; 1:500 laterally
Total Settlement	1 inch in first 10 years

Notes:

1. Primary and secondary settlement occurring after construction.

2. The DOR must measure differential settlement along longitudinal track segments along the track (surface profile uniformity) in the vertical plane of each rail at the midpoint of a 62-foot-long chord.

Commentary: Table 701-4 was established based on Subgrade Settlement Criteria in Set 522 Track Construction.

701.3.8 Ground Improvement

701.3.8.1 The DOR must design ground improvement to achieve performance requirements with respect to global stability, bearing capacity and settlement. The ground improvement design must include a construction quality assurance program that specifies observation and testing methods to verify the design objectives.

701.3.9 Special Inspection and Testing of Soil and Foundation

701.3.9.1 The DOR must follow IBC Chapter 17 Special Inspection and Tests for the foundation inspection and test of the building structures covered in Set 720 Building Structures.

701.3.9.2 Bridge and Elevated Guideway Structure Foundations and Walls Supporting, Protecting, or Potentially Impacting Tracks,

701.3.9.2.1 The Contractor must perform special inspections and provide documentation during construction of the geotechnical types of Work. Documentation, requirements, and the frequency of special inspections must be in accordance with the requirements of Set 701 and the Mandatory Standards. Additional requirements are provided in Section 701.3.10.10 Geotechnical Special Inspection Plan (GIP).

701.3.10 Reporting and Documentation

701.3.10.1 The DOR must compile and deliver the obtained and developed Geotechnical information for projects in geotechnical report(s). The information may be reported in a combination of Site Investigation Plan, Data Report, Recommendations Report (or memoranda), and/or Baseline Report, as outlined in the contract Scope of Work.

Commentary: DOR may be required to provide additional reports that are not discussed in Set 701 upon the request of Sound Transit Geotechnical Engineer or its representative.

701.3.10.2 The construction contract documents must not include reports containing interpretation and/or recommendations (GRR) and other geotechnical recommendation memoranda.

Commentary: The GRR and other geotechnical reports including interpretation and/or recommendations may be provided to construction contractors for information only, can't be used as the basis for their proposal or bidding.

701.3.10.3 In addition to other project requirements and codes and standards listed in Set 701, geotechnical reports, memoranda, calculations, documents, and records must meet the latest edition of the applicable requirements of the following references:

701.3.10.3.1 WSDOT GDM.

701.3.10.3.2 Essex, J. Geotechnical Baseline Reports for Construction, Suggested Guidelines. ASCE Technical Committee on Geotechnical Reports of the Underground Technology Research.

701.3.10.3.3 FHWA Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications. Publication No. FHWA-ED-88-053.

701.3.10.3.4 FHWA Subsurface Investigations – Geotechnical Site Characterization. Publication No. FHWA-NHI-01-031. NHI Course No. 132031.

701.3.10.4 The geotechnical DOR must sign and seal the reports, memoranda, and calculations appropriately in compliance with the requirements of WAC 196 and/or WAC 308-15. At least the individual who performed and prepared the design, if she/he is a licensed PE or Licensed Engineering Geologist in the State of Washington, and the first line reviewer must sign and seal the report(s). The geotechnical DOR must be a licensed PE in the state of Washington with at least 15 years of relevant experience.

701.3.10.5 GSIP

701.3.10.5.1 The DOR must prepare and implement a site investigation and testing program to establish the geotechnical conditions for design and analysis of the project. The GSIP must be approved prior to mobilization of investigation equipment to the site. Utilize geologic mapping, previous explorations, and other available existing information in development of the plan.

Commentary: As appropriate, the DOR may perform site visits in development of the plan. The plan must present the scope and purpose of the investigation, outline the proposed explorations, and present reasoning behind each of the proposed explorations.

701.3.10.5.2 The GSIP must include a contingency plan and procedures if unexpected soil and/or groundwater contamination is encountered during the investigation.

701.3.10.5.3 The DOR must increase the number of monitoring wells to be 10 percent more than what is approved by the Sound Transit Geotechnical Engineer or its representative and monitor ground tables at the site for at least two years.

701.3.10.6 GDR

701.3.10.6.1 The GDR must be a factual presentation of the site investigation and the collected geotechnical data. The report must include a summary of all the factual geotechnical data including the results of borings and the laboratory tests. The GDR must not include interpretations of the subsurface conditions and design recommendations.

701.3.10.7 GRR

701.3.10.7.1 The GRR is intended for use by the design team. The construction contract documents must not include the GRR. The GRR presents an interpretation of the subsurface conditions, describes the methods and procedures of geotechnical analyses, and provides all geotechnical design and construction recommendations required for the project. The GRR must include calculations packages used to develop the design and construction recommendations.

701.3.10.7.2 If the DOR chooses to issue recommendations in a series of memoranda to address design needs as the design progresses, the DOR must compile the memoranda into a single GRR document when the geotechnical design has been substantially completed. The compiled GRR must include an executive summary, table of contents, and the design and construction recommendations memoranda. A compiled GRR must include all design recommendations for the project.

701.3.10.8 GBR

701.3.10.8.1 The GBR establishes a general understanding of the subsurface conditions between the contractor and the owner. The GBR serves as a risk allocation tool. The contractual representations (or baselines) of the GBR express the anticipated (or assumed) subsurface conditions, which are the singular contractual interpretation of the subsurface for determination of a differing site condition. The baselines define specific ground conditions that the contractor must rely upon in the development of her/his price proposal. The contractor may choose to assume adverse subsurface condition described in the GBR. However, the GBR provides the basis for evaluating a materially different subsurface condition in claims.

701.3.10.8.2 GBRs for Construction (ASCE) and WSDOT GDM are the guiding documents in creation of all Sound Transit GBRs. If the GBR is included within the contract documents, it must take precedence over all other geotechnical documents. The DOR must avoid repeating the information presented in the GDR to the extent practical in the GBR. The GBR baselines are not intended for use in the final design.

701.3.10.8.3 As the GBR allocates risk between the owner and the contractor, both Sound Transit and its consultants must be integral in the development of the baselines of the GBR. The GBR author(s) must have considerable knowledge and experience in writing GBRs as well as at least 15 years of geotechnical design and construction experience that is relevant to the region and project requirements. Because the risks for each project are unique and the determination of baselines impacts both costs and schedule, the DOR must employ a rigorous GBR development and review process. The DOR must link the process to the project risk register as well as the cost and schedule estimates.

701.3.10.8.4 The process must be outlined and reviewed by the Sound Transit Geotechnical Engineer or its representative prior to its initiation. Steps to consider for inclusion in the GBR development process include:

701.3.10.8.4.1 Providing an annotated outline for GBR. Annotations must provide added discussion of information in each section of the GBR.

701.3.10.8.4.2 Identifying the parameters to baseline within the GBR. Include use of the risk register to ensure inclusion of previously identified risk items, newly identified risk items, and to adjust risk impacts as appropriate.

701.3.10.8.4.3 Preparing and presenting “best estimate” or “reasonable and realistic” baselines. Present consequences of different levels of baseline adversity. Discussion must include bid price, number of change orders, total project cost, schedule impacts, and impact to public and safety. The Sound Transit project team will provide direction on the level of adversity for baselines.

701.3.10.8.4.4 Incorporating GBR baselines into the risk register, schedule, and cost estimate.

701.3.10.8.4.5 Performing an independent review of final and draft GBR. The consultant review must provide a review of the GBR as an addition to the work of the staff involved in the GBR creation.

Commentary: The Sound Transit project team may use third-party review for complex projects where in-house expertise is insufficient.

701.3.10.8.4.6 Performing a page-turn review of contract documents and GBR to ensure compatibility. Include GBR author(s) in this page-turn review. The DOR must pay special attention to payment provision to ensure they line up with anticipated conditions from the GBR, and the DOR must ensure the GBR is highest on order of precedence for geotechnical documents.

701.3.10.8.4.7 There are additional considerations for design-build projects that include a GBR. The Sound Transit project team may provide an opportunity to the potential bidders to obtain additional subsurface information that is critical to the planning and design during the bidding phase. If this is included, a GBR modification process must be considered. The processes by which these issues are incorporated into the contract documents must be made on a project-specific basis. Review ASCE for guidelines.

701.3.10.9 GIMP

701.3.10.9.1 The DOR must develop, use, and follow a GIMP when geotechnical instrumentation is required to monitor structures, facilities, utilities, other project elements, or when Quality Assurance monitoring is required. When the DOR requires instrumentation and monitoring of the work for construction purposes, include the instrumentation in the GIMP by supplement.

Commentary: The GIMP is not intended to cover geotechnical instrumentation used for site characterization work (subsurface investigation).

701.3.10.9.2 Elements Requiring Monitoring

The DOR must prepare and submit the GIMP and all supplements to the Sound Transit Geotechnical Engineer or its representative for review before deploying geotechnical instrumentation. The DOR must consider survey points to monitor deformations as geotechnical instrumentation. The Contractor must install geotechnical instrumentation to monitor the following:

701.3.10.9.2.1 Sensitive facilities as identified by the DOR.

701.3.10.9.2.2 Temporary shoring.

701.3.10.9.2.3 Settlement and settlement rates of embankments and structures where settlements are estimated to be greater than 2 inches.

701.3.10.9.2.4 Differential settlement and settlement rates of transitions less than 20 feet in length between different wall types, different fill material, rapid changes in soil stratigraphy and/or transitions to and from areas of ground improvement.

701.3.10.9.2.5 Porewater pressures for staged embankment construction.

701.3.10.9.2.6 Groundwater and settlement if dewatering systems are used.

701.3.10.9.2.7 Ground and structure vibrations when impact or vibratory methods are used for the installation of ground improvement, shaft casings, or driving piling.

701.3.10.9.3 Alert Levels, Action Levels, and Corrective Action Plans

701.3.10.9.3.1 The DOR must identify alert and action levels for the instrumentation readings unless the Sound Transit project team has included specific alert and action levels in the Contract.

701.3.10.9.3.2 The DOR must identify alert and action levels in the GIMP for each instrument. The analysis to determine the alert and action instrumentation reading levels must consider the allowable limits for all the existing structures and utilities in the vicinity of the proposed construction.

701.3.10.9.3.3 The DOR must develop and include Corrective Action Plans in the GIMP. Corrective Action Plans must identify the steps to be taken if instrument readings reach an action level.

701.3.10.10 GIP

The GIP must require the inspection and documentation of the temporary and permanent project elements listed below at the frequencies noted below.

Commentary: The DOR may require additional geotechnical special inspection and it must be referenced in the GIP.

701.3.10.10.1 Soil Bearing Verification – Periodic Inspection.

701.3.10.10.2 Deep Foundations, Casings, and Sheet Piles – Continuous Inspection.

701.3.10.10.3 Field Testing – Continuous Inspection.

701.3.10.10.4 Non-destructive Testing of Drilled Shafts – Periodic Inspection.

701.3.10.10.5 Soldier Piles, Ground Anchors, Soil Nails, Micro-piles – Continuous Inspection.

701.3.10.10.6 Grouting Operations – Continuous Inspection.

701.3.10.10.7 Ground Improvement – Continuous Inspection.

701.3.10.10.8 Dewatering System Construction – Continuous Inspection.

701.3.10.10.9 Dewatering System Operation and Maintenance – Periodic Inspection.

701.3.10.10.10 Trenchless Technology (including directional drilling, micro-tunneling, ramming, jacking) – Continuous Inspection.

701.3.10.10.11 Soil and Rock Slope Cuts – Periodic Special Inspection.

701.3.11 Low Impact Development

701.3.11.1 The DOR must support Low Impact Development following local AHJ requirements (stormwater manuals, etc.) and Set 901 Storm Drainage.

701.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

701.4.1 System Breakdown Structure

701.4.2 System Sites and Locations

701.5 SYSTEM INTERFACE REQUIREMENTS

Table 701-5 lists requirement sets that are typically coordinated and may have dependencies with this Set.

The description of the interfaces below is provided to highlight only the major interface elements between Geotechnical and the other discipline sets. The list is not intended to capture all interface elements. The DOR must review and coordinate all interface requirements between geotechnical and the other disciplines at each phase of the design and/or construction.

Table 701-5: Interface Between Geotechnical and Other Disciplines

SET SERIES	SET NAME	SET 701 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	
500	Track	X
600	Fire/Life Safety	
700	Structures	X
800	Architecture	
900	Civil	X
1000	Mechanical-Electrical and Building Systems	
1100	Technology	
1200	Security	

701.5.1 Traction Electrification

701.5.1.1 Coordinate geotechnical design affected by stray current requirements of Set 222 Stray Current Corrosion Control.

701.5.2 Track

701.5.2.1 Coordinate track clearances with Set 520 Vehicle Clearances and Track Spacing.

701.5.2.2 Coordinate track clearances with Set 530 Track Clearance and Spacing.

701.5.2.3 Coordinate subgrade requirements for at-grade track with Set 522 Track Construction.

701.5.3 Structure

701.5.3.1 Coordinate geotechnical design with Set 720 Building Structures, Set 721 Bridge and Elevated Structures, and Set 722 Tunnel Structures.

701.5.4 Civil

701.5.4.1 Coordinate Low Impact Development with Set 901 Storm Drainage.

701.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

701.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

701.7.1 Interface and Integration Management

701.7.2 Design Management

701.7.3 Manufacturing and Construction Management

701.7.4 Installation Management

701.7.5 Inspection and Testing Management

701.7.6 Training, Pre-Revenue Operations

701.7.7 Certification Management

701.8 APPENDICES (NOT USED)

END SET - 701

720 BUILDING STRUCTURES

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SET - 720 TABLE OF CONTENTS

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FIGURES

SET - 720 BUILDING STRUCTURES

720.1 INTRODUCTION

720.1.1 Document Scope

720.1.1.1 This Set covers the structural analysis and design criteria for new buildings and structures similar to buildings on Link and commuter rail projects, including, but not limited to, the parking garages, station structures, aboveground buildings of the underground stations, elevated and at-grade platforms, canopies, operation and maintenance facility buildings and pre-engineered/pre-fabricated buildings.

720.1.1.2 It covers the structural analysis and design criteria for non-structural components that are attached to structures and for their supports and attachments, including, but not limited to, architectural, mechanical, and electrical components. It also covers signage and artwork support structures that are supported on the ground or attached to the transit facilities.

720.1.1.3 See Set 722 Tunnel and Underground Structures Design for underground stations and platforms. See Set 721 Bridges and Elevated Structures for the design of the supports for the civil and electrical components attached to the elevated guideway.

720.1.1.4 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 720 owner to determine the technical source for the design criteria.

720.1.2 Regulations, Codes, Standards, and Guidelines

720.1.2.1 This list contains the codes and standards referenced in this set arranged in alphabetical order. The version of the codes and standards are established by Authorities Having Jurisdiction (AHJs). Latest code version must govern if not required by AHJ. If the code version is different from what is referenced in this set, the DOR must consult with Sound Transit Structural Engineer or their representative for further clarification.

720.1.2.2 International Regulations, Codes, Standards, and Guidelines

720.1.2.2.1 International Building Code (IBC) with local amendments.

720.1.2.3 Federal and National Regulations, Codes, Standards, and Guidelines

720.1.2.3.1 American Associate of State Highway and Transportation Officials (AASHTO) Guide Specifications for LRFD Seismic Bridge Design.

720.1.2.3.2 AASHTO LRFD Bridge Design Specifications.

720.1.2.3.3 AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals.

720.1.2.3.4 American Concrete Institute (ACI) Building Code Requirements for Structural Concrete (ACI 318 and Commentary).

720.1.2.3.5 ACI 360 Guide to Design of Slab-on-Ground.

720.1.2.3.6 ACI 362.1R Guide for the Design and Construction of Durable Concrete Parking Structures.

720.1.2.3.7 ADA Standards for Transportation Facilities (DOT) (ADA Standards).

720.1.2.3.8 American Institute of Steel Construction (AISC) Specification for Structural Steel Buildings (AISC 360).

720.1.2.3.9 American Institute of Steel Construction (AISC) Seismic Provisions for Structural Steel Buildings (AISC 341).

720.1.2.3.10 American Institute of Steel Construction (AISC) Steel Construction Manual.

720.1.2.3.11 AISC 303: Code of Standard Practice for Structural Steel Buildings and Bridges.

720.1.2.3.12 AISC Steel Design Guide 11: Vibrations of Steel-Framed Structural Systems Due to Human Activity.

720.1.2.3.13 American Society of Civil Engineers – Structural Engineering Institute (ASCE SEI), ASCE 7 Minimum Design Loads for Buildings and Other Structures.

720.1.2.3.14 ASME A17.1: Safety Code for Elevators and Escalators.

720.1.2.3.15 Steel Deck Institute (SDI) Standards.

720.1.2.3.16 TMS 402 Building Code Requirements for Masonry Structures.

720.1.2.4 State and Local Regulations, Codes, Standards, and Guidelines

720.1.2.4.1 WABO-SEAW White Paper 8- Guidelines for Snow Load Design in Washington State.

720.1.2.4.2 Washington Administrative Code (WAC).

720.1.2.4.3 WSDOT Geotechnical Design Manual (WSDOT GDM).

720.1.2.4.4 Washington State Accessibility Standards.

720.1.2.5 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

720.1.2.6 Other Jurisdictions (Not Used)

720.1.2.7 Sound Transit Regulations, Codes, Standards, and Guidelines (Not Used)

720.1.3 Abbreviations and Acronyms

720.1.3.1 CMU–concrete masonry unit

720.1.3.2 DOR–designer of record

720.1.3.3 ERS–earthquake resisting system

720.1.3.4 LRV–light rail vehicle

720.1.3.5 MDE–maximum design earthquake

720.1.3.6 MSE–mechanically stabilized earth

720.1.3.7 NLTHA–non-linear time history analysis

720.1.3.8 ODE–operation design earthquake

720.1.3.9 PT–post-tensioned

720.1.3.10 SFRS–seismic force resisting system

720.1.3.11 SOG–slab-on-ground

720.1.4 Definitions and Classifications (Not Used)

720.1.5 References (Not Used)

720.1.6 Disclaimer

720.1.6.1 The Commentaries are provided to explain the intensions of the corresponding requirements in the main text. In case there are any conflicts between the Commentary and main texts from the DOR's perspective, the DOR must follow the requirements conveyed by the main text and bring them to the attention of Sound Transit.

720.2 STAKEHOLDER NEEDS

720.2.1 Passenger Experience (Not Used)

720.2.2 Operational Needs

720.2.2.1 Below grade structure waterproofing.

720.2.2.2 Garage concrete durability and cracking control.

720.2.2.3 Station concrete durability.

720.2.3 Maintenance Needs

720.2.3.1 Equipment maintenance access.

720.2.4 Safety Needs

720.2.4.1 Fall protection.

720.2.4.2 Seismic design in conformance with IBC to ensure Life Safety or better during the IBC Design Earthquake and Collapse Prevention or better during the Maximum Considered Earthquake.

720.2.5 Security Needs (Not Used)

720.2.6 Reliability, Availability and Maintainability Needs (Not Used)

720.2.7 Environmental and Sustainability Needs (Not Used)

720.3 SYSTEM REQUIREMENTS

720.3.1 General Requirements

720.3.1.1 The DOR's calculation must satisfy the following requirements:

720.3.1.1.1 The calculation must provide the element deflections, demands, capacities, and their demand-capacity ratios at a sufficient number, uniformly distributed cross sections with additional result cross sections to capture peak critical demands (such as point loads), and changes in capacities. The calculation must provide envelope results in all cases, and detailed breakdowns of results for each load case when requested by Sound Transit for verification.

720.3.1.1.2 The calculation must clearly define all load cases and identify them for all results.

720.3.1.1.3 When the Excel spreadsheet is used, the calculation must show enough information and readable equations in electronic PDF format so that Sound Transit's independent checker can follow the calculations.

720.3.2 Loads

720.3.2.1 The DOR must follow IBC with local jurisdiction amendments, ASCE 7, and the following additions, whichever is more critical. The version of the codes and standards are established by AHJ. If AHJ requires a different code version from what is referenced in this set, the DOR must consult with the Sound Transit Structural Engineer or their representative for further clarification.

720.3.2.2 The DOR must show the loading criteria for which the structures are designed on structural drawings. Use load plans to show different dead Load and live Load distributions.

720.3.2.3 Dead Load

720.3.2.3.1 Concrete Unit Weight

720.3.2.3.1.1 The unit weight of normalweight concrete must be no less than 150 pounds per cubic feet. The unit weight of hydrophobic concrete must be no less than 155 pounds per cubic feet for the elevated slab design. The weight of the concrete unit used for the elevated platform that is supported by the guideway substructure must follow the Unit Weights in Set 721 Bridges and Elevated Structures.

720.3.2.3.2 Superimposed Dead Load for Garage

720.3.2.3.2.1 Garage roof and floor loading must include superimposed uniform dead load due to the weights of all mechanical, electrical, and plumbing attachments, the overlay for drainage, and concentrated loads from the signage attachments where applicable. The minimum uniform superimposed dead load is 5 pounds per square foot.

720.3.2.4 Live Load

720.3.2.4.1 Pedestrian Loads, Service, and Emergency Walkway Loads

720.3.2.4.1.1 The DOR must design the pedestrian areas for a uniform pedestrian load of 100 pounds per square foot. Design stairways for a uniform load of 100 pounds per square foot or a concentrated load of 300 pounds, whichever produces the greater load effects.

720.3.2.4.1.2 The DOR must design the service and emergency walkways for the same loads listed above at minimum, and increase them if dictated by the Project Requirements, codes, or AHJ.

720.3.2.4.2 Platform Concentrated Loads

720.3.2.4.2.1 In addition to the uniform live load specified in this set, IBC, and ASCE 7, the DOR must design the platform and concourse floors for a concentrated load due to the greater of (1) the mobility device of no less than the greater of 700 pounds on two wheels or ADA standards, or (2) maximum wheel load from a vehicle load 4,500 pounds for a lift or mobility device. Apply the uniform load and the concentrated load concurrently.

720.3.2.4.3 Storage Space, Mechanical Equipment Rooms, Hallways and Pathways Used for Hauling Equipment

720.3.2.4.3.1 The DOR must design electrical equipment rooms, including the electrical closet, electrical distribution room, and electrical room (main), pump rooms, storage space, communication rooms, and mechanical equipment rooms for a minimum uniform live load of 250 pounds per square foot, to be increased if storage or equipment loads so dictate. The uniform live load must include the concrete equipment pad weight. See Set 001 General, Section Definitions and Classifications, for room definitions.

Commentary: By evaluating the maximum uniform load due to equipment weight plus 6-inch house-keeping concrete pad (75 pounds per square foot), also considering that Sound Transit has no control over the equipment weight and equipment layout, it has been determined that 250 pounds per square foot live load for all mechanical and electrical rooms is reasonable and it should not be reduced.

720.3.2.4.3.2 The DOR must design the fan room in tunnel stations and battery room for a minimum uniform live load of 350 pounds per square foot, to be increased if equipment loads so dictate. Design the fan room in garages for a minimum uniform live load of 250 pounds per square foot, to be increased if equipment loads so dictate. See Set 001 General for the fan room definition.

Commentary: Uniform live loads listed above are the same as what is specified in Metro Rail Design Criteria Rev. 9 Section 5.

720.3.2.4.3.3 Load must include the weight of CMU wall or other cladding system at their designed locations.

720.3.2.4.4 The DOR must design the structures supporting elevators, escalators, or passenger conveyors for the maximum reactions as prescribed by the manufacturer of the units considered.

720.3.2.4.5 Routes used for installation, maintenance, removal/replacement of equipment, or architectural components.

720.3.2.4.5.1 The DOR must design all routes from the road to any equipment or architectural component installation point for the loads resulting from installation, maintenance, and removal/replacement of this equipment or architectural component. The total load for maintenance must include the lifting device as needed, such as the forklift and gantry. Provide the load calculation along with the equipment/architectural component circulation access diagram to the Sound Transit Operation and Structural Engineer for review and approval. The DOR must design the affected structural components to adequately support the lifting device. Include this information in the final operations and maintenance manual.

720.3.2.5 Snow Load

720.3.2.5.1 The DOR must design for the snow load prescribed in IBC with local amendments and WABO-SEAW White Paper, whichever is more stringent. When using WABO-SEAW White Paper, all exterior horizontal surfaces less than 5 degrees (8.75 percent slope) must include a 5 pounds per square foot rain on snow surcharge load in addition to the snow load. The design of the building roof below other structures and the platform that is covered by canopy must follow this requirement.

Commentary: The pressure of 5 pounds per square foot rain on snow surcharge load is to account for drainage clogging and/or water ponding.

720.3.2.6 Wind Load

720.3.2.6.1 Wind load must follow IBC, ASCE 7, and the wind load factors provided by the local AHJ.

720.3.2.6.2 Unless the signage or artwork support structure fundamental frequency is greater than or equal to 1 hertz, the gust-effect factor must be taken as a minimum of 1.14.

Commentary: Structures not meeting the frequency criteria must be considered as a wind-sensitive structure and it is not conservative to apply the gust-effect factor as 0.85. ASCE 7-16 requires complex procedure to calculate the gust-effect factor. According to AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals (First Edition 2015) Section 3.8.6, "The gust effect factor, G, shall be taken as a minimum of 1.14."

720.3.2.6.3 Transitory Wind Pressure at Confined Spaces

720.3.2.6.3.1 Tunnels and confined spaces subject to "piston effect" wind pressure from transit vehicles must follow Set 722 Tunnel and Underground Structure Design.

720.3.2.7 Force Effects due to Foundation Differential Displacements

720.3.2.7.1 The DOR Structural Engineer must design for the loads induced on the structure by differential settlement or foundation differential lateral displacement that is calculated by a DOR Geotechnical Engineer. See ASCE 7 Chapter 12 "Seismic Design Requirements for Building Structures" Table 12.13-3 "Differential Settlement Threshold" for allowable differential settlement for building structures. Elevated platform and guideway substructure differential settlement must follow Set 721 Bridges and Elevated Structures and Set 701 Geotechnical Engineering.

720.3.2.8 Self-straining Force and Effects due to Temperature Variation

720.3.2.8.1 The DOR must follow the operational temperature range as specified in Set 721 Bridges and Elevated Structures for calculating the self-straining force and effects resulting from contraction or expansion caused by the temperature variation.

720.3.3 Building Analysis and Design

720.3.3.1 Building structural analysis and design must follow the requirements in IBC with local amendments, ASCE 7, and the exceptions and additions in this set.

720.3.3.2 Deflection Check

720.3.3.2.1 The DOR must check the building structural system and members thereof for serviceability according to IBC Chapter 16 "Structural Design" Section 1604.3, "Serviceability." Use full dead load when calculating the deflection per IBC Table 1604.3, "Deflection Limits."

720.3.3.2.2 Structural drawings must show, for beams that will be attached by non-structural items, the maximum displacements under combined loads to allow coordination of non-structural items for displacement compatibility.

720.3.3.3 Torsion Design

720.3.3.3.1 The DOR must design the concrete member subject to torsion in accordance with ACI 318. In a statically indeterminate structure where the torsional moment for a member can be reduced by redistribution of internal forces (i.e., compatibility torsion), the DOR must provide torsional reinforcement to withstand the maximum factored torsional moment per ACI 318 Chapter 22 "Torsional Strength" Section 22.7.5, "Cracking Torsion," or higher to limit the crack width due to torsion.

720.3.3.4 Foundation

720.3.3.4.1 Building foundation design on liquefiable sites must follow ASCE 7 Chapter 12 “Seismic Design Requirements for Building Structures” Section 12.13.9, “Requirements for Foundations on Liquefiable Sites.” See Set 701 Geotechnical Engineering for the maximum considered depth for liquefaction. This requirement applies to all building structures listed in 720.1.1 except the substructure supporting the elevated platform and elevated guideway. Elevated platform and guideway substructure must follow Set 721 Bridges and Elevated Structures.

720.3.3.4.2 The Design Builder must design structural site improvements such that the static settlement (non-seismic) that occurs during construction and through the warranty period will not affect the functionalities of the utilities. The Design Builder is responsible for ensuring slope requirements for walkways and utilities that interface between the interior and the exterior of the building are within Design Requirements and code allowable tolerances after the static settlement has occurred.

720.3.3.4.3 The Design Builder must provide a Settlement Monitoring Plan based on the Geotechnical Design Report with 100 percent design submittal. The Settlement Monitoring Plan must address how the Design Builder will document static settlements experienced during construction of the building structure. If the settlement is found to be outside of specified tolerances and is found to affect the functionality of the site improvements, the Design Builder must be responsible for the repairs. The Design Builder must submit all data collected during the monitoring period to Sound Transit.

720.3.3.5 Deferred Submittal

720.3.3.5.1 The DOR must review and approve the deferred design performed by the subconsultant before fabrication. A Structural Engineer registered in the state of Washington must sign and stamp the cladding, stair, pre-engineered metal building, and equipment anchorage designs.

720.3.3.6 SOG

720.3.3.6.1 SOG design must follow ACI 318 and ACI 360.

720.3.3.6.2 When foundation ties are required according to ASCE 7, Chapter 12 “Seismic Design Requirements for Building Structures” Section 12.13.8.2, “Foundation Ties,” the design must provide grade beams instead of using the SOG as the foundation tie.

Commentary: If the SOG is designed as the foundation tie, any work that cuts through SOG during the service life of the building, such as trenching, could impair the complete load path of SOG serving as the foundation tie and make the building structurally unsafe.

720.3.3.7 Maintenance Access and Fall Protection

720.3.3.7.1 Roof Access and Fall Protection

720.3.3.7.1.1 See Set 804 Fall Protection for requirements on roof fall protection.

720.3.3.7.2 Fall Protection Support

720.3.3.7.2.1 The DOR must provide calculations to prove that all supporting members for the fall protection anchor are adequate in both the strength limit state and service limit state under the anchor load that is in conformance with WAC 296-880-40020. The test is not a substitution of the calculation.

720.3.3.7.3 Sump Pump Access and Hoisting

720.3.3.7.3.1 The design must provide access to the sump pump and the hoisting for any pump weighing 50 pounds or more. Make sure there is sufficient clear access to pull the pump straight out of the sump or manhole without having to maneuver around pipes, conduits, and other equipment or structures. The design must include, at minimum, connection points, safe access to the pump (fall protection, platform that is in conformance with WAC), and means to get the removed sump pump to exterior road. Submit this design for the review and approval by the Sound Transit Operations and Structural Engineer.

720.3.3.7.4 See Set 804 Fall Protection for other requirements.

720.3.3.8 Below Grade Concrete

720.3.3.8.1 Waterproofing must meet IBC Chapter 18 "Soils and Foundations," Section 1805.3 "Waterproofing" as the minimum requirements with the following changes and additions.

720.3.3.8.2 Waterproofing must meet the Water Tightness Performance Criteria specified in Set 722 Tunnel Structures.

720.3.3.8.3 Below grade concrete structure with one side in contact with the earth must provide waterstops at all joints. The exterior wall or slab penetration detail must be watertight. The design must not use bentonite waterproofing system below the maximum water table or as the waterproofing for the structures required to be Tightness Class 1 in Water Tightness Performance Criteria. The design must provide subsoil drainage system per IBC.

720.3.3.8.4 Use a water-based hydrophobic admixture in the concrete for the below grade walls and floors forming the elevator and escalator pits, LRV service pits, and traction power substation (TPSS) basement.

720.3.3.8.5 The exception in IBC Chapter 18 "Soils and Foundations", Section 1805.4.3, "Drainage Discharge" is not allowed.

720.3.3.8.6 Elevator and escalator pit walls and bottom slab, including the sump walls, must be at least 12 inches thick with two layers of reinforcement.

720.3.3.8.7 Equipment Rooms

720.3.3.8.7.1 See Set 722 Tunnel and Underground Structure Design.

720.3.3.9 MSE Walls and Structures

720.3.3.9.1 The design must not use MSE wall facing to provide vertical support for structural components. When designing the interconnection between the structure supported on MSE fill and the structure supported on deep foundation, the DOR must include the differential displacement between the deep foundation and MSE fill when calculating the drift.

720.3.3.10 CMU wall

720.3.3.10.1 The DOR must not use CMU for the elevator shaft.

Commentary: Kent garage design used CMU wall as the elevator shaft. One CMU wall below the roof slab cracked as the result of thermal load and water intrusion freeze and thaw. This elevator had to be shut down for an extended period of time for the repair. Several cracks were noticed at other elevator shaft CMU walls with some of them across the anchors of the elevator frame. This is considered as a safety hazard and the elevator had to be shut down.

720.3.3.10.2 Support the CMU wall on concrete curb wall below ground. The top of concrete curb must not be narrower than the CMU wall thickness.

720.3.3.10.3 Separate the top of CMU wall serving as the partition wall from the bottom of floor deck that is above the wall. Provide vertical separation joint with compressible material at the intersection and the corner of the CMU partition wall.

720.3.3.10.4 Separate a load bearing CMU wall from a non-load bearing CMU wall with vertical separation joint.

720.3.3.10.5 Design and detail the CMU wall to eliminate any cracks under normal service conditions due to thermal effect and/or differential settlement.

720.3.3.11 Vibration

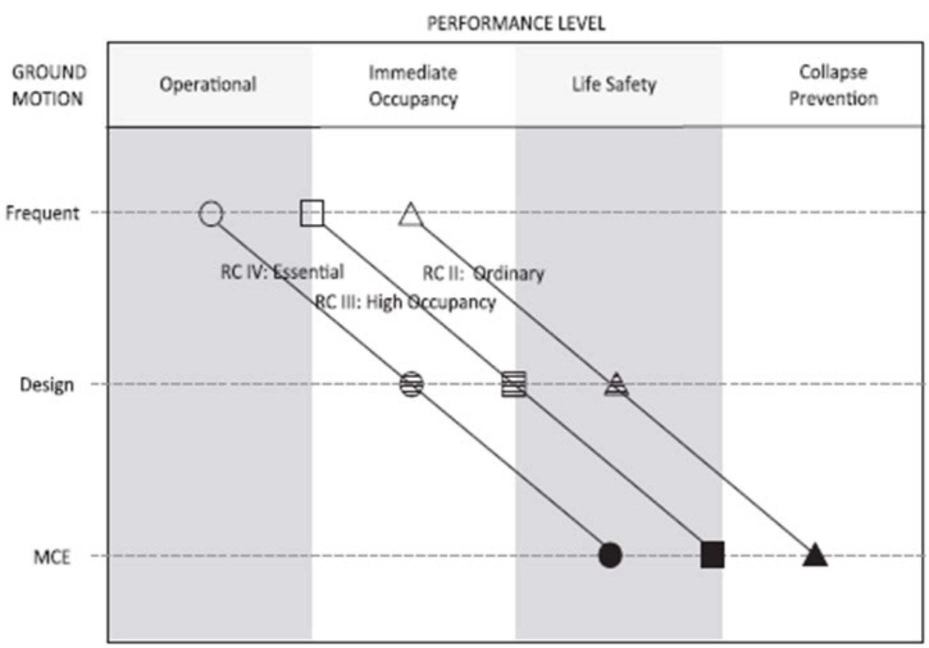
720.3.3.11.1 The DOR must check the steel framed stairs and floors for vibration serviceability due to human activities and meet AISC Design Guide 11, Floor Vibrations Due to Human Activity, Figure 2.1, “Recommended peak acceleration for human comfort for vibrations due to human activities.”

720.3.3.12 Seismic Analysis and Design

720.3.3.12.1 The DOR must perform the seismic design of building structures covered by this requirements set in accordance with IBC, local amendments, and ASCE 7, with the exceptions and additions herein.

Commentary: Structures designed and detailed per IBC and ASCE 7 will meet the following performance levels according to ASCE 7-16 Figure C11.5-1 as shown below.

Figure 720-1: ASCE 7-16 Figure C11.5-1 Expected Performance as Related to Risk Category and Level of Ground Motion



Commentary: As such, the seismic performance for Ordinary Structures (Risk Category II) is Collapse Prevention under Risk-Targeted Maximum Considered Earthquake (MCE_R), Life Safety at Design Earthquake, and Immediate Occupancy at frequent earthquake. Risk Category III structure such as the station has better seismic performance as shown by the hatched square.

Commentary: According to site-specific ground motion procedure for seismic design in Chapter 21 of ASCE 7-16 and the MCE_R maps shown in Chapter 22 of the same code, MCE_R ground motions incorporate a target risk of structure collapse equal to 1 percent in 50 years based upon a generic structural fragility.

MCE_R spectral response accelerations are taken as the lesser of the spectral response accelerations from the probabilistic ground motions and the deterministic ground motions. Probabilistic MCE_R spectral response acceleration at 0.2 seconds or 1 second is determined as the product of the Risk Coefficient Cr, and the corresponding probabilistic spectral response acceleration from a 5 percent damped acceleration response spectrum that has a 2 percent probability of exceedance within a 50-year period (i.e. the seismic event that has a return period of 2475 years) from 2014 United States Geological Survey (USGS) Seismic Hazard Maps. According to ASCE 7-16 Figure 22-18A and Figure 22-19A, in Greater Seattle area the Risk Coefficient Cr is around 0.91 and 0.89 for 0.2-second period and 1-second period, respectively. Because the station structures are designed as Risk Category III with the Importance Factor of 1.25, the structural performance will still be at least Collapse Prevention under the MDE that has a return period of 2475 years. This is in line with the seismic performance goal of elevated guideway under the MDE as defined in Set 721 Bridges and Elevated Structures.

720.3.3.12.2 The DOR must use the seismic analysis procedures listed in ASCE 7 Chapter 12 "Seismic Design Requirements for Building Structures", Table 12.6-1, "Permitted Analytical Procedures," with the exception that nonlinear response history procedure as prescribed in ASCE 7 Chapter 16," Nonlinear Response History Analysis," is not permitted unless approved by the Sound Transit Design Requirements Set 720 owner.

720.3.3.12.3 The new building seismic force resisting system must meet the seismic design requirements in ACI 318, AISC 341, or TMS 402 for concrete, steel, or masonry structures, respectively. Performance based analysis and design is not allowed for new building design. Structures vertically supported by a guideway substructure must follow Appendix 1 in this requirements set in lieu of this requirement.

720.3.3.12.4 Seismically isolated structures as prescribed in ASCE 7 Chapter 17, "Seismic Design Requirements for Seismically Isolated Structures" and structures with damping systems as prescribed in ASCE 7 Chapter 18, "Seismic Design Requirements for Structures with Damping Systems" are not allowed unless approved by the Sound Transit Design Requirements Set 720 owner.

720.3.3.12.5 The DOR must design the support and anchorages of mechanical, electrical, and architectural components for the Component Importance Factor (Ip) in accordance with ASCE 7 Chapter 13, "Seismic Design Requirements for Nonstructural Components" with the additions in Table 720-1. Design equipment prefabricated buildings or ground-supported structures for the Risk Category specified in Table 720-1. The Ip factor and the risk category listed in these two tables are the minimum requirements.

720.3.3.12.5.1 A registered structural design professional with a PE license or licensed Structural Engineer (takes precedence if required elsewhere) registered in the state of Washington must stamp and sign the associated seismic calculations and drawings and submit for review.

Table 720-1: Mechanical, Electrical, and Architectural Component Importance Factors

Item Description	Component Importance Factor, I_p	*Commentary*
Artwork Support	1.0	
Backup Power System (Generator/Uninterrupted Power Supply)	1.5 required if supporting a fire pump; 1.0 for others	
Clean Agent Fire Suppression	1.5 required when clean agent system is provided in lieu of a required fire protection system; 1.0 for others	
Communication - Other	1.0	
Emergency Communication	1.0	*NFPA 72 required systems*
Emergency Responder Radio Coverage System	1.0	*Based on the recommendation from ST SEI group, this is not required to function for life-safety purpose after an earthquake. Cities have their own community emergency system.*

Item Description	Component Importance Factor, I_p	*Commentary*
Elevator not identified as occupant evacuation elevator	1.0	
Elevator identified as occupant evacuation elevators in IBC Section 3008	1.5	
Escalator not required for emergency egress	1.0	
Escalator required for emergency egress per IBC and/or NFPA 130 and its enclosure	1.5	
Emergency lighting	1.0	
Fire alarm	1.0	
Fire Protection Pre-action Release Systems	1.5	
Fire Protection Sprinkler Systems	1.5. Systems designed to NFPA 13 seismic requirements are deemed to satisfy ASCE 7. Seismic calculation per NFPA 13 must be reviewed and stamped by a registered structural design professional employed or hired by the sprinkler contractor.	
Glazed curtain wall	1.0	
System that conveys, supports or contains hazardous materials that are not in Group H occupancy per IBC	1.5	
HVAC ductwork	1.0	
Other Mechanical/Electrical/Plumbing components that do not fall into Ip of 1.5 per ASCE 7-16 13.1.3	1.0	
SCADA/EVS	1.0	
Signage	1.0	
Smoke Control	1.5	
Stairs and its enclosure	1.5	*People will use any stair for emergency egress even if the stair is not counted as the egress stair*
Link Control Center (LCC)	1.5	
Data center equipment	1.5	
TPSS	1.0	
All components in Risk Category IV structure	1.5 (exceptions to be determined by ST Structural Engineer or their representative)	

Notes for Tables 720-1:

1. The Component Importance Factor (Ip) in Table 720-1 is the minimum requirement. DOR must upgrade to Ip = 1.5 if required by the Project Requirement, design codes, or AHJ.

Table 720-2: Structures Supporting or Housing Mechanical and Electrical Equipment Risk Categories

Item Description	Location	Risk Category	*Commentary*
Communication house	NL	II	*Based on the recommendation of ST communication group. The radio equipment in this building is not for broadcasting information to the public and is not necessary for the emergency response.*
Data center building	NL	IV	
Elevator identified as occupant evacuation elevators in IBC Section 3008	NL	IV	
Escalator not required for emergency egress	Station	III	
Escalator required for emergency egress	NL	IV	
Link Control Center building	NL	IV	
Signal bungalow and equipment case	NL	II	*Based on the recommendation of ST train control and system engineers, this building does not need to be designed for emergency response.. If the bungalow fails and trains stop, then the Link Control Center (LCC) can direct the train operator via radio to proceed in a signal bypass mode to places for either passenger evacuation or even operate the complete system via radio commands to assist with larger scale community evacuation. All of this is conditional on there still being overhead contact system (OCS) power. For commuter rails, the trains can still operate, as they are self-propelled. Any dark signal would be treated as a stop and would be enforced by Positive Train Controls. All rail signal systems are considered “fail safe”. Any event severe enough to damage the building will cause trains to stop.*
TPSS prefabricated building	NL	III	*Based on the recommendation of ST system engineer. The “power generating station” is Risk Category III, and like the power station, there is also possible electrocution in TPSS. In addition, the failure of TPSS will have a big impact on ST’s facilities. Thus, TPSS building should be treated at the same level for Risk Category as the power station.*

Notes for Tables 720-2:

1. Abbreviations: NL - No location limit.
2. The Risk Category listed in Table 720-2 is the minimum requirement. DOR must upgrade to the higher Risk Category if required by the Project Requirement, design codes, or AHJ.

720.3.3.13 Earth Retaining Wall Design

Commentary: 2018 IBC has limited information on earth retaining wall design, and this has caused inconsistency on design approaches from DORs. AASHTO, on the other hand, has very detailed and up-to-date information on how to consider the total lateral force applied to the wall due to seismic and static earth pressure. After comparing the two codes, it has been determined that it is appropriate to design the retaining walls at the aboveground stations following the AASHTO approach. For the earth retaining structure that is required by AHJ to follow IBC, the requirements provided herein are in line with AASHTO LRFD 9th edition 11.6.5.1 and 11.6.5.2.2.

720.3.3.13.1 The DOR must follow Table 720-3 for the earth retaining wall that is in the scope of this set.

Table 720-3: Earth Retaining Wall Design Requirements

Wall Category	Design Requirements
Earth retaining wall at aboveground station that protects, supports, or potentially impacts the track	Follow the requirements in Set 701 Geotechnical Engineering, AASHTO and WSDOT GDM. See Set 721 Bridges and Elevated Structures for LRV design load and the Sounder train vehicle load.
Earth retaining wall at aboveground station that does not protect, support, or potentially impact the track	MDE as defined in Set 721 Bridges and Elevated Structures and follow the requirements in AASHTO and WSDOT GDM.
Building basement wall that retains soil, earth retaining wall around or inside a building, and earth retaining wall that is required to follow IBC by AHJ	Follow requirements in 720.3.3.13.2 through 720.3.3.13.7 and IBC with local amendments, whichever is more stringent.

720.3.3.13.2 When designing the earth retaining structure per IBC, the DOR must calculate the total lateral force applied to the wall due to seismic and earth pressure load by the combined effect of dynamic earth pressure (P_{AE}) and horizontal inertia force due to seismic loading of the wall mass (P_{IR}).

720.3.3.13.3 Geotechnical Report must provide the dynamic earth pressure according to IBC Chapter 18 "Soils and Foundations," Section 1803.5.12 "Seismic Design Categories D through F". Use P_{AE} = 1.5 * Dynamic lateral earth pressure due to design earthquake ground motions.

720.3.3.13.4 Seismic loading of the wall mass, P_{IR} = Kh (Ww +Ws), and where

Kh = seismic horizontal acceleration coefficient. See 720.3.3.13.6

Ww = the weight of wall

Ws = the weight of soil that is immediately above the wall, including the wall heel

720.3.3.13.5 To calculate the combined effect of P_{AE} and P_{IR}, considering them not to be concurrent, investigate the following two cases:

720.3.3.13.5.1 Combine 100 percent of the seismic earth pressure (P_{AE}) with 50 percent of the wall inertial force (P_{IR}), and

720.3.3.13.5.2 Combine 50 percent of P_{AE} but no less than the static active earth pressure force, with 100 percent of the wall inertial force (P_{IR}).

720.3.3.13.5.2.1 Use the more conservative result from these two analyses for design of the wall.

720.3.3.13.6 For cantilever earth retaining wall, seismic horizontal acceleration coefficient (Kh) = 0.5* PGA_M.

720.3.3.13.6.1 For building basement wall, earth retaining wall inside a building and the wall that cannot tolerate more than 1-inch lateral displacement: seismic horizontal acceleration coefficient (Kh) = 1.0 * PGA_M.

720.3.3.13.6.2 PGA_M = MCE_G peak ground acceleration adjusted for site class effects. See ASCE 7 11.8.3.2 within Section 11.8.3 "Additional Geotechnical Investigation Report Requirements for Seismic Design Categories D through F".

*Commentary: Sound Transit requires PGA_M that corresponds to the seismic event with 2,475-year return period instead of multiplying it by 2/3 to IBC Design Earthquake level. The 2018 IBC 1803.5.12.1 states, "the determination of dynamic seismic lateral earth pressure on foundation walls and retaining walls supporting more than 6 feet of backfill height due to design earthquake ground motions." Sound Transit requires PGA_M, which is above and beyond IBC, to ensure consistent seismic performance for all retaining walls in Sound Transit's inventory. Cantilever retaining walls are capable of 1 inch to 2 inches of lateral displacement during the seismic event with 2,475-year return period. According to AASHTO 11.6.5.2.2, Kh may be reduced by half without conducting a deformation analysis using the Newmark method or a simplified version of it. Building basement walls and retaining walls inside a building are usually connected to the slab at the top and/or connected to the walls in the perpendicular direction, thus 1.0 * PGA_M is reasonably conservative.*

720.3.3.13.7 Stability check

720.3.3.13.7.1 The DOR must follow IBC Chapter 18 "Soils and Foundations", Section 1807.2.3, "Safety Factor" to check stability for sliding and overturning. Do not use Alternative Basic Load Combinations in IBC 1605.3.2. Additionally, the Geotechnical Report must not allow the allowable coefficient of friction to increase by one-third.

720.3.3.13.8 Retaining Wall Types

720.3.3.13.8.1 See Set 701 Geotechnical Engineering for the requirements on the retaining wall types.

720.3.3.14 Longitudinal reinforcement of columns and structural walls must extend into the footing, mat, or pile cap, and must be fully developed for tension at the interface as the minimum requirement.

Commentary: This requirement is a lesson learned from one previous project that, for a column that was part of the lateral force resisting system, the post-installed column dowels were not fully developed for tension in their foundation.

720.3.3.15 Design all stairs as egress stairs in accordance with ASCE 7 Chapter 13 "Seismic Design Requirements for Nonstructural Components", Section 13.5.10, "Egress Stairs and Ramps."

720.3.3.16 The design of slabs supported by metal deck must follow Steel Deck Institute (SDI) standards. The DOR must design slabs continuous over beam supports for negative moment. Add shrinkage-reducing admixtures as prescribed in Section 720.3.4.11.2 and limit the total water content as prescribed in Section 720.3.4.11.3 to reduce the cracks in the concrete on metal deck.

720.3.3.17 Transfer Beam

720.3.3.17.1 When a transfer beam is used to distribute the load from the structures above it to that part of the structure directly below it and the transfer beam is not part of the lateral force resisting system, the DOR must check the frame in accordance with ACI 318 Chapter 18 "Earthquake-Resistant Structures", Section 18.14, "Members Not Designated as Part of the Seismic-force-resisting System." The induced moments and shears in the transfer beam must not exceed the design moment and shear strength of the member at any section along the beam length. Follow ACI 318 Section 18.14.3.2 for rebar detailing requirements.

720.3.3.18 Support and Underpinning of Existing Structure

720.3.3.18.1 See Set 721 Bridges and Elevated Structures.

720.3.3.19 Corrosion Control

720.3.3.19.1 See Set 721 Bridges and Elevated Structures.

720.3.3.20 If the design requires photovoltaic panels, it must provide the support structure for the panels.

720.3.4 Parking Garage Structural Design Requirements

720.3.4.1 The garage design must employ cast-in-place concrete and PT slab construction. The minimum thickness of PT slab is 5 inches. The design must not use steel deck either as a composite system or stay-in-place form. Do not use steel beams or precast beams to support the garage deck.

720.3.4.2 The garage design must follow ACI 362.1R for the design and construction of durable concrete parking structure for Coastal Chloride Zone I (Zone CC-1).

Commentary: According to ACI 362.1R, Exposure Zone II is defined as freezing occurs and deicing salt is infrequently used. Coastal Chloride Zone (Zone CC-1) is defined as within Zone 1 and between 1/2 and 3 miles from a major saltwater body. Both Zone II and Zone CC-1 have the same requirements for concrete minimum strength, air content, rebar cover and sealer. Sound Transit Operations apply deicer that contains chloride ions to all exposed surface that is subject to snow and ice.

720.3.4.3 The garage concrete exposure class must follow ACI 318 durability requirements and the following additions. Show concrete exposure classes and concrete maximum water-cement ratios on the design drawings.

720.3.4.3.1 The garage roof deck and other uncovered decks must use hydrophobic concrete with durability greater than or equivalent to concrete exposure class F3/C2/W1 as specified in ACI 318.

720.3.4.3.2 The garage floors, ramps, concrete stairs, and high traffic areas must meet concrete exposure Class F2/C2/W1 as specified in ACI 318 at minimum. A high traffic area is defined as the area within 100 feet in all directions from the garage entrance or exit.

720.3.4.3.3 The garage slab on the ground must meet concrete exposure Class F2/C1/W1 at minimum, except the high traffic area, which must meet 720.3.10.3.2.

720.3.4.4 The top concrete cover for PT tendon and mild reinforcement in slabs and beams must be no less than 1-1/2 inches, even if the member is classified as Class U per ACI 318 Chapter 24 “Serviceability Requirements,” Section 24.5.2 “Classification of Prestressed Flexural Members”. The bottom concrete cover for PT tendon and mild reinforcement must be no less than 1 inch.

Commentary: This requirement is to ensure the long-term durability of prestressed members considering the potential reduction of the top cover during the design life of the garage due to the vehicles with studded tires. On E360 garage and Mercer Island park-and-ride, there are spots on the floor or roof deck where the PT tendons only have a very thin layer of spalled concrete cover.

720.3.4.5 The top concrete cover for mild reinforcement in concrete stairs must be no less than 1-1/4 inches and the bottom concrete cover must be no less than 3/4 inches. Top reinforcement must be epoxy-coated or galvanized.

720.3.4.6 The parking garage design must consider the entire garage as “exposed to weather.”

720.3.4.7 The maximum spacing of separate joints for expansion and contraction in garage slabs must be no more than 400 feet.

720.3.4.8 All floor decks must have a minimum PT precompression of 175 psi and the roof deck must have a minimum PT precompression of 200 pounds per square inch. This requirement does not apply to the temperature PT tendon.

720.3.4.9 Temperature and Shrinkage Reinforcement

720.3.4.9.1 Provide a minimum post-tension pre-compression force of 150 psi at elevated floor decks, and 200 psi at roof decks, parallel to the span of the beams. Locate PT tendons at mid-height of the slab thickness and spaced equally between beams in accordance with ACI 318 Sections 7.6.4.2 and 7.7.6.3.1.

720.3.4.9.2 When PT tendons are provided as temperature and shrinkage reinforcing per the requirement above, the amount of mild steel reinforcing must be no less than 0.36 percent. Distribute the mild steel reinforcing for temperature and shrinkage in two equal layers (top and bottom) for slab thickness equal to or greater than 7 inches.

Commentary: E360 garage PT roof deck cracking map shows extensive shrinkage and temperature cracks parallel to the short direction of slabs. Sound Transit's consultant recommended the use of PT temperature tendons in roof and floor slabs, then mild steel for temperature and shrinkage reinforcement. It was suggested to use PT tendons in the long span beams (however, PT should not be used in Moment Frame beams). For applications such as all levels of a parking garage, the ACI 318-14 minimum mild steel temperature and shrinkage reinforcing requirement (.0018) should be doubled to help minimize cracking (.004) and quadrupled to eliminate cracking (0.008). Furthermore, ACI 224R-01 Section 3.5.2 states, "the minimum-reinforcement percentage, which is between 0.18 to 0.2 percent, does not normally control cracks to within generally acceptable design limits. To control cracks to a more acceptable level, the percentage requirement needs to exceed 0.6 percent." E360 garage roof deck temperature and shrinkage reinforcement in the long direction is mild rebar with a ratio of 0.18 percent and the roof deck concrete is Hycrete concrete. Both the roof deck and floor deck mix designs are in compliance with 720.3.4.11. This shows that a good concrete mix design alone without enough temperature and shrinkage reinforcement is not adequate in preventing temperature and shrinkage cracks. According to the Sound Transit consultant specializing in garage design, the roof traffic coating is not needed if the roof is designed properly to reduce the cracks.

720.3.4.10 Roof and floor deck design must consider the locations of the stiff restraining vertical structural components, and place closure pours between these components where practical. Minimum reinforcement provided for temperature and shrinkage must be shown on the design drawings.

720.3.4.11 Concrete mix design for the garage roof and floor decks must meet the following requirements:

720.3.4.11.1 Perform shrinkage tests in accordance with ASTM C157 on concrete mixes for PT slabs. The shrinkage at 28 days must be no more than 0.025 percent for the closure strips and 0.035 percent for other areas of PT slabs.

720.3.4.11.2 Include a shrinkage-reducing admixture of no less than 1.0 gallon per cubic yard in the roof deck concrete mix design and in the closure pour concrete mix design.

720.3.4.11.3 For roof and floor slabs, limit the total water content of the slab and beam concrete mix to 250 pounds per cubic yard.

720.3.4.12 The DOR must design the PT slab with closure pour strips that are cast after initial shrinkage and creep occurs. PT slab closure pours must remain open for a minimum of 60 days after post-tensioning the slab to allow for creep and shrinkage movements to sufficiently develop. Provide at least one closure strip for PT slab lengths between 250 feet to 325 feet. Provide at least two closure strips for slab lengths between 325 feet to 400 feet.

Commentary: This requirement is to reduce the cracking associated with the closure pour. According to ADAPT Structural Concrete Software System Technical Notes, the fraction of the PT slab shortening due to creep and shrinkage for post-tensioned floor system at 30 days is 43 percent, while at 60 days is 56 percent. Caltrans requires 60 days on closure pours for deck closure per Caltrans Structure Technical Policy 5.4. In addition, Northgate garage floor slab shows some cracks related to the closure pour. The limitation on the lengths between closure strips is based on PTI manual (6th edition).

720.3.4.13 The slopes of the slabs must be such that it provides positive drainage without ponding. See Set 830 Parking Facilities Layout for the slope requirement. Floor slabs must slope away from all stairs and elevators to prevent water from flowing into stair and elevator openings.

720.3.4.14 Columns must not be located in the drive aisle. Restrict garages to passenger vehicles only. Check all columns for the vehicle barrier system load as specified in IBC Chapter 16 "Structural Design," Sections 1607.9 “Vehicle Barriers” and 1607.10 “Impact Loads”, acting simultaneously with other design loads. If the garage is open to vehicles heavier than passenger vehicles, check all columns for the vehicle impact load in accordance with IBC 1607.7.1 loads and the design criteria, which must be approved by the Sound Transit Structural Engineer or their representative.

720.3.5 Station and Platform Structural Design Requirements

720.3.5.1 Design all stations and platform structures as Risk Category III “Buildings and other structures that represent a substantial hazard to human life in the event of failure” in IBC Chapter 16 “Structural Design,” Section 1604.5 “Risk Category”, except the stations on bus rapid transit (BRT) projects.

Commentary: Require all Link and commuter rail train stations to be Risk Category III to ensure consistent risk category and seismic performance on the entire system. BRT stations are allowed to follow 2018 IBC because there are alternate routes.

720.3.5.2 Platform deformations relative to vehicle floors in both vertical and horizontal directions must comply with ADA requirements for transportation facilities.

720.3.5.3 Platform concrete must follow ACI 318 durability requirements with the additions outlined in 720.3.5.3.1. and 720.3.5.3.2. Show concrete exposure class and concrete maximum water-cement ratio on the design drawings.

720.3.5.3.1 Elevated platform concrete without topping and the concrete for exterior stair must meet F3/C2/W1 at minimum.

720.3.5.3.2 For at-grade platform and slab-on-ground concrete exposure, class must meet F2/C1/W1 at minimum.

Commentary: Sound Transit Operations sprays deicer that contains chloride ion on platforms. To ensure concrete durability, elevated platform without topping is required to be exposure Class C2; slab-on-grade is allowed to be exposure Class C1 because it is uniformly supported by soil and its damage will not cause a structural failure.

720.3.5.4 Locate structures or non-structural components on Link projects out of the clearance envelope of LRV defined in Set 520 Vehicle Clearances and Track Spacing plus 3 feet, unless this component is protected by a barrier wall, or a continuous wall as prescribed in Set 721 Bridges and Elevated Structures and is outside the Clearance Line as specified in Set 520. For the commuter rail train, locate structures and non-structural components on the platform outside the Clearance Line as specified in Set 530 Track Clearance and Spacing.

720.3.5.5 Structures that are beside the track, e.g., canopy and elevator, must be checked for ODE with the Response Modification Coefficient (R) equal to 1. The total deformation of the structure due to structure deformation must not encroach the train clearance envelope. See Set 530 Track Clearance and Spacing and Set 520 Vehicle Clearances and Track Spacing for commuter rail train and LRV train clearance envelope, respectively.

720.3.5.6 Combined Elevated Guideway and Station Structure Seismic Design Requirements

720.3.5.6.1 The seismic design of elevated platform that is supported by the same substructure as the guideway must follow the requirements specified below. See Set 721 Bridges and Elevated Structures for the guideway and substructure design and the definitions of Operating Design Earthquake ODE and MDE.

720.3.5.6.2 General Requirements

720.3.5.6.2.1 The engineering design team must include a Seismic Design Manager who is responsible for harmonizing criteria and ensuring that the work of design disciplines (Geotechnical, Structural – Guideway and Building, Architectural, Mechanical, Electrical, Civil, etc.) are consistent with the resulting design criteria.

720.3.5.6.2.2 Because the most common seismic design procedures of both IBC and AASHTO rely on ductile inelastic (plastic) response of the SFRS, 720.3.5.6 is written to address such response. If an alternative SFRS, such as seismic isolation, auxiliary damping, or other system not relying on inelastic response is utilized, the DOR must develop a project-specific seismic design approach for approval by Sound Transit Design Requirements Set 720 and 721 owners.

720.3.5.6.2.3 These requirements are intended to be used with the response spectrum analysis approach to design, such as the Equivalent Lateral Force and Modal Response Spectrum Analysis in IBC and the Elastic Dynamic Analysis coupled with the Nonlinear Static Procedure in AASHTO. This approach is appropriate for combined structures that do not include an intermediate concourse level that is integral with the guideway structure. Structural elements controlled by AASHTO must meet the AASHTO requirements, and those structural elements controlled by IBC must meet the IBC/ASCE 7/ASCE 41 requirements.

720.3.5.6.2.4 When an intermediate concourse level is present and is integral with the elevated guideway structure, the elevated guideway structural system does not fall within the scope of the AASHTO seismic specifications. The AASHTO criteria does not fully address the required seismic qualification process for such a system, and the DOR must use either the ASCE 41 Nonlinear Static Procedure (NSP) (particularly the target displacement provisions in 7.4.3.3.2 of ASCE 41) or an NLTHA to assess FCS performance. Use of NLTHA requires that project-specific design criteria and site-specific input acceleration or displacement histories be developed for the project. Requirements Set 720 and 721 owners must approve such an enhanced approach.

720.3.5.6.2.5 If an intermediate concourse level is present and is integral with the elevated guideway structure, the design team or the design-build contractor for design-build project must conduct an independent peer review of the SFRS, including the input ground motions, for structurally combined stations with intermediate concourse levels. The peer review team must be separate from the design team and the design team's organization. The peer review team must be composed of engineers familiar with IBC and engineers familiar with AASHTO. The Sound Transit design manager must approve the peer review team. The peer review must begin at the preliminary engineering stage to develop reasonable criteria for bidding and should continue through Issued for Construction documents to satisfy Sound Transit and AHJs. The DOR must get written approval from the peer review team that the method of analysis, basis of design beyond what is prescribed in this requirements set, and the design have satisfactorily addressed the team's comments before 100 percent design is complete. The DOR must involve the AHJ from the start of a project to enable agreement on codes and methods used to justify code compliance.

720.3.5.6.2.6 In section 720.3.5.6, "IBC" is taken to mean the combination of IBC, ASCE/SEI 7, material specifications, such as ACI, and local jurisdiction modifications. Likewise, "AASHTO" is taken to mean the combination of the Sound Transit Design Requirements Set 721 Bridge and Elevated Structures and the AASHTO Guide Specifications for LRFD Seismic Bridge Design.

720.3.5.6.3 Design Ground Motions

720.3.5.6.3.1 For Structurally Combined Station guideway systems, the design must address the ODE, MDE, and IBC seismic events. The design must harmonize ground motions for the MDE and IBC (MCE_R and resulting design spectrum, including 2/3rds factor, redundancy factor, and ratio of geomean to maximum ground motions) seismic events in terms of design response spectrum shape and amplitude. Enveloping of response spectra for maximum response (i.e., taking the maxima of the two spectra) may be permitted when the IBC and MDE spectra do not correspond to one another, provided the effects of all applicable adjustment factors are appropriately considered in the harmonization that the design must consider the end use of the enveloped spectra. For example, if the design uses a single analysis for both IBC and AASHTO, then the enveloped spectra must satisfy both IBC and MDE, thus potentially making some checks conservative relative to their controlling code or specification. See the definitions of ODE and MDE in Set 721 Bridges and Elevated Structures.

720.3.5.6.3.2 For stand-alone non-combined building-type structural systems within a station, the DOR may assess only the IBC seismic events provided the structure does not protect or support the track or is not located beside the track. For non-combined guideway structures within a station, the DOR must assess ODE and MDE.

720.3.5.6.3.3 The drawing set structural general note sheet of Functionally Combined Structure (FCS, see definition in Appendix 1) must include the design response spectrum for the ODE, MDE, and IBC events.

720.3.5.6.3.4 It is acceptable to cite the source of the data as belonging to another DOR's drawing set, but each building or guideway discipline's plan set must show all applicable coefficients and design response spectra for the design covered by a given discipline.

720.3.5.6.4 Seismic Force Resisting Systems/Earthquake Resisting Systems

720.3.5.6.4.1 FCS (including separate stand-alone structures) must have a viable SFRS or ERS. For a system to be "viable," the following must occur:

720.3.5.6.4.1.1 The design must provide a targeted and pre-determined plastic mechanism that meets the equilibrium, compatibility, and stress-strain constitutive principles for the SRFS under consideration. DOR must verify this requirement by using Nonlinear Static Procedure (NSP), commonly referred to as pushover analysis, as required by AASHTO and as used in ASCE 41, to demonstrate that the intended mechanism can form and that it has sufficient displacement capacity to meet the MDE or IBC demands. The plot of the system force versus displacement is referred to as the NSP backbone curve. The design must conduct an independent peer review for use of ASCE 41 as verification of the design intent of ASCE 7.

720.3.5.6.4.1.2 The design must identify the expected energy-dissipating inelastic elements.

720.3.5.6.4.1.3 Such ductile elements must be capable of delivering the expected inelastic deformations and the DOR must detail such elements to achieve the expected deformations.

720.3.5.6.4.1.4 The DOR must identify capacity protected elements and design for the simultaneous overstrength plastic mechanism forces expected in the system, as required by AASHTO. Acceptance criteria for IBC-controlled elements and actions must follow ASCE 7 Article 16.4.2 "Element-Level Acceptance Criteria" and its commentary guidance for determining the nature of component actions as critical, ordinary, or noncritical based on the extent of collapse that may occur given the element's failure. Although Article 16.4.2 is part of the Nonlinear Response History Analysis chapter of ASCE 7, the criteria listed in this article is reasonable and adaptable to the NSP procedure that will be used to assess IBC-controlled elements that are part of an AASHTO-controlled system. Alternately, the design may follow ASCE 41 Article 7.5.3 "Non-linear Procedure".

720.3.5.6.4.1.5 If the design uses a system that does not rely on ductile inelastic response, then the DOR must develop a project-specific criterion and get approval from the Requirements Set 720 and Set 721 owner.

720.3.5.6.4.2 The DOR must include a set of sketches or diagrams of the combined intended SFRS in the calculations and on the structural plan general note sheets. Additionally, the DOR must include this same information in the maintenance manual. The purpose of these requirements is to provide post-earthquake inspectors or future engineering teams critical information relating to the intended seismic behavior of the structures.

720.3.5.6.4.2.1 The DOR must identify both inelastic energy dissipating and capacity protected elements on the sketches.

720.3.5.6.4.2.2 Additionally, the DOR must include a sketch indicating both the transverse and longitudinal principal structure directions under the respective directional loading.

720.3.5.6.4.2.3 For structurally combined systems, the longitudinal and transverse NSP backbone curves and submitted calculations must show both capacity and demand for the ODE, MDE, and IBC. Note that while the ODE is nominally a fully elastic check, showing ODE demand on the NSP backbone curves provides a relative indication of the demands relative to the larger MDE and IBC demands.

720.3.5.6.5 Structurally Combined Systems

720.3.5.6.5.1 When designing structurally combined systems using provisions from both AASHTO and IBC, where IBC element design forces are developed with system-level force-reduction factors (R/Ie factors), the DOR must assess the actual combined system as proportioned with the NSP to verify system performance. “As proportioned” means the use of the actual member strengths. The DOR must use ASCE 41 to address IBC-controlled element material properties, or those agreed to by the AHJ and Sound Transit.

720.3.5.6.5.2 The design must satisfy the strain limits and ductility limits of AASHTO for all bridge-controlled elements, and elements that are controlled by the IBC must meet the rotation limits for concrete elements for the Life Safety Performance Level of ASCE 41. This requirement is meant to produce a single, complete system that satisfies the displacement-capacity check of AASHTO/ASCE 41.

720.3.5.6.5.3 The DOR must document specific requirements of AASHTO and IBC such as regularity, balanced stiffness, P-Δ, displacement amplification, risk category, detailing, redundancy, vertical and horizontal irregularity in the Basis of Design. The DOR must address them during design and harmonize when conflicts occur.

720.3.5.6.5.4 The IBC element force requirements are determined satisfactory if all IBC-controlled inelastic elements have effective displacement ductility demands less than the corresponding limit as provided in ASCE 41 for the respective element type, as calculated from the NSP for the IBC ground motion.

720.3.5.6.5.5 IBC-controlled inelastic elements must meet the prescriptive element detailing requirements, as required by ACI for the structural material that comprises the IBC-controlled elements.

720.3.5.6.5.6 Where intermediate mass elements exist, such as concourses, the DOR must use either the ASCE 41 NSP or an NLTHA to verify system performance.

720.3.5.6.5.7 The DOR must evaluate structural elements that will not provide the desired inelastic ductile response as specified below.

720.3.5.6.5.7.1 Examples of such elements are typical bridge-type superstructures, typical bridge cross beams, long-span prestressed beams not meeting the ACI 318 special moment frame requirements, deep beams as defined by ACI 318, collector elements, and short columns (clear height-to-width ratio less than 2.5). Such elements may be seismically non-ductile because their flexural resistance is unequal in positive and negative bending, because they are not confined transversely to be ductile, or they are shear-critical, meaning that they may fail in shear before achieving the maximum plastic-mechanism force.

720.3.5.6.5.7.2 The DOR must not include such non-ductile elements as inelastic elements of combined-structure seismic force-resisting systems. Additionally, if ductile plastic mechanism action is expected in the SFRS, the DOR must apply the capacity design for non-ductile elements, including consideration of diminished concrete contribution to column shear strength due to ductile action in the plastic-hinging region of columns. The DOR should not design for elastic forces at the MDE level, even if further amplified by a factor of 1.5, because the premature failure in the elastically designed element may still occur. However, some exceptions may occur, and these are addressed in Section 720.3.5.6.6.

720.3.5.6.5.7.3 Include such non-ductile elements as capacity protected elements of such systems. Capacity protected elements/actions are all those elements and force resultants (e.g., shear) that are part of the structural plastic mechanism but are not ductile elements themselves and therefore must resist the maximum forces that can develop. Such elements are typically bridge superstructures, concourse floor systems isolated by moment release, cap beams, foundations, and shear in columns.

720.3.5.6.5.7.4 The DOR must design the platform as the diaphragm under seismic load in both longitudinal and transverse directions for the diaphragm, chord, collector loads per ASCE 7, and design the platform serving as the horizontal diaphragm and the platform longitudinal girder following the capacity design principals against column over-strength forces per AASHTO Guide Specifications for LRFD Seismic Bridge Design (SGS).

720.3.5.6.5.8 Elements of systems that follow specific standard's inelastic system requirements must use that system's detailing requirements.

720.3.5.6.5.9 The DOR must harmonize the detailing requirements of elements of systems that integrate ductile features of the bridge (AASHTO) and building (IBC) specification/code, coordinate through the Seismic Design Manager, and get approval from Sound Transit Structural Engineer or their representative.

720.3.5.6.6 Exception to Capacity Protection

720.3.5.6.6.1 When a single-level structure with no intermediate concourse, controlled by AASHTO, does not develop the complete intended plastic mechanism at the MDE (i.e., limited inelastic action has occurred in some elements, but a full plastic mechanism has not yet formed at the design demand), the DOR may find it difficult or undesirable to design for full capacity protection. In this case, the DOR may consider an exception to full capacity protection provided both the two following conditions are met:

720.3.5.6.6.1.1 All columns that are part of the intended plastic mechanism can withstand the full overstrength plastic hinging shear force corresponding to the intended plastic mechanism; and

720.3.5.6.6.1.2 All non-yielding elements of the ERS (including superstructure, foundations, cap beams, and platform structure) can withstand the forces corresponding to 1.5 times the MDE displacement, and none of the inelastic elements have reached their strain/displacement limits before the system reaches 1.5 times the MDE displacement.

Commentary: Conforming to both criteria allows for uncertainty in both the ground motion and structural response estimation and ensures that shear failure in columns, which can lead to collapse, does not occur.

720.3.5.6.7 Building-Type Structures Supported by Elevated Guideway or Other Stand-Alone Structures

720.3.5.6.7.1 The DOR must design building-type structures (e.g., canopies) that are supported by either guideway or stand-alone structures for the dynamic effects resulting from both the supporting structure and the dynamic effects of the supported elements. The design of the canopy column connections to the platform must meet ASCE 7 and must not be less than the overstrength forces.

720.3.5.6.8 Soil-Foundation-Structure Interaction

720.3.5.6.8.1 The DOR must include the interaction of the elevated guideway structures (typically supported by deep foundations) and adjacent stand-alone structures in the design when stand-alone structures are within the zone of influence of the guideway foundation passive soil resistance.

Commentary: The DOR geotechnical engineer may infer this zone of influence from the anticipated p-y response of the guideway deep foundations.

Commentary: Bounding of response estimates, particularly displacements, is permitted in lieu of full soil-foundation-structure interaction analysis.

720.3.5.6.9 Separation between Structures and Drift within Structures

720.3.5.6.9.1 Separation between structures must exceed the MDE displacements calculated with Square Root Sum of Square (SRSS), except as required below in Sections 720.3.5.6.9.4 and 720.3.5.6.9.5.

720.3.5.6.9.2 The DOR must increase IBC displacements by a factor of 1.5*R/Cd to estimate an equivalent MDE displacement. The DOR must base displacements and relative drift within AASHTO-controlled structures on the MDE displacements following any magnification due to short-period adjustment per Article 4.3.3 of the SGS. The DOR must include these drifts when non-structural elements, such as glazing and curtain-wall construction, are adjacent to or connected to the guideway structure.

720.3.5.6.9.3 The structural design drawings must show the magnitude of allowable and expected movements at all movement joints and refer to the corresponding structural and architectural details. Foundation settlement for the liquefiable soil must include liquefaction settlement.

720.3.5.6.9.4 When elements span between structures, such as floor joints for egress that are supported on both sides of the joint, the design must meet ASCE 7 provisions for "Members Spanning Between Structures."

720.3.5.6.9.5 As required by both AASHTO and IBC, when calculating displacements of the individual structural systems that are used to size separation joints, the DOR must include deformation components contributed by the foundations, including partial uplift of building-element shear walls, deformation of deep foundations, and the effect of liquefaction on system lateral stiffness and any other soil-foundation-structure interaction components. When sizing joints due to displacements between significantly different mass and stiffness structures, the DOR must use the absolute values of the displacements.

720.3.5.6.9.6 The design must provide separation gaps from the ground level up to the top of the structure.

720.3.5.6.9.7 The story drift of the substructure supporting the platform must meet ASCE 7 Chapter 12 "Seismic Design Requirements for Building Structures" Table 12.12-1 "Allowable Story Drift".

720.3.5.6.10 Settlement

720.3.5.6.10.1 The DOR must provide differential settlement estimates for the ODE, MDE, and IBC and meet the requirements in Set 701 Geotechnical Engineering and Set 721 Bridges and Elevated Structures.

Commentary: See Appendix 1- Commentaries to 720.3.5.6 Combined Elevated Guideway and Station Structures Seismic Design Criteria.

720.3.6 Operations and Maintenance Facility Building Design Requirements

720.3.6.1 Design the operation and maintenance facility building that maintains LRVs and BRT buses as Risk Category III structure "Buildings and other structures that represent a substantial hazard to human life in the event of failure".

Commentary: The LRVs parked inside the operation and maintenance building are expensive and have a long lead time to replace. This fits the description of Risk Category III structure, as listed in ASCE 7-16 Table 1.5-1, as "Buildings and other structures not included in Risk Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure." The operation and maintenance building on BRT project maintains buses that are required to be able to run and support recovery efforts after a disaster.

720.3.7 Artwork and Signage Structural Support and Anchorage Design

720.3.7.1 The artwork, signage support, and anchorage design must follow IBC with local amendments, ASCE 7, and the additions in this requirements set. The additional fatigue check for guideway signs or traffic signal structures must follow Set 721 Bridge and Elevated Structures. The design calculation and drawings must be stamped by a professional engineer registered in the state of Washington and submitted for review and approval by Sound Transit Structural Engineer or their representative before fabrication.

Commentary: Sound Transit Structural Engineers performed several case studies to compare the design wind pressure on signage based on ASCE 7-16 versus AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals. The case studies have shown that the design wind load calculation following ASCE 7-16 is conservative.

720.3.8 OCS Pole and Foundation Design

Commentary: The following requirements are based on the recommendations from OCS Research Task - Pole and Foundation Design dated June 2022.

720.3.8.1 This section only covers OCS pole and foundation structural design. See Set 221 Overhead Contact System for other requirements on OCS.

720.3.8.2 Governing Codes

720.3.8.2.1 The design must apply the following codes:

720.3.8.2.2 IBC – governs OCS foundation design.

720.3.8.2.3 ASCE 7 – governs the loads, including wind and ice load, and load combinations.

720.3.8.2.4 ACI-318 – governs the design of reinforced concrete structures, such as OCS foundations.

720.3.8.2.5 AISC – governs steel design for OCS poles.

720.3.8.3 Loads and Deflection Limits

720.3.8.3.1 Dead load must include the self-weight of the system, the static termination loads of any dead-ends, and the static lateral and/or vertical load due to wire deviation. Dead load deflection at the top of the pole must not exceed 2 percent of the pole height.

720.3.8.3.2 Live load must include the weight of ice on the system, the wind pressure applied to the wires and supports (with and without ice), and the loads due to increased tension on fixed termination systems in cold weather. Lateral deflection at the contact wire height under live load must not exceed 1 inch.

720.3.8.3.3 The OCS pole deformation under individual or combined loads must not encroach the train clearance envelope. See Set 520 Vehicle Clearances and Track Spacing train clearance envelope. Pole deformation must include the deformation due to the foundation displacement and rotation.

720.3.8.4 OCS Foundation and Anchor Design

720.3.8.4.1 OCS pole anchorage strength and its supporting structure, such as bridges or retaining walls, must be no less than the plastic capacity of the corresponding pole multiplied by 1.1. For OCS pole anchored to drilled shaft or spread footing foundations that rely on soil bearing to develop strength, the foundation capacity must be no less than the plastic capacity of the corresponding pole multiplied by 1.2.

720.3.8.4.2 Top elevations of OCS support foundations must meet the following requirements:

720.3.8.4.2.1 Ballasted/soil location in dedicated right-of-way (i.e., maintenance yard) – the top of foundation must be flush with grade with bottom of base plate at least 3 feet above top of foundation. See System Standard Drawing for baseplate detail. Baseplate must not encroach into the clearance envelope of LRV defined in Set 520 Vehicle Clearances and Track Spacing.

Commentary: Sound Transit Operations prefer to leave the space below the baseplate open so the hardware can be accessed for torquing and inspection. Any trash collected below the base plate can be cleaned.

720.3.8.4.2.2 Embedded location in dedicated right-of-way (i.e., viaduct) – See 720.3.8.4.2.1.

720.3.8.4.2.3 Ballasted/soil location in public right-of-way (i.e., landscaping area beside guideway) – See 720.3.8.4.2.1.

720.3.8.4.2.4 Embedded location in public right-of-way (i.e., sidewalk location adjacent to guideway) – See 720.3.8.4.2.1.

720.3.8.4.3 Foundation Design

720.3.8.4.3.1 Follow foundation recommendations in the geotechnical report for the foundation design. See Set 701 Geotechnical Engineering for requirements.

720.3.8.4.3.2 Drilled Shaft Foundation

720.3.8.4.3.2.1 Provide calculation to verify the deflection of the foundation at ground level does not exceed 1/2 inch. This is to ensure that the associated pole deflection does not compromise the contact wire position or vehicle clearances.

720.3.8.4.3.2.2 Clearance between the foundation and any subsurface utilities will typically be governed by the utility owner but must be no less than a minimum clearance of 2 feet accounting for the necessary constructability clearance.

720.3.8.4.3.2.3 Clearance between the foundation and other critical subsurface obstructions, such as basements or retaining wall soil nails, must be no less than 2 feet to suit OCS construction clearance but should also require a site-specific calculation in all such cases.

720.3.8.4.3.2.4 The calculation must include the non-effective depth at the upper portion of drilled shaft foundations. Ballast or disturbed soil at surface level does not provide adequate lateral bearing resistance for a drilled shaft foundation, and the non-effective depth must be defined in the criteria and should not be less than 2 feet.

720.3.8.4.3.3 Shallow Foundation or Alternative Foundation Types

720.3.8.4.3.3.1 Coordinate the design of shallow foundations or alternative foundation types with any underlying utilities to ensure no adverse load is brought to bear on the utilities due to the mass of the foundation.

720.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

720.4.1 System Breakdown Structure

720.4.2 System Sites and Locations

720.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this Requirement Set and other requirement sets.

Table 720-4: Interface Between Building Structures and Other Disciplines

SET SERIES	SET NAMES	SET 720 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	X
400	Vehicle	
500	Track	X
600	Fire-Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

720.5.1.1 This set provides the miscellaneous building structural design and equipment anchorage design requirements for Set 100 Series Train Control and Signals.

720.5.1.2 This set provides OCS pole and foundation design, miscellaneous building structural design, and equipment anchorage design requirements for Set 200 Series Traction Electrification.

720.5.1.3 This set provides the miscellaneous building structural design and equipment anchorage design requirements for Set 300 Series Operational Communications.

720.5.1.4 See Set 500 Series Track for the train dynamic envelope and clearance line to locate building structures and non-structural components.

720.5.1.5 This set provides the miscellaneous building structural design and equipment anchorage design requirements for Set 600 Series Fire/Life Safety.

720.5.1.6 See this set for multiple interfaces with other Set 700 series.

720.5.1.7 This set provides the signage and artwork structural design requirements for Set 800 Series Architecture. See Set 830 Parking Facilities Layout for other requirements on the garage design. See Set 821 Station Layout – Commuter Rail and Set 822 Station Layout – Light Rail for other requirements on station design.

720.5.1.8 This set provides the piping or utility line anchorage design requirements for Set 900 Series Civil.

720.5.1.9 This set provides the miscellaneous building structural design and equipment anchorage design requirements for Set 1000 Series Mechanical-Electrical and Building Systems.

720.5.1.10 This set provides the miscellaneous building structural design and equipment anchorage design requirements for Set 1100 Series Technology.

720.5.1.11 This set provides the miscellaneous building structural design and equipment anchorage design requirements for Set 1200 Series Security.

720.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

720.6.1 Building Structure Materials

720.6.1.1 The DOR must design the building structural components using only concrete, steel, and masonry in accordance with IBC and the exceptions and additions in this set.

720.6.1.2 Reinforced Concrete

720.6.1.2.1 Reinforced and prestressed concrete design must follow IBC and ACI 318, with the following exceptions and additions:

720.6.1.2.1.1 The reinforcement for the substructure supporting the elevated platform must follow Set 721 Bridges and Elevated Structures.

720.6.1.2.1.2 Deformed non-prestressed longitudinal reinforcement as specified in ACI 318 Article 20.2.2.5 (i.e., deformed non-prestressed longitudinal reinforcement resisting earthquake-induced moment, axial force, or both, in special moment frames, special structural walls, and all components of special structural walls including coupling beams and wall piers) and used in beams and columns of the gravity system that fits the description of ACI 318 Article 18.14.3.3 (i.e., where the induced moments and shears exceed the design moment capacity or design shear capacity, or if induced moments or shears are not calculated) must use ASTM A706 with the appropriate grade following ACI 318.

Commentary: ASTM A706 has good control on the tensile strength and elongation. The use of ASTM A615 in these elements requires meeting the additional requirements in ACI 318-14 20.2.2.5b, which is complicated and can lead to issues. Besides, the availability of ASTM A615 will likely become a special order according to the input from some local suppliers.

720.6.1.2.1.3 Prestressing steel must conform to the following standards:

720.6.1.2.1.3.1 Low relaxation steel strand ASTM A416 Grade 270 (AASHTO M203).

720.6.1.2.1.3.2 High-strength steel bar ASTM A722 Grade 150 (AASHTO M275).

720.6.1.2.1.4 Transverse reinforcement detailing must follow the requirements of ACI 318 Sections 25.7.2.1 through 25.7.2.3 and enclose the beam prestressed and non-prestressed longitudinal reinforcement.

720.6.1.2.2 Minimum Concrete Compressive Strength (f’c) at 28 days must meet the following requirements and other requirements in this set, whichever is more stringent:

720.6.1.2.2.1 Aboveground cast-in-place structures with mild reinforcement, footings, deep foundations, basement walls, and retaining walls, f’c = 4,000 pounds per square inch.

720.6.1.2.2.2 Cast-in-place prestressed concrete, f’c = 6,000 pounds per square inch.

720.6.1.2.2.3 Precast pre-tensioned concrete, f’c = 5,000 pounds per square inch.

720.6.1.2.3 Concrete durability must satisfy the requirements in this set. Concrete minimum strength at 28 days must meet the minimum compressive strength requirements in ACI 318 Table 19.3.2.1 “Requirements for Concrete by Exposure Class”.

720.6.1.2.4 Structural components that are in contact with the earth must be concrete.

Commentary: 2018 IBC 1805.3.2 allows walls required to be waterproofed to be of concrete or masonry. Exclude masonry wall in this application.

720.6.1.2.5 Reinforcement detailing must follow requirements in IBC and ACI 318. For non-prestressed and prestressed beams of Classes U, T, and C with beam height exceeding 36 inches, longitudinal skin reinforcement must follow ACI 318 Article 9.7.2.3 in Section 9.7.2 “Reinforcement Spacing”.

720.6.1.3 Structural Steel and Miscellaneous Steel

720.6.1.3.1 Steel design must meet the requirements in IBC, AISC 360, AISC 303, AISC Steel Construction Manual and AISC 341.

720.6.1.3.2 See Standard Specification Section 05 12 00 for the acceptable structural steel types.

720.6.1.4 Masonry

720.6.1.4.1 Masonry design must follow IBC and TMS 402 Building Code Requirements for Masonry Structures and this set.

720.6.1.5 Anchors

720.6.1.5.1 Anchor design must follow ACI 318-14, Chapter 17, “Anchoring to Concrete,” with the following addition:

720.6.1.5.1.1 The design must not use adhesive anchors installed overhead to resist tension.

720.6.1.5.2 Anchors for installing any structural or non-structural components must have the report from ICC Evaluation Service (ICC-ES) or International Association of Plumbing and Mechanical Officials (IAPMO) approving their use to resist seismic load and in cracked concrete.

720.6.1.5.3 Post installed anchor design calculation must specify the concrete as “cracked.”

720.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

720.7.1 Interface and Integration Management

720.7.2 Design Management

720.7.3 Manufacturing and Construction Management

720.7.4 Installation Management

720.7.5 Inspection and Testing Management

720.7.6 Training, Pre-Revenue Operations

720.7.7 Certification Management

720.8 APPENDICES

720.8.1 Appendix 1, Commentaries to 720.3.5.6 Combined Elevated Guideway and Station Structure Seismic Design Requirements

APPENDIX 1 – COMMENTARIES TO 720.3.5.6 COMBINED ELEVATED GUIDEWAY AND STATION STRUCTURE SEISMIC DESIGN REQUIREMENTS

PREFACE:

The target audience are users of the Design Requirements and Authorities Having Jurisdiction (AHJ), with assistance in interpretation for the specific project at hand from Sound Transit Structural Engineer, Sound Transit's Consultants, or Contractors' Engineers.

BACKGROUND:

Engineering teams on Sound Transit projects often design stations that are functionally combined elevated guideway and station structures, or Functionally Combined Structure for short (FCS). Operationally, such structures act as one, but physically, the structures may be a "combined" guideway and station structure; they may be composed of individual structures that are self-supported and ostensibly, "stand-alone", or the stations may be a combination of both types.

720.3.5.6 is intended to provide clarification of criteria and address common challenges that have arisen on FCS projects. Such challenges may be internal to the design team or they may also create ambiguous submittals and subsequent responses from the AHJ over building and station structures.

COMMENTARIES TO 720.3.5.6:

The objective of a rational design approach for combined stations can be met by appropriate application of the Sound Transit Design Requirements, AASHTO, and IBC documents, including "harmonization" of conflicting criteria provisions. However, application of these documents without skillful and thoughtful consideration of the desired seismic behavior will not result in a structure that meets the seismic performance objectives.

*1. **Design Ground Motions**. At the present time and due to different versions of specified ground motion for the IBC and AASHTO, variations in the design ground motion response spectra often occur. Harmonization of the design criteria requires comparison of the design ground motions, including soil adjustment factors, risk-targeting, maximum (IBC) versus geomean (AASHTO), near-fault factors, United State Geological Survey updates, and any other differences to develop a single ground motion to use for each of the design levels – ODE, MDE, and IBC. A simple enveloping of the spectra is considered adequate, but the design team should consider the causes of any conflicts and resolve them conservatively relative to the two design approaches – IBC and AASHTO.*

The designers, including the Seismic Design Manager, of a combined structure where both IBC and AASHTO spectra affect the analysis and design of the structural system, need to understand that the IBC/ASCE 7 documents address design from a reduced-force and displacement perspective based on R and Ie, while AASHTO uses the unreduced displacements for design checks. This can be confusing to users of both specifications, and recognition of this difference is part of the required harmonization process. The displacement calculation used to design members spanning between structures in ASCE 7 is the only time the unreduced displacement corresponding to the MCE_R *is used.*

The DOR must assess structurally combined systems for the ODE and, as permitted in the DCM, station structures that are separated from the elevated guideway structure are not required to be designed for the ODE. The design for the ODE loading becomes a strength load case with load factors and resistance factors of 1.0.

*2. **Seismic Force-Resisting Systems/Earthquake Resisting Systems**. Both the IBC and AASHTO seismic design provisions seek to produce structural systems that may respond to earthquake shaking with some level of damage but that such systems will satisfy a life-safety performance objective where loss of* *life is prevented under MDE. The commentary provided below is intended to provide background perspective on issues or questions that have arisen on similar Sound Transit projects.*

ASCE 7 Article C12.1 states: "Structures designed in accordance with this standard are likely to have a low probability of collapse but may suffer serious structural damage if subjected to the risk-targeted maximum considered earthquake (MCE_R) or stronger ground motion."

Similarly, AASHTO Article 3.2 states, "bridges shall be designed for the life safety performance objective considering a seismic hazard corresponding to a seven percent probability of exceedance in 75 years. Higher level of performance, such as the operational objective, may be established and authorized by the Bridge Owner." (Note that Sound Transit has established and authorized both an operational earthquake (ODE) and changed the design earthquake event to a Maximum Design Earthquake (MDE) with a return period of 2,500 years – approximately 3 percent probability of exceedance in 75 years.) Article 3.2 further states, "Life Safety for the design event shall be taken to imply the bridge has a low probability of collapse but may suffer significant damage and that significant disruption to service is possible."

Note that the mapped Risk Coefficients, C_{RS} and C_{R1}, used to convert MCE hazard to MCE_R probability of collapse are 1.0 and 0.96 for 0.2 seconds and 1.0 second spectral response, respectively, in ASCE 7-10. These values shifted downward to approximately 0.91 in ASCE 7-16. These factors provide perspective on the difference between hazard-based and risk-targeted MCE ground motions. It is also useful to note that, as of the time of the writing of this document, AASHTO is considering transitioning to risk-targeted ground motions.

Both the IBC and AASHTO are primarily based upon SFRS that depend upon inelastic response (either plastic hinging or plastic axial yielding) of specifically selected elements that can be detailed to provide reliable inelastic response under seismic loading. The remaining elements of the structural system are then designed to remain essentially elastic with no inelastic response and therefore no damage. In the IBC, the remaining elements are designed using "overstrength" forces or "probable strength" forces, and in the AASHTO method, the remaining elements are designed using capacity protection principles and overstrength forces applied at the full plastic mechanism. Capacity protection at the full plastic mechanism level using displacement-based assessment is a more rigorous assessment of the maximum internal forces that can develop than the force-based prescriptive methodology the IBC provides. This challenge with the force-based design methodology is one reason that ASCE 41 provides the NSP method for assessment of existing buildings.

To achieve the desired response, the IBC and AASHTO prescriptively select locations of inelastic response based on assumptions about the construction type building with multiple stories and high column axial loads or bridge with long specialized superstructure spans and relatively light column axial loads. This prescriptive approach simplifies seismic design and when applied to moment-resisting frame systems leads to the strong-column-weak-beam conceptual description for buildings and weak-column-strong- beam conceptual description for bridges.

Generally, IBC-controlled elements follow IBC criteria, and AASHTO-controlled elements follow AASHTO criteria. There are instances where these criteria intersect, and accordingly harmonization of criteria must occur. An example is platform framing that is structurally integrated with the guideway superstructure and supporting beam. In that instance, rather than designing the platform framing as a ductile element per the IBC/ASCE 7/ACI, the platform and its framing can be designed using the guideway overstrength forces as a capacity protected system. Harmonization of criteria would address such an intersection of criteria.

Displacement-assessment methodologies, such as those in the AASHTO Seismic Guide Specifications and in the ASCE 41 existing building evaluation document are, in principle, quite similar. Both methods address ductile mechanism-based, capacity-protected systems. The details of application between the two methodologies are different and too extensive to address in this memorandum. However, understanding *the basis of the two documents will lead to a parallel view where the ductile elements in AASHTO correspond to displacement-controlled actions in ASCE 41, and capacity protected elements and actions (e.g., column shear) in AASHTO correspond to force-controlled actions in ASCE 41. The NSP assessment methodology is similar between the two documents and, with appropriate harmonization, can be applied to combined structural systems covered in this document. The ASCE 41 NSP includes methodology to address multiple stories and their mass distribution in the development of the push-over deformation shape over the height of the structure. This is effective in dealing with combined stations having intermediate concourses. Use of the ASCE 41 NSP for the guideway structure will require harmonization. An additional consideration in harmonization of the two criteria is the assessment at the target displacement for AASHTO and ASCE. Two different target displacements may be needed, or a controlling displacement selected. The precise steps to complete such harmonization will be case- specific to the structure in question and will need to be addressed on a case-by-case basis. The potential use of elements of both versions of NSP and their reconciliation is another reason that a Seismic Design Manager is required in this memorandum.*

Comparisons between IBC and AASHTO are made informally, and often designers and building officials view AASHTO seismic designs as inconsistent with IBC designs. A principal reason for this is rooted in the weak-column-strong-beam design concept that underpins AASHTO seismic design. This design concept is appropriate for bridge type structures that are single-story structures where axial loading of columns is quite low consequently permitting highly ductile columns to be built, which will provide ductile structure response to large earthquakes. This concept also addresses relatively long-span superstructures that do not lend themselves to inelastic, ductile seismic response. Whereas for building systems, weak-beam systems are used which is appropriate for multi-story structures with high axial load ratios in the columns. Thus, the beams provide the mechanism for inelastic plastic deformation.

Another difference in how IBC and AASHTO designs are perceived relates to the terms "life-safety" (LS) and "collapse-prevention" (CP). AASHTO uses these essentially interchangeably, whereas the IBC views these as two separate limit states. The reality is that AASHTO limits are roughly equivalent to IBC life-safe designs.

Because of these perceived differences, a small benchmarking comparison of displacement capacities was undertaken to address the differences in limit states quantitatively. This was accomplished using column designs that meet the AASHTO displacement design procedure, follow the AASHTO detailing requirements, and just meet the strain limits and displacement capacity. Note that the displacement ductility limits were not considered, because these add conservatism to the AASHTO limits. These column designs were compared with the available inelastic capacities to those of ASCE 41-17 Table 10-9 for the LS, CP, and total displacement at collapse limits.

Ten columns were compared in terms of plastic rotation capacity and lateral displacement capacity. Data were taken from a National Highway Institute course on seismic design of bridges. Column sizes, heights, axial load ratios, and longitudinal and transverse steel ratios were reasonably typical of bridge columns and of guideway columns built for Sound Transit, although not identical.

The ratios of AASHTO to ASCE 41 plastic rotation capacities and displacement capacities are shown in Table 720-5 below. These comparisons indicate that the AASHTO capacities are consistently conservative relative to ASCE because all ratios are less than 1.0. The comparisons also indicate that AASHTO designs are closer to the ASCE LS limits than to the CP limits, although AASHTO designs are still conservative relative to the IBC even at the LS limit state. The median collapse displacement comparisons likewise are conservative with AASHTO displacements placing no higher than 50 percent of the ASCE full median collapse limit. Thus, it is reasonable to state that AASHTO designs correspond to LS limit states as defined by ASCE and IBC, and AASHTO is also consistently conservative relative to the LS limit state.

Therefore, a guideway design by AASHTO for the MCE ground motion should provide conservative LS level performance for such ground motion, provided that the demands (MDE versus MCE_R) are essentially equivalent. An IBC-controlled structure designed using Seismic Importance Factors (i.e, of 1.25 or 1.5) should likewise provide LS level performance at the MCE_R ground motion.

Table 720-5: Comparison of AASHTO Limits to ASCE 41-17 Limits

	Plastic Rotation Capacity, θp, Ratios			Displacement Capacities, Δt, Ratios		
	ASCE 41-17 Table 10-9 Limit State Definitions and Probability of Exceedance (PE)					
AASHTO/ASCE	Life Safety 10% PE	Collapse Prevention 25% PE	Median Collapse 50% PE	Life Safety 10% PE	Collapse Prevention 25% PE	Median Collapse 50% PE
Range	0.59 to 0.92	0.42 to 0.66	0.30 to 0.46	0.66 to 0.93	0.49 to 0.69	0.36 to 0.50
Average	0.75	0.54	0.38	0.79	0.59	0.42

The comparisons in Table 720-5 address the yielding elements in an AASHTO design, and these are the columns. The non-yielding elements including superstructure, foundations, beam-column joints, abutments, and column shear action, are designed in accordance with AASHTO, to be “capacity protected” to resist the forces corresponding to the development of a full plastic mechanism, including overstrength conditions such as strain hardening and material overstrength. The AASHTO process is more conservative than that used with IBC designs where a full plastic mechanism is not required to be identified during design. Instead, the IBC design process focuses on members instead of the entire system.

Reinforced concrete detailing comparisons are often made between IBC (ACI 318) and AASHTO, and while the provisions are generally similar, they are not identical. Part of this relates to the beams being the yielding elements providing ductile response for IBC and columns providing inelastic response for AASHTO. It is not fruitful to focus at too detailed a level on comparing different specific provisions in each standard. It is more relevant to consider that the provisions of the two standards have evolved through extensive large-scale testing, field experience, and actual observed earthquake performance. The provisions of the two standards are assembled to ensure that performance will be consistent for each system.

Where AASHTO-designed guideway structures support IBC-designed building-type structures, such as canopies, the design methods of each standard should be used consistently for each system and the seismic performance expected should be as outlined above. The canopy example is a commonly encountered design challenge for Sound Transit station projects. A “Two-Stage Analysis Procedure” as defined in ASCE 7 (Section 12.2.3.2 in ASCE 7-16) is often used to analyze such systems. Where the two-stage procedure is used, the guideway should perform as it is intended by the AASHTO provisions. The canopy will typically be light and flexible enough relative to the guideway to satisfy the two-stage analysis requirements and the canopy will need to be detailed in accordance with ASCE 7 and associated material standards for the canopy to perform as intended. Even though the ASCE 7 and AASHTO provisions are both used, the system will still need to be comply with all criteria listed in ASCE 7-16, Section 12.2.3.2, noting that an equivalent R-factor will need to be calculated for the guideway structure and that period and stiffness terms are based on effective (cracked) initial stiffness, not secant stiffness, and that the lower *portion (guideway) is designed as a separate structure to the AASHTO criteria. As noted in ASCE 7, the ratio of R of the canopy to that of the lower portion (equivalent R for guideway) must not be less than 1.0.*

If an equivalent R-factor for a comparison of the AASHTO guideway to IBC/ASCE 7 methods is desired, such a factor can be determined from the NSP (pushover) analysis that is used to check the adequacy of the guideway against the AASHTO criteria. A consistent comparison of effective R factor will require differences between the AASHTO and IBC spectra to be reconciled. The Seismic Design Manager, as defined in the Provisions portion of this document, is responsible for ensuring this interpretation is resolved by the structural design teams as required.

When truly combined systems are used, harmonization as described below is required. This will involve more adaptations between the design standards.

*3. **Structurally Combined Systems**. When no intermediate concourse level exists, then harmonization of the IBC and AASHTO design provisions is relatively simple. Columns can be designed as the ductile elements in accordance with the AASHTO approach, and the platform level must be capacity protected to prevent damage to the platform structural elements. Lightweight canopies that are supported by the platform may be designed as described below. It is important that vertical circulation structures, such as elevator towers and stair/escalator elements, be articulated using complete separation or movable/sliding joints, respectively, such that they are not part of the lateral seismic force resisting mechanism.*

The individual approaches used for IBC and AASHTO seem to conflict if applied to a single structural system. This poses a fundamental challenge for combined guideway-station-type structures, particularly those with concourses at an intermediate level between the guideway and the station entrance/egress level.

The apparent conflict between IBC and AASHTO may be reconciled or "harmonized" by designing a case-specific plastic mechanism for the combined structure instead of relying on the code-based prescriptive method. For structurally combined stations, a reasonable hybrid inelastic system for a two-story configuration with an intermediate concourse is one where the columns are inelastic at their tops and bottoms and beams are inelastic at potential concourse levels, as shown in Figure 720-2, Alternative 1. Examples of such plastic mechanisms are shown in Figure 720-2 for longitudinal and transverse seismic loading directions for moment-frame seismic force-resisting systems. The intended plastic mechanism is identified with black circles denoting locations of plastic hinges, which are sufficiently ductile to permit a full plastic mechanism to form under sufficiently large earthquake lateral loading. The designer controls the locations of plastic hinges such that structural members capable of adequate ductile action define the plastic mechanism. Other adjacent members are "capacity protected" by ensuring that their strengths are larger than the corresponding plastic mechanism forces amplified by over-strength factors. By directly identifying the intended mechanism and designing for such plastic action, the intent of both the IBC and AASHTO specifications can be met.

The presence of an intermediate concourse level creates a unique challenge for the IBC and AASHTO approaches to address. The proportions of the guideway elements, span lengths transversely and longitudinally, and the mass of the concourse can lead to a situation where the guideway structure is effectively a two-level (double-deck) structure, which is not within the scope of the AASHTO design provisions. For this reason, either the ASCE 41 NSP or NLTHA is required for performance verification when an intermediate concourse is present. This challenge is discussed below.

The seismic plastic-hinging alternatives shown in Figure 720-2 each possess advantages and disadvantages that the designer must consider when determining which alternate comprises the best design. Alternate 1 typically will provide the better shear design situation for the columns, and this is important since column shear failure often leads to collapse. A disadvantage in Alternate 1 is that long-span beams of the concourse level must be detailed to form and sustain plastic hinging. This can be a *challenge when such beams are either prestressed or post-tensioned. If the beams of the concourse in Alternate 1 frame into an intermediate collector beam between columns at each bent, then combined plastic hinging of that collector under transverse earthquake loading can result in significant torsion for the longitudinal beams These combined effects may be impossible to accommodate safely. A possible solution to this situation is to decouple the longitudinal beams from the vertical bridge framing. This can be achieved by placing the longitudinal beams on supports that do not transfer longitudinal moment or very small moments via a hinge-diaphragm with a single line of vertical bars across the joint for continuity, as shown in Figure 720-2, Alternate 1A.*

Alternate 2 avoids the challenges related to a long-span concourse with plastic hinging but will likely induce higher shear demand in the columns below the concourse making this configuration of plastic hinging likely infeasible structurally.

Due to the inherent challenges of producing a consistent system that satisfies behavioral performance objectives and respective design specifications, a structurally combined system with an intermediate-level concourse is required to be assessed using NLTHA. Such assessment will be able to evaluate the relative inelastic behavior disadvantages of each system and thus show that the selected system will satisfy the desired performance goals.

Regarding design and detailing of combined elements, the platform-and-canopy-on-guideway example is helpful to revisit. Consider a system where the AASHTO designed guideway supports an integral platform at the superstructure level, and this platform supports an ASCE-designed canopy composed of steel columns and roof. With an AASHTO guideway system, the platform would be part of the capacity protected superstructure because the guideway yielding elements would be the columns.

With such a configuration of structural subsystems, the platform beams and floor system would be designed as capacity protected elements using the maximum plastic mechanism overstrength forces from the guideway plastic mechanism. The canopy columns, however, would be designed as yielding elements, and thus their connections to the platform and local platform reinforcement should also be designed using overstrength forces because these localized areas behave as collector/distributor elements. Therefore, the detailing of the platform should be customized to address its function as capacity protected superstructure and collector element for the canopy system.

Additionally, if openings due to vertical circulation elements are present, the platform at the openings must also be designed and detailed to collect forces from attached vertical circulation elements and transmit forces via diaphragm action from and around the openings to the main platform supporting elements at the guideway bent locations.

It is also possible that mass or stiffness configurations could result in irregularities as defined in IBC/ ASCE, thus requiring specific recognition in the design process. This may result in the building or IBC-controlled elements moving to a higher seismic design category in ASCE. This will require specific consideration in the harmonization process.

It is the Seismic Design Manager's role to ensure that the harmonization of requirements for such combined structural elements is accomplished and coordinated through the AHJ. These descriptions do not list all the relative advantages and disadvantages of such combined structural systems. Instead, the descriptions only serve to provide examples of issues a designer must consider.

*4. **Exception to Capacity Protection**. The ODE, MDE, and IBC earthquake design criteria may lead to structurally combined station designs that do not form a complete plastic mechanism or respond quasi-elastically under the MDE or IBC design ground motions. Reasons for this may be the ratio of the MDE to ODE ground motions, differences between MDE versus ODE performance criteria, non-seismic design constraints, or a need to keep member sizes proportional to one another. This is not unusual. In some* *cases, the structure may be more nearly fully elastic with only a few plastic hinges having formed under the MDE loading. When this occurs, it may be difficult and expensive to fully capacity protect the entire structure.*

These guidelines provide two methods of addressing the design of such partially plastic or fully elastic single-story structures when full capacity protection may not be possible. These methods provide criteria to help ensure displacement capacity above the MDE level to address uncertainty in ground motion characterization and structural response estimation due to modeling and analysis limitations.

*5. **Building-Type Structures Supported by Elevated Guideway or Other Structures**. Often ground response spectra cannot be directly used to analyze such elements. However, under certain conditions, a "Two-Stage Analysis Procedure", as defined by ASCE 7 may be used to simplify analysis. This method permits the use of ground response spectra without the dynamic coupling effect entering into the calculation. If the conditions for two-stage analysis are not met, then the ASCE 7 requirements for Nonbuilding Structures Supported by Other Structures may be used to analyze and design such structure-supported elements. This article refers the user to an article for Seismic Demands on Nonstructural Components, which includes significant discussion of analyzing subsystems supported by other structures. Because the article addresses nonstructural components, many AHJs do not feel this material should be used for life-safety design of occupied space. However, this section does provide appropriate guidance for the dynamic elastic response of primary structure supporting a smaller or "secondary" structure. The methodology presented in these two ASCE 7 articles is similar to that provided by ASCE 4-98 article 3.1.7 for the seismic analysis of safety related nuclear structures and is founded on basic structural dynamics principles.*

*6. **Soil-Foundation-Structure Interaction**. The influence of the guideway foundation movements on adjacent structures is necessary to evaluate because the guideway often is the heavier structure and is typically supported on deep foundations. When adjacent structure that may be composed of lighter construction founded on relatively shallow foundations is within the passive resistance zone around large deep foundations, such as drilled shafts, then lateral movement and potential vertical heaving of the adjacent structure may occur. The DOR Geotechnical Engineer can estimate such effects based on passive earth pressure theory and the calculated lateral seismic deformations of deep foundation analytical p-y springs.*

Displacements, especially when used to size structure separation or movement joints must include all components that contribute, including deformation of the structure with effective stiffness, short-period adjustment, foundation flexibility, and potential partial uplift of shallow foundations. AASHTO permits pounding within bridge structures, but bounding analyses of multiple frame response is required, and the structure units often are of similar mass and stiffness. In the case of a guideway structure pounding against a much smaller, light building or screen-type structure, the much heavier guideway structure can impose significant damage upon the lighter structure. For this reason, careful sizing of separation and movement joints is required. Where bounding analyses are used the following general guidance should be considered. Where expected values of foundation stiffness are used and joints between structures of significantly different mass and stiffness are to be sized, it is suggested that the absolute value of MDE displacements should be used. Examples of such structural joints would be those between guideway structures and light-framed building structures. Where structures of similar stiffness and mass are considered and where lower bound foundation stiffness is used to calculate deformations between dissimilar mass and stiffness structures, the SRSS method of combination is reasonable.

Bounding of deformations may be accomplished by decreasing or increasing the foundation stiffnesses relative to that obtained using expected values of the foundation stiffness. For shallow foundations, the recommendations of Article 8.4 of ASCE 41 may be followed. For deep foundations, the Geotechnical Engineer should provide adjustments for p-y curves used to develop the foundation stiffnesses. Significant *judgment goes into estimation of deep foundation soil parameters, and the design team should consider the combination of factors that may be relevant. For example, adjusting the p-y parameters to address potential liquefaction effects should also consider the end use of the calculated deformations to avoid excessive conservatism.*

*7. **Separation Between Structures**. Displacements must be consistent for the various ground motions considered, ODE, MDE, and IBC. This means that the IBC reduced life-safety ground-motion-induced displacements must be increased by the inverse of the 2/3rds factor given in Section 7.2 above. This increase will provide a consistent displacement to compare with that of the AASHTO-based, but Sound Transit increased, 2,500-year MDE ground motion.*

Both AASHTO SGS Article 4.3 and ASCE 7-16 Article 12.7.3 require the consideration of element stiffness that contributes significantly to displacement demand. This implies that sources of deformation, including member effective stiffness and foundation contributions, must be considered. For IBC-controlled system, ASCE 41 provides guidance for establishing such element stiffness for determining expected structural system deformations.

When a structural element spans across movement joints and that element is supported on both ends, as may be the case of an egress walkway joint with a floor cover plate, then the design must meet the movement requirements of ASCE 7 for "Members Spanning Between Structures." This provision increases the IBC movement conservatively to the full MDE displacement, and it requires the absolute value of displacements to be used in the calculation of the joint width. These requirements are intended to prevent loss of support that could lead to a life-safety hazard.

Sound Transit requires guideway structures to meet both ODE and MDE requirements. Portions of stations that are controlled only by IBC are not required to meet ODE requirements. There are two categories of functionally combined systems that are relevant to the design requirements and expectations for stations. Examples are provided below, and both displacements and forces are discussed.

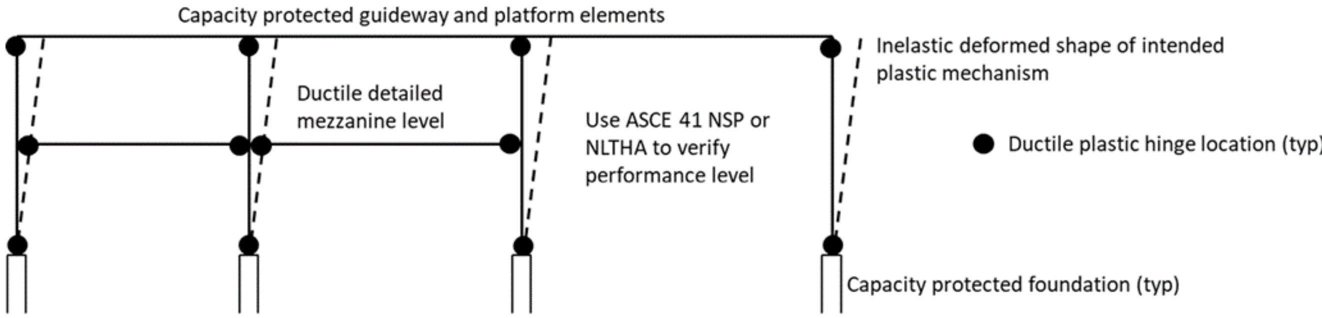
1. *Structures may be functionally combined, but completely independent structurally. Examples are (a) a headhouse that completely encloses or is adjacent to a guideway-platform structure; or (b) an elevator or stair enclosure that is isolated from the main guideway-platform structure. In such cases, separation gaps between the structures must be sized using the MDE displacements, as described above. The performance expectations are that all independent structures are life safe in MDE and MCE_R event, and that the guideway structure is operational following an ODE event. Separation gaps sized for MDE event must also maintain separation in an ODE event.*
2. *Structures may be functionally combined, but not independent structurally. Examples are (a) an escalator or stair structure supported by the guideway-platform structure, or (b) platform floor systems supported on a guideway. In the case of escalators and stairs spanning between levels, articulation joints (typically sliding joints) will be required to seismically isolate the escalator or stair framing from the main structure. The mass of this structure will be part of the guideway seismic mass and its effects must be considered in the design of the guideway and the support for the escalator or stair. The performance of this structure will not need to be assessed for ODE. On the other hand, a platform that is integrally connected (e.g., at two bent crossbeam) with the guideway, needs to be capacity protected, and the impacts of both the ODE and MDE will need to be assessed for the platform because the platform stiffness and mass affect the guideway response.*

Because the AASHTO-Sound Transit-adjusted ground motion (MDE) has a 2,500-year return period and is thus similar to the MCE_R IBC ground motion, the functionally combined, but structurally separate elements of an FCS station should have similar expected seismic performance.

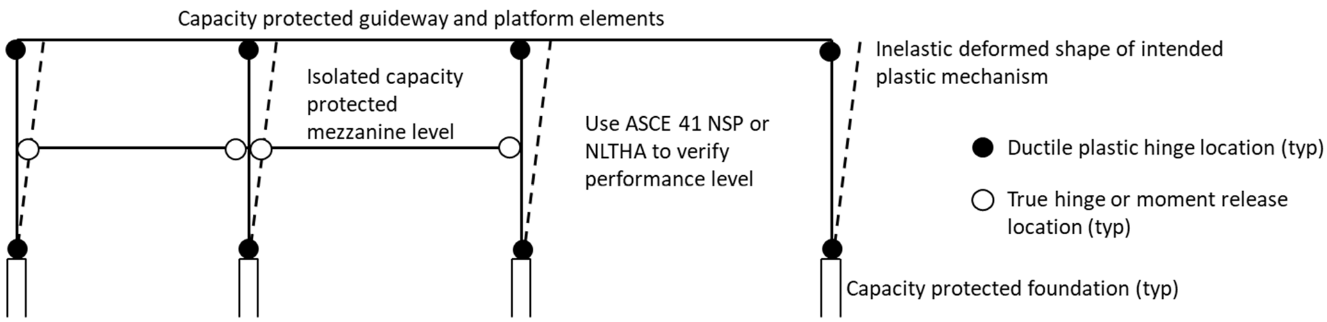
8. ***Settlement.*** *When site conditions lead to settlement, particularly differential settlement, regardless of cause, Sound Transit should be made aware of the situation and provide their concurrence if specific settlements remain unmitigated. This concurrence is necessary to inform Sound Transit of the potential for operational disruption due to settlements.*

Often the guideway structure will be supported on deep foundations that may experience downdrag, but not necessarily significant settlement. On the other hand, if elements of a FCS are supported on shallow foundations while the guideway is founded on deep foundations, then differential settlement may occur between building or station units and an impact on performance likewise will occur.

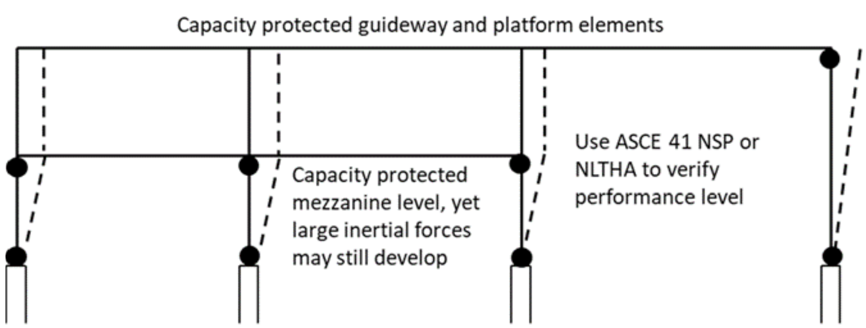
Figure 720-2: Potential Combined Guideway and Concourse Structure Plastic Hinging Mechanisms



Longitudinal Plastic Mechanism – Alternate 1 (Transverse Plastic Mechanism Similar)

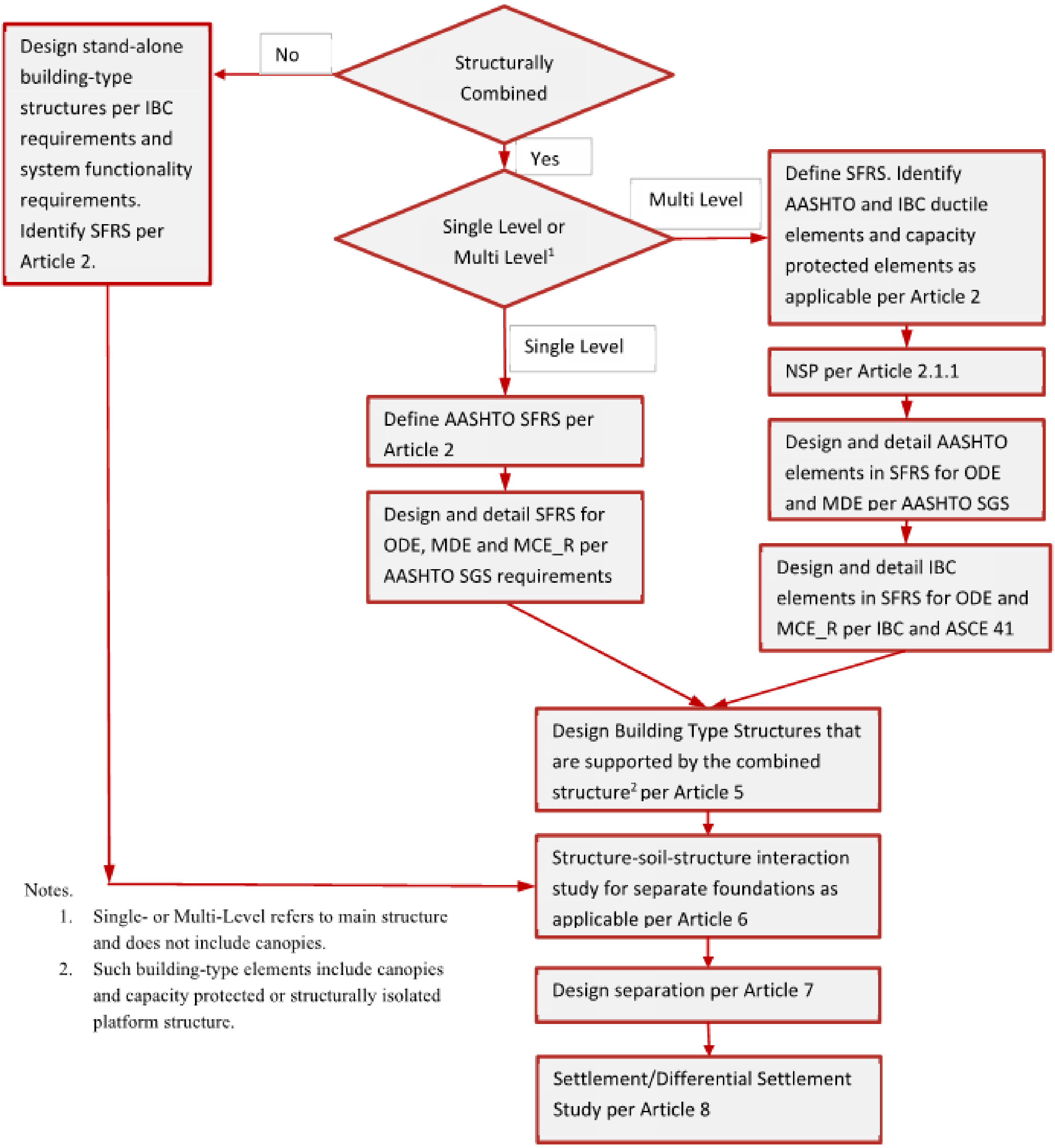


Longitudinal Plastic Mechanism – Alternate 1A (Transverse Plastic Mechanism Similar)



Longitudinal Plastic Mechanism – Alternate 2 (Transverse Plastic Mechanism Similar)

Figure 720-3: Flow Chart of Combined Structure Design



Notes.

1. Single- or Multi-Level refers to main structure and does not include canopies.
2. Such building-type elements include canopies and capacity protected or structurally isolated platform structure.

REFERENCES:

AASHTO Guide Specifications for LRFD Seismic Bridge Design, Latest Edition with Interims, American Association of State Highway and Transportation Officials. (SGS).

Building Code Requirements for Structural Concrete and Commentary, ACI 318 Latest Edition, American Concrete Institute.

International Building Code, International Code Council, Latest Edition.

Minimum Design Loads for Buildings and Other Structures, ASCE/SEI 7, Latest Edition, American Society of Civil Engineers.

Seismic Evaluation and Retrofit of Existing Buildings, ASCE/SEI 41, Latest Edition, American Society of Civil Engineers.

Seismic Analysis of Safety-Related Nuclear Structures and Commentary, ASCE 4-98, American Society of Civil Engineers.

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721 BRIDGES AND ELEVATED STRUCTURES

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SET - 721 BRIDGES AND ELEVATED STRUCTURES

721.1 INTRODUCTION

721.1.1 Document Scope

721.1.1.1 This set covers the design criteria for elevated (aerial) line structures and bridges carrying light rail and commuter rail transit loadings and/or elevated (aerial) stations, and pedestrian bridges. For special design conditions that are not specifically covered by these criteria, the DOR must bring them to the attention of Sound Transit to determine the technical source for the design criteria.

721.1.1.2 This set does not establish design criteria for moveable bridges, highway bridges, and associated highway transportation structures. The design criteria of these structures must be approved by the Requirements Set 721 owner.

721.1.1.3 This set does not provide design criteria for repair, retrofit, and rehabilitation of structures. Design criteria for repair, retrofit, and rehabilitation, including criteria contained herein, must be as approved by the Requirements Set 721 owner.

721.1.1.4 The Commentaries are provided to explain the intensions of the corresponding requirements in the main text. In case there are any conflicts between the Commentary and main texts from the DOR's perspective, the DOR must follow the more stringent requirements and bring them to the attention of Sound Transit.

721.1.1.5 The DOR must prepare design calculation in accordance with WSDOT Bridge Design Manual (BDM), Section 1.3.3, “Design/Check Calculation File,” and the requirements in Set 720 Building Structures.

721.1.1.6 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 721 owner to determine the technical source for the design criteria.

721.1.2 Regulations, Codes, Standards, and Guidelines

721.1.2.1 This list contains the codes and standards referenced in this set, in alphabetical order. The latest code version is considered the version that is current at the end of 30% design and must govern design. If the code version is different from what is referenced in this set, the DOR must consult with the Requirements Set 721 owner or his/her representative for further clarification.

721.1.2.2 International Regulations, Codes, Standards, and Guidelines

721.1.2.2.1 International Building Code (IBC) with local amendments.

721.1.2.3 Federal and National Regulations, Codes, Standards, and Guidelines

721.1.2.3.1 ADA Standards for Transportation Facilities (DOT) (ADA Standards) Accessibility Standards.

721.1.2.3.2 American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications.

721.1.2.3.3 American Association of State Highway and Transportation Officials (AASHTO) LRFD Guide Specifications for Accelerated Bridge Construction.

721.1.2.3.4 American Association of State Highway and Transportation Officials (AASHTO) LRFD Guide Specifications for Bridges Carrying Light Rail Transit Loads.

721.1.2.3.5 American Association of State Highway and Transportation Officials (AASHTO) Guide Specifications for Design and Construction of Segmental Concrete Bridges.

721.1.2.3.6 American Association of State Highway and Transportation Officials (AASHTO) Guide Specifications for LRFD Seismic Bridge Design.

721.1.2.3.7 American Association of State Highway and Transportation Officials (AASHTO) LRFD Guide Specifications for the Design of Pedestrian Bridges.

721.1.2.3.8 American Association of State Highway and Transportation Officials (AASHTO) LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals.

721.1.2.3.9 American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide.

721.1.2.3.10 American Association of State Highway and Transportation Officials (AASHTO) Guide Specifications for Seismic Isolation Design.

721.1.2.3.11 American Association of State Highway and Transportation Officials (AASHTO) Guidelines for Performance Based Seismic Design of Highway Bridges.

721.1.2.3.12 American Concrete Institute (ACI) Building Code Requirements for Structural Concrete (ACI 318) and Commentary.

721.1.2.3.13 American National Standards Institute (ANSI) American National Standards for Ladders – Fixed – Safety Requirements, ANSI-ASC A14.3.

721.1.2.3.14 American Railway Engineering and Maintenance-of-Way Association (AREMA), Manual for Railway Engineering (MRE).

721.1.2.3.15 American Society for Testing and Materials (ASTM).

721.1.2.3.16 American Society of Civil Engineers – Structural Engineering Institute (ASCE SEI). ASCE 7 Minimum Design Loads for Buildings and Other Structures.

721.1.2.3.17 Applied Technology Council (ATC) Improved Seismic Design Criteria for California Bridges: Provisional Recommendations ATC-32, 1996.

721.1.2.3.18 Federal Highway Administration and the National Highway Institute (FHWA-NHI). Drilled Shafts: Construction Procedures and LRFD Design Methods (FHWA-NHI-10-016).

721.1.2.3.19 National Cooperative Highway Research Program (NCHRP). Performance-Based Seismic Design of Bridges, NCHRP Synthesis 440, 2013, Transportation Research Board.

721.1.2.3.20 National Cooperative Highway Research Program (NCHRP). Seismic Design of Non-Conventional Bridges, NCHRP Synthesis 532, 2019, Transportation Research Board.

721.1.2.3.21 National Cooperative Highway Research Program (NCHRP). Proposed AASHTO Guidelines for Performance-Based Seismic Bridge Design, NCHRP Report 949, 2020, Transportation Research Board.

721.1.2.3.22 Occupational Safety and Health Administration (OSHA) 1926.502 - Fall protection systems criteria and practices.

721.1.2.3.23 Post-Tensioning Institute, Technical Notes.

721.1.2.3.24 PTI DC45.1-18: Recommendations for Stay Cable Design, Testing and Installation, Post-Tensioning Institute.

721.1.2.4 State and Local Regulations, Codes, Standards, and Guidelines

721.1.2.4.1 Caltrans Seismic Design Criteria (SDC).

721.1.2.4.2 Washington Administrative Code (WAC).

721.1.2.4.3 WABO-SEAW White Paper #8 - Guidelines for Determining Snow Loads in Washington State (2010).

721.1.2.4.4 WSDOT Bridge Design Manual (LRFD) M 23-50.

721.1.2.4.5 WSDOT Standard Specifications for Road, Bridge, and Municipal Construction M 41-10.

721.1.2.5 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

721.1.2.6 Other Jurisdictions

721.1.2.6.1 Priestley, M.J.N., G.M. Calvi, and M.J. Kowalsky. Displacement-Based Seismic Design of Structures. IUSS Press, Pavia, Italy, 2007.

721.1.2.7 Sound Transit Regulations, Codes, Standards, and Guidelines (Not Used)

721.1.3 Abbreviations and Acronyms

721.1.3.1 AASHTO–American Association of State Highway and Transportation Officials

721.1.3.2 ATC–alternate technical concepts

721.1.3.3 BDM–Bridge Design Manual

721.1.3.4 BL–blast loading

721.1.3.5 BR–braking force of vehicles other than Light Rail and Commuter Rail vehicles

721.1.3.6 CE–centrifugal force

721.1.3.7 CR–force effects due to creep

721.1.3.8 CT–vehicular collision force

721.1.3.9 CV–vessel collision force

721.1.3.10 DC–dead load of structural components and nonstructural attachments

721.1.3.11 DD–downdrag force

721.1.3.12 DE–derailment load

721.1.3.13 DOR–designer of record

721.1.3.14 DW–dead load of wearing surfaces and utilities

721.1.3.15 EH–horizontal earth pressure load

721.1.3.16 EL–miscellaneous locked-in force effects resulting from the construction process, including jacking apart of cantilevers in segmental construction

721.1.3.17 EQ–earthquake load

721.1.3.18 ERE– earthquake resisting elements

721.1.3.19 ERS–earthquake resisting systems

721.1.3.20 ES–earth surcharge load

721.1.3.21 EV–vertical pressure from dead load of earth fill

721.1.3.22 FR–friction load

721.1.3.23 GDS–global design strategy

721.1.3.24 HRV–commuter rail vehicle live load

721.1.3.25 LF–longitudinal force

721.1.3.26 LL–live load due to vehicles other than light rail vehicles and commuter rail vehicles

721.1.3.27 LRV–light rail vehicle

721.1.3.28 LS–live load surcharge

721.1.3.29 IC–ice and snow load

721.1.3.30 IM–dynamic load allowance due to vehicles other than light rail vehicles and commuter rail vehicles

721.1.3.31 IMR–light rail vehicle and commuter rail vehicle dynamic load allowance including both vertical and horizontal components

721.1.3.32 MDE–maximum design earthquake

721.1.3.33 NLTHA–nonlinear time history analysis

721.1.3.34 OCS–overhead contact system

721.1.3.35 ODE–operating design earthquake

721.1.3.36 PL–pedestrian live load

721.1.3.37 PS–secondary forces from post-tensioning for strength limit states—total prestress forces for service limit states

721.1.3.38 RB–rail-break force

721.1.3.39 SE–force effect due to settlement

721.1.3.40 SGS–Seismic Guide Specifications

721.1.3.41 SH–force effects due to shrinkage

721.1.3.42 TG–temperature gradient

721.1.3.43 TU–uniform temperature

721.1.3.44 WA–water load and stream pressure

721.1.3.45 WL–wind load on live load

721.1.3.46 WS–wind load on structure

721.1.4 Definitions and Classifications (Not Used)

721.1.5 References (Not Used)

721.2 STAKEHOLDER NEEDS

721.2.1 Passenger Experience (Not Used)

721.2.2 Operational Needs

721.2.2.1 Seismic performance levels are specified to protect life safety and the capital investment of the public by Sound Transit infrastructure and to minimize disruption to operations from damage due to a seismic event.

721.2.2.2 After an extreme event, the anticipated behavior and expected performance must be specified, including the locations of damage. The expected performance must state the expected operational status of the rail system after the design events.

Commentary: The ODE is required to set a standard for smaller earthquakes such that the structure can be operationally resilient. This operational performance earthquake has become more commonplace with WSDOT and other agencies. The Sound Transit ODE is specified as a slightly higher return-period because it is recognized that the transit system plays a crucial role in mass transit reliability especially after an earthquake and the seismic standards should reflect this.

Commentary: The MDE is the design for a life-safety performance level after a large earthquake. This return-period is consistent with building seismic design practice to ensure that the risk of collapse and danger to human life is low.

721.2.2.3 Refer to 721.3.3.2.4 for recovery of a disabled light rail vehicle load requirements.

721.2.3 Maintenance Needs

721.2.3.1 Maintenance access for inspection must be accommodated during structural design.

721.2.3.2 Refer to 721.3.19.9.8 and 721.3.19.9.9 for maintenance requirements for column silo inspection.

721.2.3.3 Refer to 721.3.16.5.1 for bird deterrent requirements on elevated guideways.

721.2.3.4 Maintenance loads on all structural elements must be included in design.

721.2.3.5 The DOR must provide operation and maintenance manuals for post-construction and operational use for non-typical bridge components such as cable-stay bridges and shock transmission.

721.2.4 Safety Needs

721.2.4.1 Structural design must account for passenger safety. Extreme event load combinations should meet life safety performance requirements at a minimum.

721.2.5 Security Needs

721.2.6 Reliability, Availability and Maintainability Needs

721.2.6.1 Structural design must account for material design challenges and availability. Structural components must incorporate materials that are available and constructable based on the bridge design parameters.

721.2.6.2 Structural component design must consider the reliability of the material over the life of the structure including resilience to corrosion and codified service life requirements.

721.2.6.3 Materials specified must account for short-term and long-term required maintenance including costs and must be included in the design documentation for review by the Requirements Set 721 owner.

Commentary: Steel bridge girders have been found to have long-term maintenance costs and are not a widely used girder material throughout the Sound Transit system.

721.2.7 Environmental and Sustainability Needs (Not Used)

721.3 SYSTEM REQUIREMENTS

721.3.1 Loads and Conditions

721.3.1.1 Regardless of the type of analysis employed, the design must satisfy Eq. 1.3.2.1-1 of AASHTO LRFD Bridge Design Specifications for all specified force effects and combinations thereof, unless otherwise specified.

721.3.1.1.1 *Commentary: Refer to AASHTO Guide Specifications for Bridges Carrying Light Rail Transit Loads, AASHTO LRFD Bridge Design Specifications, and WSDOT BDM for all contents that are not provided in this section.*

721.3.1.2 The design must evaluate the following permanent and transient loads and forces. Additional loads and forces may be identified by the DOR.

721.3.1.2.1 Permanent Loads:

CR = force effects due to creep

DC = dead load of structural components and nonstructural attachments

DD = downdrag force

DW = dead load of wearing surfaces and utilities

EH = horizontal earth pressure load

EL = miscellaneous locked-in force effects resulting from the construction process, including jacking apart of cantilevers in segmental construction

ES = earth surcharge load

EV = vertical pressure from dead load of earth fill

PS = secondary forces from post-tensioning for strength limit states—total prestress forces for service limit states

SH = force effects due to shrinkage

721.3.1.2.2 Transient Loads:

BL = blast loading

BR = braking force of vehicles other than Light Rail and Commuter Rail vehicles

CE = centrifugal force

CT = vehicular collision force

CV = vessel collision force

DE = light rail derailment load (DR was used in previous Revisions)

EQ = earthquake load

FR = friction load

IC = ice and snow load

IM = dynamic load allowance due to vehicles other than light rail vehicles and commuter rail vehicles

IMR = light rail vehicle and commuter rail vehicle dynamic load allowance including both vertical and horizontal components

LF = longitudinal force from train operation

LRV = light rail vehicle live load

HRV = commuter rail vehicle live load

LL = live load due to vehicles other than light rail vehicles and commuter rail vehicles

LS = live load surcharge

PL = pedestrian live load

RB = rail-break force

SE = force effect due to settlement

TG = force effect due to temperature gradient

TU = force effect due to uniform temperature

WA = water load and stream pressure

WL = wind load on live load

WS = wind load on structure

721.3.1.3 Load combinations and load factors must follow Table 721-1: Load Combinations and Load Factors.

Commentary: For LRVs, the probability that Derailment and Rail Break occur concurrently at the same location is very low as Rail Break is monitored. If Rail Break is caused by Derailment, it is unlikely that the hazard occurs during the coldest weather when Rail Break causes maximum impact. Therefore, they are considered in separate limit states (Extreme II and Extreme III), which is consistent with the practice in AASHTO Guide Specifications for Bridges Carrying Light Rail Transit Loads.

Commentary: For HRVs, if the security and safety hazard analysis show a low potential for concurrent Rail Break and Derailment, then they are considered in separate limit state (Extreme II and Extreme III).

Table 721-1: Load Combinations and Load Factors

Load Combination Limit State	DC DD DW EH EV ES EL PS CR SH	LL LRV HRV IM IMR CE BR PL LS LF	WA	WS	WL	FR	TU	TG	SE	Use One of These at a Time [f]						
										EQ	IC	BL	RB	DE	CT	CV
Strength I (unless noted)	γ_p[a]	1.65 [b] 1.75[c]	1.00	-	-	1.00	0.50/1.20	γ_{TG}[a]	γ_{SE}[a]	-	-				-	-
Strength II	γ_p[a]	1.35	1.00			1.00	0.50/1.20	γ_{TG}[a]	γ_{SE}[a]							
Strength III	γ_p[a]	-	1.00	1.00	-	1.00	0.50/1.20	γ_{TG}[a]	γ_{SE}[a]	-	-				-	-
Strength IV	γ_p[a]	-	1.00	-	-	1.00	0.50/1.20	-	-	-	-				-	-
Strength V	γ_p[a]	1.35	1.00	1.00	1.00	1.00	0.50/1.20	γ_{TG}[a]	γ_{SE}[a]	-	-				-	-
Extreme Event I	1.00	0.50 [d]	1.00	-	-	1.00	-	-	-	1.00	-				-	-
Extreme Event II	1.00	0.50 [g]	1.00	-	-	1.00	-	-	-	-	1.00	1.00		1.00	1.00	1.00
Extreme Event III	1.00	1.00	1.00	-	-	1.00	0.50/1.20	-	-	-	-		1.00		-	-
Service I	1.00	1.00	1.00	1.00	1.00	1.00	1.00/1.20	γ_{TG}[a]	γ_{SE}[a]	-	-				-	-
Service II	1.00	1.30	1.00	-	-	1.00	1.00/1.20	-	-	-	-				-	-
Service III	1.00	γ_{LL}[a]	1.00	-	-	1.00	1.00/1.20	γ_{TG}[a]	γ_{SE}[a]	-	-				-	-
Service IV	1.00	-	1.00	1.00	-	1.00	1.00/1.20	-	1.00	-	-				-	-
Fatigue I – LL, LRV, HRV, IM, IMR & CE only	-	1.75 1.40[e]	-	-	-	-	-	-	-	-	-				-	-
Fatigue II – LL IM & CE only	-	0.85	-	-	-	-	-	-	-	-	-				-	-

Notes:

a. See Article 3.4.1 of AASHTO LRFD Bridge Design Specifications.

b. For bridges designed to carry LRV loadings only. See Table 2.3-1 of AASHTO Guide Specifications for Bridges Carrying Light Rail Transit Loads. It changed from "1.75" that was used in DCM 5^{th} Rev.

c. For bridges designed to carry both LRV loading and highway traffic loading, or HRV loading only.

d. Associated mass of LL need not be included in the dynamic analysis. Mass of LRV and HRV is required to be included in the dynamic analysis

e. This load factor must be 1.75 for highway traffic and HRV loadings, and 1.40 for LRV loading.

f. Apply these loads separately because the joint probability of these events is extremely low.

g. The tracks other than the derailment track are loaded with a stationary train without dynamic load allowance for derailment load case. See 721.2.5.9.2.

721.3.2 Dead Loads: DC, DW, and EV

721.3.2.1 Dead loads must follow AASHTO LRFD Bridge Design Specifications, Article 3.5, Permanent Loads, except as supplemented or modified in this section.

721.3.2.2 The DOR is responsible for accounting for self-weight loads on the structure. The design must use the material unit weights (or greater) shown in Table 721-2: Unit Weights.

Table 721-2: Unit Weights

Material / Item	Weight
Precast Pre-tensioned or Post-tensioned Spliced Girders, including 10 pounds per cubic foot allowance for reinforcement [a]	Per WSDOT BDM
All Other Normal-Weight Reinforced Concrete [a]	Per WSDOT BDM
Unreinforced Concrete [a]	Per WSDOT BDM
Steel [a]	Per WSDOT BDM
Ballast [b]	Per AASHTO Guide Specifications for Bridges Carrying Light Rail Transit Loads
Transit Rails, Ties, and Fastening per Track (2 Rails) [b]	Per AASHTO Guide Specifications for Bridges Carrying Light Rail Transit Loads
Catenary Support System	as provided by catenary consultant

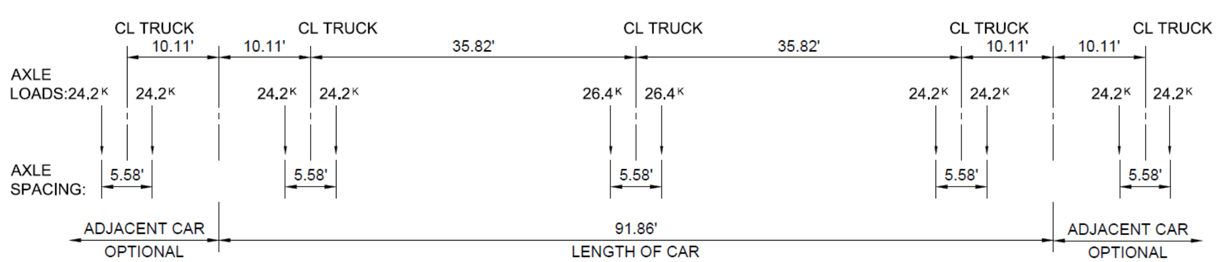
721.3.3 Live Loads: LL, LRV, HRV, IM, IMR, CE, BR, PL, LF, DE, and CT

721.3.3.1 Transient loads and vessel collision must follow AASHTO LRFD Bridge Design Specifications, Articles 3.6, 3.14 except as supplemented in this section.

721.3.3.2 Light Rail Vehicle Live Load, LRV

721.3.3.2.1 Car dimensions and axle loads of LRV are shown in Figure 721-1: Light Rail Vehicle Load (AW3) and further detailed in Set 421 Light Rail Vehicles.

Figure 721-1: Light Rail Vehicle Design Load (AW3) (kips, feet)



721.3.3.2.2 The light rail trains consist of one, two, three, or four cars, whichever combination produces the maximum force effects for the element under consideration. For structures carrying more than one track, the critical design loading of any combination of train axle loadings at any position on one or more tracks must be the vertical live loading used for structural design.

721.3.3.2.3 The above loading corresponds to AW3 in Set 421 Light Rail Vehicles. The DOR must use the vehicle live load corresponding to AW3 as the LRV unless otherwise noted. Obtain the other AW loadings by multiplying the axle loads in Figure 721-1: Light Rail Vehicle Design Load (AW3) by the ratio of the total weight for the desired AW load to the total weight for the AW3 loading.

721.3.3.2.4 Analysis must consider the recovery of a disabled LRV. Design for this procedure with two maximum length trains operating on one track over a portion of the line. Design for both trains carrying AW3 passenger loads until offloading passengers at the next station. The DOR must only consider this live load case in Strength II load combination.

Commentary: Disabled LRV recovery is not a normal operation. Furthermore, the preferred recovery operation procedure is to unload the disabled vehicle first and tow the empty vehicle using a single high-rail truck.

721.3.3.3 Commuter Rail Vehicle Live Load: HRV

Commentary: Reference to AREMA MRE Chapter 15, Section 1.3.3, "Live Load."

721.3.3.3.1 The DOR must design structures subject to commuter rail live load for AREMA Cooper E80 loading (Figure 721-2). The DOR must also check steel superstructures for the "Alternate Live Load on 4 Axles" (Figure 721-3). All load combinations and positions must be considered.

Figure 721-2: Cooper E 80 Load (LB, FT)

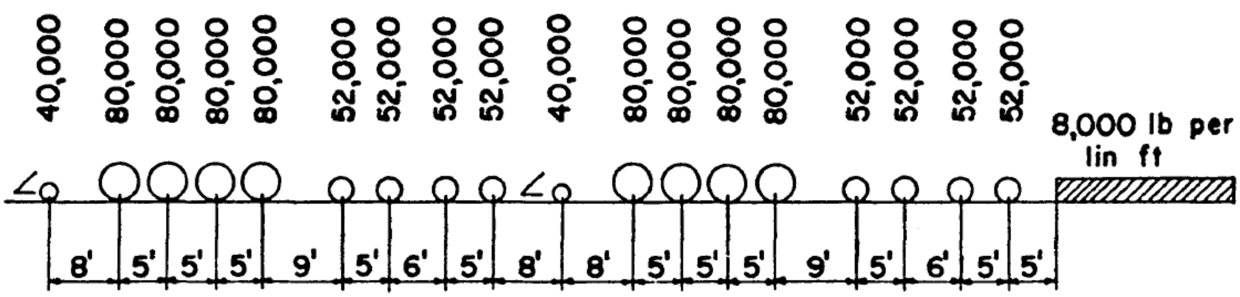
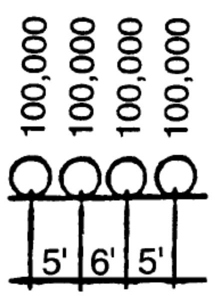


Figure 721-3: Alternate Live Load On 4 Axles (LB, FT)



721.3.3.3.2 The DOR must perform a load rating on the commuter rail bridge immediately following design completion using the live load listed above.

721.3.3.3.3 For steel bridges, the DOR must investigate the stability of spans and piers/towers with live load on only one track, and the leeward one for structures with more than one track. The live load should be 1,200 pounds per linear foot, without impact.

Commentary: Reference to AREMA MRE Chapter 15, Section 1.3.10.a, "Stability Check".

721.3.3.4 Rail Vehicle Live Load Distribution

721.3.3.4.1 Distribute Rail Vehicle Live Load to longitudinal members in accordance with the provisions of AASHTO Guide Specifications for Bridges Carrying Light Rail Transit Loads.

721.3.3.4.2 For ballasted decks supported by transverse steel beams without stringers, the portion of the maximum axle load to be carried by each beam is calculated as:

$$P = \frac{1.15AD}{S}$$

For moment: $$D = d\left(\frac{1}{1 + \frac{d}{aH}}\right)\left(0.4 + \frac{1}{d} + \frac{\sqrt{H}}{12}\right)$$

but not greater than d or S.

For end shear: D = d.

where:

P = load on a beam from one track

A = axle load

S = axle spacing, feet

d = beam spacing, feet

a = beam span, feet

n = the ratio of the modulus of elasticity of steel to that of concrete

I_b = moment of inertia of beam, inch^4

h = thickness of concrete deck slab, inches

$$H = \frac{nI_b}{ah^3}$$

D = effective beam spacing, feet

i. Apply the load P as two equal concentrated loads on each beam at each rail, equal to 0.5P. Lateral distribution of such loads must not be applied.
ii. D = d for bridges where the concrete slab extends over less than the center 75% of the floorbeam.
iii. Where d exceeds S, P must be the greater reaction of the axle loads, assuming the deck between the beams acts as a simply supported span.

Commentary: Reference to AREMA MRE Chapter 15, Section 1.3.4.2.3, "Transverse Steel Beams."

721.3.3.4.3 Distribution in Concrete Slabs – Ballasted Track: Transmit axle loads as uniformly distributed longitudinally over a length of 3 feet, plus the depth of ballast under the tie, plus twice the effective depth of slab, but not more than 5 feet or the minimum axle spacing of the loading. Wheel loads must have uniform lateral distribution over a width equal to the length of the tie plus the depth of ballast under the tie, except as limited by the proximity of adjacent tracks or the extent of the structure.

721.3.3.4.4 Distribution in Concrete Slabs – Direct Fixation Track: Transmit wheel loads to the deck slab through rail mountings placed directly on the slab, the wheel load must be assumed as uniformly distributed over a length of 3 feet along the rail. This load may be distributed transversely (normal to the rail and centered on the rail) by the width of the rail fastener pad plus twice the depth of the deck and track concrete. For derailment loads where the vehicle wheels bear directly on the slab, distribute the wheel loads over three feet of the slab in a direction perpendicular to the main reinforcement.

721.3.3.5 Rail Vehicle Live Load Multiple Presence Factor

Commentary: Reference to AASHTO Guide Specifications for Bridges Carrying Light Rail Transit Loads Section 3.2.1.1.2, "Multiple Presence of Live Load," and AREMA MRE Chapter 15, Section 1.3.3d, "Live Load."

721.3.3.5.1 For members receiving load from more than one track, the design live load on the tracks must be as follows (with impact unless stated otherwise):

721.3.3.5.2 For two tracks, full live load on two tracks.

721.3.3.5.3 For three tracks, full live load on two tracks and one-half live load on the other track. At pocket track location along Light Rail alignment, the design load must be full live load on two tracks with impact and one AW0 live load without impact on the pocket track.

721.3.3.5.4 For four tracks, full live load on two tracks, one-half live load on one track, and one-quarter live load on the remaining one.

721.3.3.5.5 For more than four tracks, as specified by the DOR and approved by the Requirements Set 721 owner.

721.3.3.5.6 The selection of the tracks for these loads must be whichever combination produces the greatest design stress in the member.

721.3.3.6 Lateral Forces from Equipment

721.3.3.6.1 For bracing systems or for longitudinal members entirely without a bracing system in steel structures, The DOR must evaluate lateral forces from equipment. Neglect lateral forces from equipment for concrete structures.

721.3.3.6.2 Apply a single moving concentrated lateral force equal to one-quarter of the weight of the heaviest axle of the specified live load, without impact, at top of low rail in either direction applied at any point along the span in addition to the other lateral forces specified. On spans supporting multiple tracks, apply the force on one track only.

721.3.3.6.3 The resulting stresses to be evaluated are axial stresses in members bracing the flanges of stringer, beam and girder spans, axial stresses in the chords of truss spans and in members of cross frames of such spans, and stresses from lateral bending of flanges of longitudinal flexural members having no bracing system. Effects of lateral bending between braced points of flanges, axial forces in flanges, vertical forces and forces transmitted to bearings need not be evaluated.

721.3.3.7 Rail Vehicle Dynamic Load Allowance, IMR:

Commentary: Reference to AASHTO Guide Specifications for Bridges Carrying Light Rail Transit Loads Section 3.2.3, "Dynamic Load Allowance: IM," and AREMA MRE Chapter 8, Section 2.2.3.d, "Impact Load," and Chapter 15, Section 1.3.5, "Impact Load."

721.3.3.7.1 These sections describe Dynamic load allowance for effects of LRV and HRV (IMR). For dynamic load allowance due to other sources (IM), follow AASHTO LRFD Bridge Design Specifications Article 3.6.2.

721.3.3.7.2 Do not apply dynamic load allowance in the following situations:

i. Retaining walls that are not subject to vertical reactions from the superstructure.
ii. Foundation components that are entirely below ground level.
iii. Apply the vertical dynamic load allowance for buried structures, in percent, other than centrifugal or derailment forces, as:

$$IMR\ (\text{Buried Structure}) = IMR\ (1.0 - 0.125\ D_E) \geq 0\%$$

Where,

D_E = the minimum depth of earth cover above the structure (ft.)

721.3.3.7.3 Dynamic Load Allowance for LRV (IMR):

i. Unless otherwise permitted for buried structures, increase the vertical static effects of the LRV, excluding centrifugal or derailment forces, by 30 percent on Direct Fixation track bridges for dynamic load allowance. For ballasted deck bridges, increase the vertical static effect by 90 percent of that specified for Direction Fixation track bridges.
ii. The dynamic load allowance for Fatigue I limit state must be 15 percent.
iii. In addition to the vertical component of dynamic load allowance, a horizontal component (hunting force), equal to 10 percent of vertical LRV must be applied simultaneously. The hunting force must act in either direction transverse to the track, through a point at five feet above the top of the low rail distributed to the individual axles of the vehicle. The hunting force transmitted to the rails and supporting structure by an axle must be concentrated at the rail having direct wheel flange to railhead contact. Design only the larger of centrifugal and hunting forces.

721.3.3.7.4 Dynamic Load Allowance for HRV (IMR):

i. The Impact load specified in this section applies to rolling equipment without hammer blow, such as diesels, electric locomotives, or tenders alone.
ii. The dynamic load allowance (impact) for ballasted decks supported by concrete superstructures must be equal to the following percentages of the live load. For continuous structures, the impact value for the shortest span throughout must be used.

For L ≤ 14 feet: $IMR = 60$

For 14 feet < L ≤ 127 feet: $IMR = 225/\sqrt{L}$

For L > 127 feet: $IMR = 20$

Where L is the span length in feet.

i. The dynamic load allowance (impact) for ballasted decks supported by steel superstructures must be equal to the following percentages of the live load. For members receiving load from more than one track, apply the impact load on the number of tracks designated in Table 721-3. Impact load due to rocking effect, RE, is created by the transfer of load from the wheels on one side of a car or locomotive to the other side from periodic lateral rocking of the equipment. Calculate RE from loads applied as a vertical force couple, each being 20 percent of the wheel load without impact, acting downward on one rail and upward on the other. Apply the couple on each track in the direction that will produce the greatest force in the member under consideration.

For L < 80 feet: $IMR = 0.9 \times (40 - \frac{3L^2}{1600})$

For L ≥ 80 feet: $IMR = 0.9 \times (16 + \frac{600}{L-30})$

Where L is the length, in feet, center to center of supports for stringers, transverse floorbeams without stringers, longitudinal girders and trusses (main members), or length, in feet, of the longer adjacent supported stringers, longitudinal beam, girder or truss for impact in floorbeams, floorbeam hangers, subdiagonals of trusses, transverse girders, supports for longitudinal and transverse girders and viaduct columns.

Table 721-3: Impact Loads for Multiple Tracks

Span Length, L	Impact
Load Received from Two Tracks	
For L less than 175 feet	Full impact on two tracks
For L from 175 feet to 225 feet	Full impact on one track and a percentage of full impact on the other as given by the formula, 450 – 2L
For L greater than 225 feet	Full impact on one track and none on the other
Load Received from More than Two Tracks	
For all values of L	Full impact on any two tracks that creates the largest load effect

721.3.3.8 Centrifugal Force, CE

721.3.3.8.1 This section describes the centrifugal forces for LRV and HRV. For centrifugal forces due to highway vehicles, follow AASHTO LRFD Bridge Design Specifications Article 3.6.3.

721.3.3.8.2 For LRV and HRV loading, design for a CE, equal to the following percentage of the live load, without impact, in all trackways for structures on curves. Apply centrifugal forces horizontally, on all tracks, at a distance 5 feet for LRV and 8 feet and 3 inches for HRV above the top of low rail.

$$C=0.00117\ S^2D \text{ or } C=6.68\ \left(\frac{S^2}{R}\right)$$

Where,

C = the CE in percent of the LL, without impact

S = the design speed in miles per hour

D = the degree of curve of the track centerline (central angle of curve subtended by a chord of 100 feet)

R = the radius of the curve of the track centerline, in feet

Commentary: The CE vertical location for HRV is based upon the assumed maximum superelevation of 6 inches.

721.3.3.8.3 For steel structures, on curves, determine the forces in a stringer, girder, or truss toward the outside and inside of curve separately, and use the greater required section on both sides. For members toward the outside of curve, apply the full impact load specified in 721.3.3.7 and the centrifugal force. Omit the effect of the centrifugal force for members toward the inside of curve.

Commentary: Reference to AREMA MRE Chapter 15, Section 1.3.6, "Centrifugal Force."

721.3.3.9 Derailment Load, DE

Commentary: Derailment loading magnitude is referenced to AREMA Manual for Railway Engineering, Chapter 12, Section 4.8.2.4, "Derailment Loading."

721.3.3.9.1 Design for derailment forces for structures supporting LRVs or HRVs. Apply vertical and horizontal derailment forces simultaneously as follows:

721.3.3.9.2 Vertical derailment load

721.3.3.9.2.1 The vertical derailment load must be produced by AW3 LRV vehicles or AREMA Cooper E80 Loading with their longitudinal axes parallel to the track.

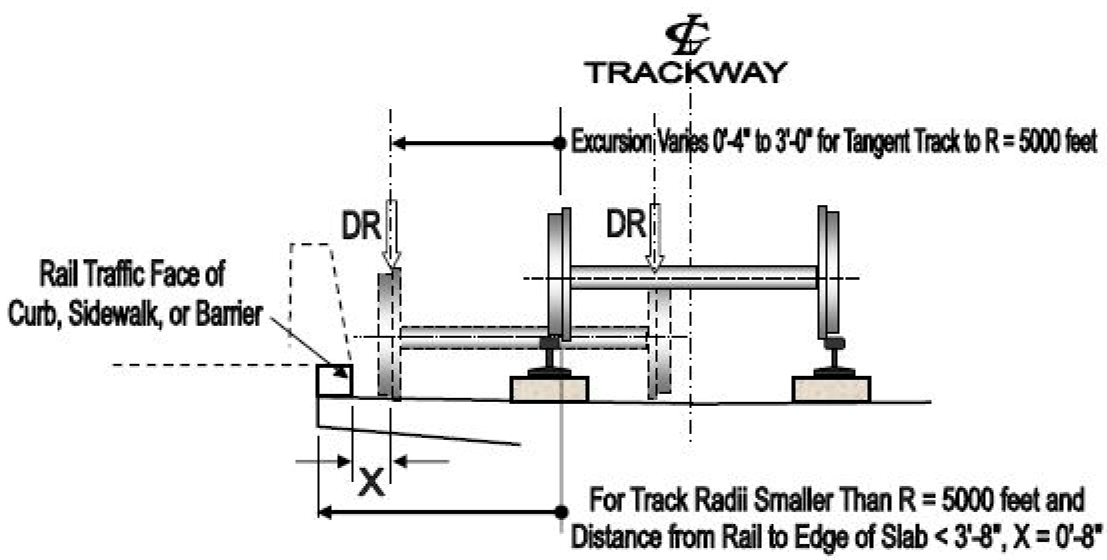
721.3.3.9.2.2 Lateral vehicle excursion must vary as follows:

721.3.3.9.2.2.1 For tangent track and curved track with radii greater than 5,000 feet, vehicle excursions must vary from 4 inches to 3 feet. Refer to Figure 721.4: Vehicle Excursion for Vertical DE Load.

721.3.3.9.2.2.2 For tracks with 5,000-foot radii or smaller, the minimum excursion is 4 inches. The maximum excursion is either 3 feet or 8 inches from the traffic face or the nearest barrier, if any, or the edge of deck, whichever is less. Refer to Figure 721.4: Vehicle Excursion for Vertical DE Load.

721.3.3.9.2.2.3 When the track design includes emergency guardrail or restraining rail the derail excursion need not exceed the specified limit of the device. Where derail excursion-limiting devices are used, one truck (two axles) must have the maximum excursions specified in this section. Design the truck excursion that results in the most critical load.

Figure 721-4: Vehicle Excursion for Vertical DE Load



721.3.3.9.2.3 Apply a vertical impact factor of 100 percent of vehicle weight when computing the equivalent static derailment load. This must be in lieu of the dynamic load allowance specified in 721.3.3.7.

721.3.3.9.2.4 Consider only one train on one track to have derailed when evaluating any component of superstructure or substructure that supports two or more tracks, with the other tracks loaded with a stationary train without dynamic load allowance.

721.3.3.9.2.5 All elements of the structure must be checked with simultaneous application of all derailed wheel loads. Do not reduce the positive moment in continuous slabs due to derailed wheel loads in adjacent spans.

721.3.3.9.3 Horizontal derailment load

721.3.3.9.3.1 For LRV, apply a uniform horizontal DE load equal to 40 percent of a single fully loaded vehicle acting 5 feet above top of rail and normal to the barrier wall for a distance of 10 feet or the length of the barrier wall, whichever is less, along the barrier wall for cross sections having clearance between the clearance envelope of LRV and the barrier wall of 6 inches to 3 feet. Any structure elements that are not less than 10 feet continuous along the track within 3-foot clearance to the clearance envelope of LRV must be designed for the barrier wall load. Any discrete structural elements that are less than 10 feet continuous along the track within 3-foot clearance to the clearance envelope of LRV must be protected by a barrier wall or connected by a wall structure that is designed for the barrier wall load. The height of the barrier wall or the continuous wall structure that connects the discrete structure elements must be 12 feet above the top of rail or the height of the structure elements, whichever is less. The barrier wall must extend beyond each end of the discrete structure element being protected a distance of at least 5 feet measured parallel to the track.

721.3.3.9.3.2 For HRV, design must follow requirements in AREMA Manual for Railway Engineering.

Commentary: Reference to AREMA Manual for Railway Engineering Chapter 8, Section 2.1.5, "Pier Protection."

721.3.3.10 Longitudinal Force, LF

721.3.3.10.1 Due to Acceleration and Deceleration

721.3.3.10.1.1 For LRV, compute the magnitude of LF as follows: For decelerating trains, LF must be equal to 28 percent of LRV without dynamic allowance. For accelerating trains, LF must be equal to 14 percent of LRV without dynamic allowance. Apply this force to the rails and supporting structure as uniformly distributed load over the length of the train in a horizontal plane at the top of low rail. Consider various combinations of acceleration and deceleration forces when the structure supports more than one track and design for the most critical load considering the permitted direction of travel on each track. Application of multiple presence factors specified in Section 721.3.3.5 is required.

721.3.3.10.1.2 For HRV, longitudinal force must be specified in AREMA MRE Chapter 8, Section 2.2.3.j, "Longitudinal Force."

721.3.3.10.2 Due to Restraint of Continuous Welded Rail

721.3.3.10.2.1 Do not terminate the continuous welded rail on an elevated structure unless designing the structure to withstand the imposed loads.

721.3.3.10.3 Due to Rail Bumping Posts

721.3.3.10.3.1 This section applies to LRV as no rail bumping posts are installed on the commuter rail alignment.

721.3.3.10.3.2 The transfer of loads due to collision between any rail transit cars traveling at the design speed and any structure-mounted rail bumping post must be limited to 200 kips, including dynamic allowance. Only attach the bumping post to the rail it protects to transfer the load to the structure through rail seat assemblies. Design the structure for the loads transmitted through the rail seat assemblies for only one loaded bumping post at one time.

721.3.3.10.3.3 For structural design, divide the bumping post load evenly between the two attached rails. Design structures to resist the lesser of 200 kips or the total available restraint by the rail seal assemblies on the structure supporting the rails and the bumping post under consideration.

721.3.3.11 Loads on Railings

721.3.3.11.1 Loads on railings in public areas must conform to IBC requirements. Railing for elevated structures, away from public areas, must be designed for the fall protection loads specified in OSHA 1926.502(b) and WAC 296-880-40005, "Guardrail Systems."

721.3.3.12 Live Load on Walkways

721.3.3.12.1 Design raised siding walkways for the greater of a uniformly distributed load of not less than 100 pounds per square foot, or a concentrated load not less than 1,000 pounds, the estimated maximum wheel weight of sanding carts. The walkway grating deflection under the live load must not exceed that as specified by the grating manufacturer. Where the bridge is accessible to off-track equipment, design walkways for the equipment wheel load demands.

721.3.3.12.2 Design requirements for tail track and emergency/maintenance walkways on aerial guideways can be found in Set 522 Track Construction and Set 601 Fire/Life Safety.

721.3.4 Wind Loads: WL and WS

721.3.4.1 Wind loads follow AASHTO LRFD Bridge Design Specifications Article 3.8, except as modified in this section.

721.3.4.2 The DOR must collect the historical wind and climate data and utilize special wind studies to determine wind loads and to evaluate aeroelastic stability for wind-sensitive bridges, as defined in AASHTO LRFD 3.8.3.1. The selected wind study method must be determined by a wind specialist and approved by the Requirements Set 721 owner (or his/her representative). Wind studies, testing parameters and methods, and testing must be developed and performed by a firm and individuals experienced in this type of wind-assessment (the Work). Specifically, the individual(s) and testing facility must have recent experience in the assessment and testing of cross-sectional and fully aero-elastic models (with terrain effects where applicable) and appropriate facilities, or access to appropriate facilities, to perform the Work. The qualifications and experience of the wind specialist proposed for the work are to be submitted to Requirements Set 721 owner for review and written approval prior to proceeding with the Work. At the discretion of the DOR, regardless of the contracting delivery method, the wind studies and testing may be performed during preliminary and/or final design. However, the DOR must be solely responsible for all ramifications of the Work and the scheduling of the work with respect to the quality and acceptability of the final design, and any delays and additional costs that may arise from the need to perform additional testing and/or incorporate design. The wind studies, testing, and resulting design and details must be subject to an independent peer review at the discretion of Sound Transit.

Commentary: Special wind studies, with or without wind tunnel tests, have been widely used to predict the wind-induced response of wind-sensitive bridges, as well as to estimate wind loading. It is important to note that small difference in the bridge deck cross sectional shape, such as modification of the railings, may change the wind-induced response of the bridge greatly. AASHTO LRFD, Section 3.8.3, "Wind-Induced Bridge Motions," provides minimum design guideline for bridge subjected to wind-induced effects. The types and level of the wind study (with or without wind tunnel test) for wind-sensitive bridges must be determined by a wind specialist with Sound Transit approval.

721.3.4.3 Wind Pressure on Rail Vehicles:

721.3.4.3.1 For LRVs operating on elevated structures with the underside of the main girders not more than 40 feet above the mean retarding surface, wind on live load, WL must consist of a transverse wind load of 200 pounds per linear foot of train and a longitudinal wind load of 40 pounds per linear foot of train.

721.3.4.3.2 For LRVs operating on elevated structures with the underside of the main girders more than 40 feet above the mean retarding surface, WL must consist of a transverse wind load of 300 pounds per linear foot of train and a longitudinal wind load of 60 pounds per linear foot of train.

721.3.4.3.3 For HRVs operating on elevated structures, WL must consist of a transverse wind load of 320 pounds per linear foot of train and a longitudinal wind load of 80 pounds per linear foot of train.

721.3.4.3.4 Apply the transverse and longitudinal loads described above simultaneously. Apply the transverse force to the rail and superstructure as loads concentrated at the axle locations in the horizontal plane 6 feet and 4 inches above the top of the lower rail for LRVs and 8 feet and 3 inches above top of lower rail for HRVs. Apply the longitudinal force to the rails and superstructure as a uniformly distributed load over the length of the train in a horizontal plane with the same heights where transverse force is applied.

721.3.4.3.5 These loads apply to the design of superstructure and substructure elements supporting a single track. For the design of elements supporting two tracks, these loads must be increased by 30 percent when both tracks are loaded; this factor accounts fully for shielding the effect of vehicle-on-vehicle as the two trains run alongside each other.

721.3.5 Earth Pressure: EH, ES, LS, and DD

721.3.5.1 Earth pressures must conform to AASHTO LRFD Bridge Design Specifications Article 3.11, except as modified in this section.

721.3.5.2 LS: LS must conform to AASHTO LRFD Bridge Design Specifications Article 3.11.6.4, except that Light Rail transit loading and Commuter Rail transit loading may be applied as a uniform surcharge equal to 3 and 11 additional feet of earth with a unit weight of 130 pounds per cubic foot, respectively.

721.3.6 Force Effects due to Superimposed Deformations: TU, TG, RB, SH, CR, SE, and PS

721.3.6.1 Force effects due to superimposed deformations must conform to AASHTO LRFD Bridge Design Specifications Article 3.12, except as modified in this section.

721.3.6.2 Design the structure for stresses and deformations due to TU and TG resulting from temperature changes above or below the normal temperature of 64 degrees Fahrenheit. Movements due to temperature changes must use coefficients of thermal expansion of 0.0000060 feet/foot. per degree for concrete and 0.0000065 feet/foot. per degree for steel. Operational temperature ranges for various materials are as follows:

721.3.6.2.1 Concrete

721.3.6.2.1.1 Between 10- and 100-degrees Fahrenheit for aboveground and permanently buried less than 5 feet.

721.3.6.2.1.2 Between 20- and 90-degrees Fahrenheit for permanently buried and underground with over 5 feet of soil cover.

721.3.6.2.1.3 Between -9- and 99-degrees Fahrenheit for factored design temperature for expansion joints of concrete bridges

721.3.6.2.2 Structural Steel

721.3.6.2.2.1.1 Between 0- and 145-degrees Fahrenheit for exposed and aboveground, permanently buried less than 5 feet. See Set 522 Track Construction further commentary.

721.3.6.2.2.1.2 Between 0- and 120-degrees Fahrenheit for non-exposed and aboveground, permanently buried less than 5 feet.

721.3.6.2.2.2 Between 20- and 90-degrees Fahrenheit for permanently buried and underground with over 5 feet of soil cover.

721.3.6.2.2.3 Between 15- and 160-degrees Fahrenheit factored design temperature for expansion joints of steel bridges.

Commentary: Reference to WSDOT BDM, Chapter 9, Section 9.1.2B, "Thermal Effects for Expansion Joints."

721.3.7 Ice and Snow Load: IC

721.3.7.1 IC must conform to AASHTO LRFD Bridge Design Specifications Article 3.9, except as modified in this section.

721.3.7.2 Design for snow and rain on snow effects must evaluate a uniform snow load of no less than 30 pounds per square foot on all exposed area on elevated structures.

721.3.7.2.1 Commentary: Reference to the SEAW Snow Load Analysis for Washington, 2nd edition, WABO-SEAW White Paper #8-2010, Guidelines for Determining Snow Loads in Washington State, 2010 edition, King County Ground Snow Load Analysis.

721.3.8 Fatigue

Commentary: Reference to AREMA MRE Chapter 15, Section 1.3.13, "Fatigue."

721.3.8.1 The major factors governing fatigue demand are the number of stress cycles and the magnitude of the stress range. The live load stress range is the algebraic difference between the maximum and minimum stress due to live load, impact load, and centrifugal load. In regions where the unfactored permanent loads produce compression, evaluate fatigue only if the compressive stress is less than the greatest live load tensile stress caused by the Fatigue I load combination specified in Table 721-1.

721.3.8.2 For LRV, the fatigue load must be single four-car train with AW3 loading with impact as specified in 721.3.3.7.3. Use the number of stress cycles (N) caused by passage of rail trains during the 100-year design life (approximately eight million cycles).

721.3.8.3 For HRV, the fatigue load must be Cooper E80 loading with impact. The DOR must take Mean Impact Load for fatigue design by applying the percentage indicated in AREMA MRE Table 15-1-7, Assumed Mean Impact Load Percentages, to the impact load specified in 721.3.3.7.4. Select the number of stress cycles (N) to be considered from AREMA MRE Table 15-1-6, Number of Stress Cycles, N, unless traffic surveys or other considerations indicate otherwise. N depends on the span length in the case of longitudinal members, and on the number of tracks in the case of floor beams, hangers, and certain truss members. For span lengths exceeding 300 feet, an analysis is required for each bridge component using influence lines and the preceding car types and load frequencies, accounting for the effect of lightly loaded vehicles interspaced within the design train.

721.3.9 Earthquake Effects, EQ

721.3.9.1 Refer to 721.3.21.

721.3.10 Other Extreme Loads: CV and BL

721.3.10.1 Vessel collision load, CV, and blast loading, BL, must conform to AASHTO LRFD Bridge Design Specifications Articles 3.14 and 3.15, respectively.

721.3.11 General Design Guidelines

721.3.11.1 The design must conform to the requirements in AASHTO LRFD Bridge Design Specifications or AASHTO Guide Specifications for LRFD Seismic Bridge Design, and conform to WSDOT BDM where specified herein. If Sounder is operating on any portion of BNSF Railway or Union Pacific Railroad right-of-way, the guidelines for design and construction for the respective railroad must govern.

721.3.11.2 See minimum clearance requirements in Set 530 Track Clearance and Spacing for commuter rail and Set 520 Vehicles Clearance and Track Spacing For LRV.

721.3.11.3 Where structural design is such that operational constraints such as lower train speeds or limiting number of simultaneous train loading are required, the contract drawings must specify the detailed limitation requirements. The DOR must minimize the need for operational constraints during design.

721.3.11.4 The primary structural members must use concrete and/or steel. Only use other materials on the primary structural members with an approved deviation. Bridge substructure may use cast-in-place reinforced concrete construction without an approved deviation.

721.3.11.5 Structure types will be restricted to those historically used by Sound Transit or those that have been accepted for general use by other transportation authorities, and for which it can be demonstrated that the design of the structure types and components will perform well for the intent of the project and under the project's commitments and environmental conditions.

721.3.11.6 When replacing structures under active rail service, Accelerated Bridge Construction (also referred to as "ABC") techniques may be considered, but only with the approval of the Requirements Set 721 owner. ABC construction must conform to AASHTO LRFD Guide Specifications for Accelerated Bridge Construction.

Commentary: A bridge may consist of different span superstructure types upon approval by Sound Transit if project-specific commitments and requirements pertaining to structure type and aesthetics are satisfied.

721.3.11.7 Structures that contain fracture critical member(s) as defined by AASHTO LRFD Bridge Design Specifications are not permitted. Deviations can be submitted to Sound Transit for review when supported with a type, size, and location report in accordance with the WSDOT BDM.

721.3.11.8 If a Strut-and-Tie method is used in design, an independent review by a qualified senior engineer with relevant design experience at least equal to or greater than the DOR is required.

721.3.12 Deflection and Vibration Control

721.3.12.1 For structures that support LRVs, design girders of simple or continuous spans so that the deflections due to a single four-car train with AW3 plus dynamic allowance must not exceed 1/1000 of the span length. For bridges that carry more than one track, the deflection due to the combined design LRV load with multiple trains plus dynamic allowance must not exceed 1/800 of the span length. The deflection of cantilever arms due to total design LRV load plus dynamic allowance must not exceed 1/375 of the cantilever arm. For total design LRV load, see 721.3.3.5 for the Multiple Presence Factor.

Commentary: Refer to AASHTO Guide Specifications for Bridges Carrying Light Rail Transit Loads Chapter 2.4.

721.3.12.2 For structures that support commuter rail vehicles, the DOR must meet the deflection requirements in AREMA MRE Chapter 15, Section 1.2.5, "Deflection" and Section 1.13.3, "Deflection."

721.3.12.3 To limit vibrational amplification due to the dynamic interaction between the superstructure and the rail car, the first-mode natural frequency of flexural vibration of each simple span guideway must not be less than 2.5 hertz. Upon the approval of the Requirements Set 721 owner, spans having lower natural frequencies may be used, provided that the design considers possible vibrational interactions between the structure and the rail car, and the effect on vertical impact loading.

721.3.12.4 The DOR must conduct a special structure-vehicle dynamic interaction analysis if the first-mode natural frequency of flexural vibration of any span guideway is less than 2.5 hertz. Use a single four-car train with AW3 in the vibration analysis. The model must account for movement of the vehicle along the structure at its maximum speed and all other potential resonance speeds. Structural damping must be 0.5% (steel and composite), 1.0% (prestressed, post-tensioned concrete), 1.5% (reinforced concrete).

721.3.12.5 When a single- or two-span bridge superstructures has a first mode of vertical vibration that is less than 2.5 hertz, or for multiple span structures when one span in a series of three consecutive spans has the first mode of vibration at less than 2.5 hertz, the analysis must contain sufficient degrees of freedom to allow modeling of the structure and vehicle truck spacing on a time history basis. The analysis must check the vertical acceleration at the deck level against the comfort limit of 0.1 acceleration of gravity.

721.3.12.6 This section applies for multiple simple span structures where more than one span in a series of three consecutive spans has a first mode of vibration less than 2.5 hertz, and for multiple-span structures with superstructures that are continuous over, or integral, with supports, where the first mode of the structure vibration is less than 2.5 hertz. The analysis must contain sufficient degrees of freedom to allow modeling of the structure, vehicle truck spacing, vehicle primary suspension, vehicle secondary suspension, the car body, and the track imperfections provided by Sound Transit Track team. The analysis must make provision for a time history placement of the vehicle along the structure to model the passage of the transit vehicle. The analysis must check the vertical acceleration at the car floor level against the comfort limit of 0.1 acceleration of gravity.

721.3.12.7 The analysis must determine whether dynamic allowance in excess of that specified in 721.3.3.7 is required for the design of the structure. The analysis must determine whether certain operational considerations such as speed restriction or other provisions are required to ensure the safe operation of the rail transit over the structure.

721.3.13 Rail/Structure Interaction

721.3.13.1 Design for transverse (radial) and longitudinal rail/structure interaction forces due to temperature variations in the continuous welded rail. Base the transverse and longitudinal forces in continuously welded rail on the maximum rail temperature rise and drop. Refer to Set 522 Track Construction for rail temperature and rail neutral temperature definitions. The rail temperature rise is the difference between the highest rail temperatures to the lowest rail neutral temperature. The temperature drop is the difference between the maximum rail neutral temperature and the minimum rail temperature. In addition, The DOR must conduct analysis for forces caused by the rail structural constraints under the effects of post-tensioning, creep, and shrinkage of the concrete. Apply these forces in a horizontal plane at the top of low rail as follows:

Commentary: California High Speed Rail DCM Section 31.2.2.3.5 states “RSI analysis shall consider a specific construction method and construction schedule as well as time-dependent deformations of CR, SH, and PS as specified in AASHTO LRFD Articles 4 and 5.”

721.3.13.2 Transverse Force

721.3.13.2.1 The DOR must apply the transverse force in each direction.

721.3.13.2.2 Determine the magnitude of the transverse rail forces, particularly in curved structures, by non-linear analysis of the rail-structure interaction that accurately models the structure, the rail, and the non-linear behavior of the direct fixation fasteners.

721.3.13.3 LF

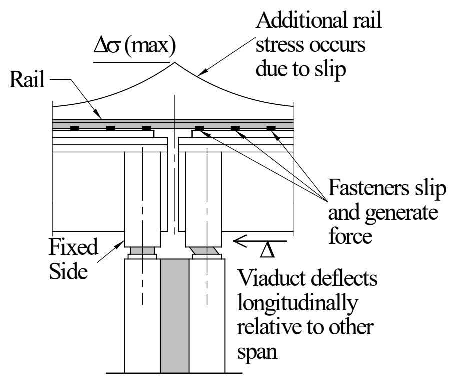
721.3.13.3.1 Determine the magnitude of the longitudinal rail forces by a non-linear analysis of the rail-structure interaction that accurately models the structure, the rail, and the non-linear behavior of the direct fixation fasteners.

721.3.13.3.2 Elevated structures must be designed to accommodate the temporary loads associated with rail break and rail replacement. In addition, the Link elevated structures must be capable of maintaining a broken rail with a gap no greater than 3 inches at any one rail supported by the structure.

721.3.13.4 Axial Rail Stress Limits

721.3.13.4.1 The limit of additional axial rail stress arising from rail-structure interaction effects for the Service Limit States: Δσ = 20 ksi

Figure 721-5: Axial Rail Stress Diagram at Expansion Joint



721.3.13.5 Rail Rotation

Commentary: The rail rotation and settlement limitations are established to ensure safe train operations in accordance with track engineering requirements.

721.3.13.5.1 Relative expansion joint rotation limits no greater than: θ < 0.005 rad about transverse axis.

Figure 721-6: Rail Rotational About Transverse Axis

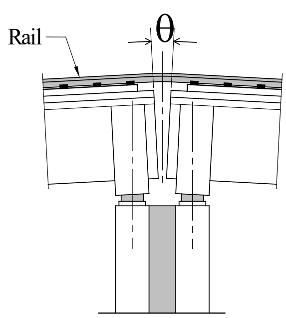
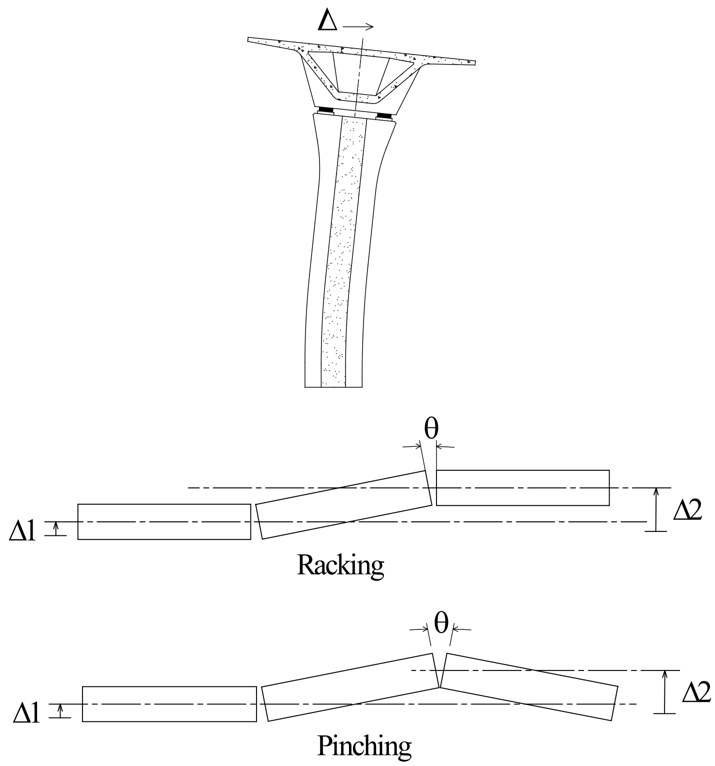


Figure 721-7: Rail Alignment Due to Deflected Shape

721.3.13.5.2 Relative rotation of the vertical axis at the expansion joint due to lateral deflection must be no greater than: θ < 0.0015 rad.

Figure 721-8: Rail Rotational about Vertical Axis



721.3.14 Settlement Limits for Service Limit States:

721.3.14.1 Under any service limit state, design the foundation of the elevated structures such that calculated differential settlement between adjacent piers must not cause a gradient in the rail profile that exceeds 1/2400 of the sum of the lengths of any two adjacent spans.

721.3.14.2 For track settlement limits, see Set 522 Track Construction.

721.3.14.3 Under any service limit state, the total settlement at each pier or abutment must not exceed 1 inch.

721.3.15 Pedestrian Bridges

721.3.15.1 The DOR must design pedestrian bridges for a uniform pedestrian loading of 100 pounds per square foot. Where vehicle access is not prevented by permanent means, the DOR must also design for the Vehicle Load specified in AASHTO LRFD Guide Specification for Pedestrian Bridge Section 3.2, Vehicle Load (LL), or the concentrate load from maintenance equipment determined by Set 720 Building Structure – Platform Concentrated Loads, whichever is more critical, concurrently with a uniform construction load of 25 pounds per square foot. Pedestrian bridge roof or floor snow load must not be less than the snow load specified in Set 720 Building Structure. The DOR must provide the load calculation along with the inspection and maintenance access diagram for Requirements Set 721 owner (or his/her representative) review and approval and include this in the final operations and maintenance manual.

721.3.15.2 Pedestrian bridges located within WSDOT Right-of-Way must follow AASHTO LRFD Guide Specifications for Design of Pedestrian Bridges or WSDOT BDM, whichever is more stringent.

721.3.15.3 Pedestrian bridges that are not located within WSDOT Right-of-Way must follow IBC with local amendments and Section 721.3.15.1, in addition to the requirements below.

721.3.15.3.1 The DOR must use the AASHTO LRFD Strength I load combination with the Vehicle Load, including impact, as applicable.

721.3.15.3.2 For bridges accessible to the general public, the DOR must follow fracture toughness requirements specified in AASHTO LRFD Guide Specification for Pedestrian Bridges Section 4.2, “Fracture.”

721.3.15.3.3 The DOR must perform a load rating on the bridge in accordance with AASHTO Manual for Bridge Evaluation if construction vehicles are anticipated on the bridge in excess than the design maintenance vehicle.

721.3.15.3.4 The DOR must perform a vibration analysis on the bridge in accordance with AASHTO LRFD Guide Specification for Pedestrian Bridges Chapter 6.

721.3.15.4 The DOR must ignore the contribution of steel deck in structural resistance.

Commentary: Steel deck is considered sacrificial.

721.3.16 Concrete Structures

721.3.16.1 Minimum Concrete Design Strengths at 28 Days

721.3.16.1.1 For all underground reinforced concrete cast-in-place structures, including abutments, spread footings, and drilled-in caissons – f’c = 4,000 psi.

721.3.16.1.2 For drilled shafts and cast-in-place piles – f’c = 5,000 psi except use 5000P for drilled shaft per WSDOT Standard Specifications 6-02.3(2)A1.

721.3.16.1.3 For all aboveground reinforced concrete cast-in-place structures, including columns, cap beams, and superstructure for elevated structures and bridges – f’c = 4,000 psi except 4000D for bridge deck per WSDOT Standard Specifications 6-02.3(2)A1.

721.3.16.1.4 For post-tensioned concrete – f’c = 6,000 psi

721.3.16.1.5 For precast pre-tensioned concrete – f’c = 5,000 psi

721.3.16.2 Creep

721.3.16.2.1 All concrete elements must be designed to include the effects of creep. The creep coefficient must incorporate the effects of the maximum concrete design temperature specified in 721.3.6.2.1 which is noted to be greater than that specified in AASHTO LRFD Bridge Design Specifications.

721.3.16.3 Reinforcing and Prestressing Steel

721.3.16.3.1 All concrete reinforcement must be deformed and conform to ASTM A615 or ASTM A706. For elements requiring ductility and/or welding, the design must specify A706 Grade 60 reinforcing steel. ASTM A706 Grade 80 is permitted to be used as straight bars in capacity protected members only. Use of Grade 80 reinforcing steel for hooks, headed bar, splices, and couplers must be approved by the Requirements Set 721 owner. Other reinforcing bars conforming to ASTM A615 or ASTM A706 with a yield strength exceeding 60 kilopounds per square inch may be used selectively to reduce congestion, reduce weight, and speed up installation with approval by the Requirements Set 721 owner, but must not be used for longitudinal reinforcement for ductile members in SDC B, C, and D, including foundations where in-ground hinging is considered as part of the Earthquake Resisting System (ERS).

Commentary: The use of Grade 80 reinforcement is commented on by other well-established agencies. AASHTO Guide Specifications for LRFD Seismic Bridge Design Sections 8.4.1, Reinforcing Steel, and 8.5, Plastic Moment Capacity for Ductile Concrete Members for SDCs B,C, and D, “ASTM A 706 Grade 80 *reinforcing steel may be used in capacity-protected members but shall not be used in members where plastic hinging is expected." Caltrans Seismic Design Criteria Commentary C3.3.3: "Grade 80 bars are not to be used in SCMs (seismic critical members) until definitive data from ongoing research becomes available. Use of Grade 80 reinforcing steel for headed bar terminations, hooks, and couplers may be permitted on a project-specific basis (PSDC) abased on available of specific project data."*

721.3.16.4 Bridge Decks

721.3.16.4.1 New Commuter Rail bridges must have ballasted decks. See Set 522 Track Construction for the minimum ballast depth below the tie. Ballast curbs must accommodate increased ballast depths due to superelevated tracks, or meet the minimum longitudinal grade, and must be no less than 24 inches high above the highest top of rail to accommodate future grade raises.

721.3.16.4.2 Construct the bridge deck slab with reinforced concrete. Provide a concrete deck at least 8 inches thick. Stay-in-place (also referred to as "SIP") deck forms are not permitted. When incorporating precast SIP panels into the bridge deck, a minimum depth of 5-inch topping slab is required. Full-depth precast deck panels are not permitted.

721.3.16.4.3 Bridge decks must have a longitudinal grade of at least 0.5 percent to longitudinal deck drain collection points to provide positive drainage.

721.3.16.4.4 The structural portion of concrete bridge decks must have a minimum transverse cross slope of at least 2 percent.

721.3.16.5 Box-shaped Concrete Girders

721.3.16.5.1 Box-shaped concrete girders must have interior diaphragms spaced equally across the span length, in accordance with AASHTO LRFD Bridge Design Specifications requirements.

721.3.16.5.2 Protect vent holes, drain holes, and other openings not required for inspection access in box-shaped girders from access by vermin. The design must cover the openings greater than 1 inch in diameter through the exterior with galvanized wire mesh screen. The wires must have a maximum spacing of 1 inch in both directions. Design and detail vent holes in accordance with WSDOT BDM Section 5.2.6.B, Access Hatch, Air Vent Holes and Inspection Lighting. In addition to the number of vent holes specified in the BDM, one vent hole per web must be provided at the far end of the access hatch and at a spacing of no greater than 100 feet. The added vent holes must be on exterior and interior webs. Design and detail drain holes in accordance with WSDOT BDM Section 5.3.8, Drain Holes.

721.3.16.5.3 Utilities, longitudinal restrainers, and other components requiring inspection or maintenance are not permitted inside prestressed concrete tub girder cells or box girder cells that have a clear height of less than 4 feet.

721.3.16.5.4 Drain lines must be kept outside of the box girder section to facilitate inspection and maintenance. Drain lines must be kept tight to the deck soffit. Provide bird deterrent where this is not possible. Drain lines must be kept out of view where possible.

721.3.16.6 Wide Flange Prestressed Concrete Girders

721.3.16.6.1 Bird deterrent spikes must be installed on the top side of all bottom flanges of prestressed concrete girders at least 10 feet from the end of each girder as it terminates at the girder stops. The bird spikes must be installed at the non-exposed inner sections of the girders and are not required on the outside exposed faces of the girder. The bird spikes must adhere to the concrete surface sufficiently to be resilient from bird or wind activity.

721.3.16.7 Segmental Bridges

721.3.16.7.1 Design and construction of segmental bridges must be in accordance with the requirements of AASHTO Guide Specifications for the Design and Construction of Segmental Bridges, except as modified in this section.

721.3.16.7.2 In the short-line span-by-span construction method, each segment is cast next to the previous segment in a special adjustable casting machine. An entire span is assembled, post-tensioned, and erected so that it is self-supporting before the next span is erected. For short-line span-by-span construction, the DOR must leave a gap of 6 inches to 24 inches between segments over the piers and the midsegments of the span. The gaps must be filled with a closure pour to correct any unaccounted field conditions.

721.3.16.8 Bent Caps

721.3.16.8.1 All exposed horizontal surfaces on bent caps located outboard of the guideway girders on both sides must have bird deterrent spikes specified for installation. The bird spikes must cover the entire exposed horizontal area on both sides.

721.3.16.9 The design of the elevated platform must conform to the requirements in Set 720 Building Structures.

721.3.16.10 The DOR must design concrete anchors, including cast-in-place and post-installed anchors, in accordance with ACI 318, Chapter 17, “Anchoring to Concrete” and Set 720 Building Structures.

721.3.16.11 Attach the plinth by means of reinforced cast-in-place concrete in the elevated guideway deck. Drilling and bonding the plinth reinforcement anchorage is only acceptable at stations and special trackwork. Special concrete mix design must be used for plinth construction to ensure durability and satisfactory consolidation especially under the slobber plates in the top-down construction.

721.3.16.12 The DOR must not use the hinge diaphragm detail in WSDOT BDM Section 5.6.2.E.3, Girder End Type C, at end of simply supported spans due to the concerns on durability performance (corrosion and fatigue) and inspection access.

721.3.16.13 The DOR must provide analysis to justify the proposed shipping and handling details by the contractor if:

i. deck overhang formwork brackets are attached to the girder
ii. wind loads are present
iii. or the girder is erected in such a manner that one end is supported at the top by a lifting device while the other end is seated on a girder transport vehicle or bearing, or a separate set of erection devices are used
iv. the girder must be checked for stresses and lateral stability

721.3.16.14 The design must implement Grout Type 1 specified in WSDOT Standard Specifications Section 9-20.3(1), Grout Type 1 for Post-Tension Applications, as corrosion protection for post-tensioning tendons.

Commentary: This requirement is due to the concern around the long-term performance of flexible filler. Refer to PTI Technical Notes Issue 19, Selection of Filler Material for Multistrand PT Tendons.

721.3.16.15 Concrete stress limits for all superstructure types under final conditions in the pre-compressed tensile zone must be limited to zero in the top and bottom fibers under service load levels according to WSDOT BDM 5.8.2.

721.3.17 Structural Steel

721.3.17.1 Composite action may be utilized between a concrete deck and its supporting steel members if shear connectors are designed in accordance with AASHTO LRFD Bridge Design Specifications Article 6.10.10, "Shear Connectors." Composite action may be included when satisfying the deflection requirement. The design must not use steel deck either as a composite system or stay-in-place form.

721.3.17.2 The distance between centers of outside trusses or girders must be sufficient to prevent overturning by the lateral load demands. In no case must the distance be less than 1/20 of the span length for through spans, nor must it be less than 1/15 of the span for deck spans. Where the track is supported by a pair of deck girders or stringers, the distance center to center must be at least 6 feet 6 inches. If multiple girders or stringers are used, the DOR must arrange them closely spaced together to distribute the track load uniformly to all members.

721.3.17.3 Paint all steel superstructures in accordance with Sound Transit Standard Specifications.

721.3.17.4 Metal, except for fillers, must be at least 3/8 inch thick. Parts subject to marked corrosive influences must be of greater thickness or else the design must protect them against such influences. The DOR must proportion the thickness of gusset plates connecting the chords and web members of a truss for the transferred force, and the gusset plate thickness must be at least 1/2 inch.

721.3.17.5 Load paths that are sufficiently rigid to transmit all forces must be provided by connecting all transverse members to components comprising the cross section of the longitudinal member in order to resist distortion-induced fatigue.

721.3.17.6 Bracing must be provided in accordance with AREMA MRE Chapter 15, Section 1.11, "Bracing."

721.3.17.7 The lateral bracing of the compression chords of trusses or compression flanges of deck girders and through girders must be proportioned for a transverse shear force in any panel equal to 2.5 percent of the total axial force in both members in that panel, in addition to the shear force from the lateral load demands.

721.3.17.8 For steel beam and girder deck spans requiring lateral bracing, an eccentric load must be applied as a verification to cross frames, diaphragms, and anchor bolts only, in accordance with AREMA MRE Chapter 15, Section 1.3.10.b, "Stability Check." The load factor used for this check must be 0.875. This analysis is not required on floor systems and anchor bolts of through truss spans and through girder spans. Apply a single line of wheel loads, (Q), equal to the design load per rail, including full design impact, at an eccentricity of 5 feet from the centerline of track, but no farther than the edge of the deck.

721.3.18 Substructure Design

721.3.18.1 Abutments and Piers

721.3.18.1.1 Abutment and pier skews must be limited to 30 degrees.

721.3.18.1.2 Provide positive drainage behind abutments. The drainage system must remove free water as close to the bottom of the abutment as practical. The drainage system must collect the water from behind the abutment using a drainage blanket and perforated pipe at least 6 inches in diameter. A drainage blanket made from granular material is an acceptable material. The drainage system must be piped to daylight, tied into a curb and gutter system, or tied into a storm sewer system. The design must use weep holes at least 3 inches in diameter if the drain water does not have detrimental impacts on objects or features in front of the abutment. Weep holes must be located 6 inches above the finish ground line and must be hydraulically connected to adjacent weep holes. Weep holes must be spaced not greater than 10 feet on center.

721.3.18.1.3 For abutments and piers supporting bridges over commuter railways located less than 25 feet clear from the centerline of the nearest railroad track, the design must provide pier protection that conforms the requirements of AREMA Manual for Railway Engineering, Chapter 8, Section 2.1.5, “Bridge Substructure Protection.” For abutments and piers supporting bridges over light rail railways located less than 25 feet clear from the centerline of the nearest railroad track but more than 3 feet clear of the clearance envelope of LRV, the design must either provide emergency guardrail to limit the lateral movement of derailed vehicles or provide pier protection that can resist the lateral collision load defined in 721.3.3.9.3. When the substructure is within 3-foot clearance to the clearance envelope of LRV, no matter if emergency guardrail is provided, see 721.3.3.9.3 for load requirements.

721.3.18.1.4 The placement of bridge abutments and piers must account for current and future water and flood patterns. The design allowance must be incorporated due to future changes.

721.3.18.1.5 The DOR must evaluate collision for the abutments and piers located within the clear zone of roadways that carries vehicle traffic as defined by the AASHTO Roadside Design Guide. The design must conform to the requirements of WSDOT BDM Article 3.16.7, “Vehicular Collision Force: CT.”

721.3.18.1.6 Pier columns must be in circular shape or a polygonal shape similar to circular.

Commentary: Polygonal shapes used for pier columns have typically proven to be the more cost-effective option.

721.3.18.2 Spread Footings

721.3.18.2.1 The DOR must not use spread footings to support structures in a stream or river environment without approved protection from undermining.

721.3.18.2.2 For spread footings that do not meet the requirements of AASHTO Guide Specifications for LRFD Seismic Bridge Design 6.3.2, “Modeling of Footings,” the DOR must design use a beam-on-elastic foundation design approach that is approved by the Requirements Set 721 owner (or his/her representative).

721.3.18.3 Piles and Drilled Shafts

721.3.18.3.1 The design must not use battered piles and battered drilled shafts.

721.3.18.3.2 The following pile types are acceptable for new structures:

721.3.18.3.2.1 Driven steel H pile.

721.3.18.3.2.2 Driven steel pipe piles (open-ended or close-ended).

721.3.18.3.2.3 Precast/prestressed concrete pile.

721.3.18.3.2.4 Reinforced concrete piles.

721.3.18.3.2.5 Concrete-filled steel tubes.

721.3.18.3.3 See WSDOT BDM Section 6.7.1, “Corrosion of Steel Foundation,” for corrosion rates when designing a steel foundation.

721.3.18.3.4 See WSDOT BDM Section 7.10, “Concrete-Filled Steel Tubes,” for design of concrete-filled steel tubes.

721.3.18.3.5 Design and detail drilled shafts in accordance with WSDOT BDM Section 7.8, Shafts.

721.3.18.3.6 The DOR must not design permanent casing as structural unless it is designed as a concrete-filled steel tube.

721.3.18.3.6.1 Construction Considerations

721.3.18.3.7 Make special consideration to keep excavations for substructure construction to a minimum adjacent to active tracks. A method to reduce the excavation depth is to use a top-down construction method, such as installing columns or piles then exposing them later, when the bridge is in service, thus requiring initial excavation only to a depth required to construct the pier caps.

721.3.18.3.8 Make special consideration for construction under rail traffic. Position and design foundation and substructure elements in such a manner to reduce their impact on rail traffic when constructed. Consider precast elements in order to speed construction and reduce the impact on rail traffic.

721.3.19 Miscellaneous Design

721.3.19.1 Design for uplift by providing a positive connection to all elements, including the connection of superstructure to the substructure.

721.3.19.2 The structural design of light rail bridges must accommodate the construction of sound barriers at a future time. The design must allow for bridge and track inspection access with the attachment of barriers to the structures.

721.3.19.3 Design the light rail OCS support and connection on elevated guideways to resist the plastic capacity of the OCS pole. Pole failure under an extreme event must not cause damage to guideway structure.

721.3.19.4 Railings

721.3.19.4.1 The design requirements herein are for railings at elevated structures, away from public areas. See IBC for design requirements of railings in public areas.

721.3.19.4.2 Provide emergency railing, or equivalent physical barrier, on both sides of the bridge. The top rail must at least 42 inches above the surface of walkways. Emergency railings must have a minimum of three horizontal intermediate rails. Clear spacing between rails, or between the rail and the top of walkways, must not exceed 12 inches. Use steel cable or round tubular sections for the horizontal rails.

721.3.19.4.3 Provide emergency railing, or equivalent physical barrier, on both non-platform sides of the elevated stations with center loading platform. The top rail must be at least 42 inches above vehicle floor level if the gap between the emergency railing and the vehicle is less than 5 feet wide. Other railing designs must be in accordance with 721.3.19.4.2. See 721.3.3.11 for design loads without public access.

Commentary: This requirement is to address a potential hazard of insufficient fall protection when wrong side doors open on elevated stations with center loading platform. A passenger could be leaning on the door on the non-platform side of the station when the operator opens the wrong side door by mistake. It could result in the passenger falling over the emergency railing and off the guideway if the gap between the emergency railing and vehicle is less than 5 feet wide and the top rail is less than 42 inches above vehicle floor level. Discussion indicates that implementing precision door control is cost prohibitive. Providing high emergency railing is the preferred solution.

721.3.19.5 Bridge Bearings

721.3.19.5.1 The DOR may supplement bridge bearings by additional shear-resisting devices, primarily to help transfer seismic lateral forces, provided that the movement required to engage the shear-resisting devices does not cause failure of a bearing device itself under the ODE seismic event.

721.3.19.5.2 Bearing replacement operations generally require lifting of superstructure elements using hydraulic jacks. The DOR is responsible for calculating anticipated lifting loads and stipulating these loads on the contract drawings. The design must be in accordance WSDOT BDM, Section 9.2.9, “Bearing Replacement Considerations.” The DOR must include the rail-structure interaction in the lifting load calculation. The DOR must size all hydraulic jacks and design the relevant structural elements for 200 percent of the calculated lifting load. In all cases, the DOR must verify from the manufacturer’s literature that appropriate hydraulic jacks are available to operate within the space limitations imposed by a particular design situation. The DOR must stipulate the hydraulic jack model(s) and jacking point locations for bearing replacement on the contract drawings. The bearing assembly must be removable and replaceable by raising the bridge superstructure no greater than 1/4 inch. Design for bearing and end diaphragm must be readily accessible for inspection and bearing replacement. Additionally, the end diaphragm must be designed to be jacked up for bearing replacement during non-revenue hours.

721.3.19.5.3 The DOR must slope the bearing seat at abutments and intermediate piers away from the seats to prevent ponding at the seats due to expansion joint failure or other situations. The slope must be at least 1.5 percent. The DOR must provide sufficient opening, 3 inches wide by 2 inches high minimum, to drain the water if the expansion joints are above a confined space.

721.3.19.5.4 The design must provide bird deterrent around the bearing seats if there is perching space.

721.3.19.6 Structural Support for Signs, Luminaires, and Traffic Signals

721.3.19.6.1 The design of structural supports for guideway signs, luminaires, and traffic signals must be in accordance with the requirements in Set 720 Building Structures. The gust factor for wind design must not be less than 1.14 per AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals.

721.3.19.6.2 In accordance with AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, design for fatigue is required for the following structure types.

721.3.19.6.2.1 Common lighting poles and roadside signs (except square lighting poles as they are smaller structures and normally have not exhibited fatigue problems).

721.3.19.6.2.2 Overhead cantilevered sign structures,

721.3.19.6.2.3 Overhead cantilevered traffic signal structures,

721.3.19.6.2.4 High-mast lighting towers,

721.3.19.6.2.5 Overhead non-cantilevered sign structures, and

721.3.19.6.2.6 Overhead non-cantilevered traffic signal structures.

721.3.19.7 The design of conduit support must satisfy the requirements in WSDOT BDM Section 10.8, “Utilities Installation on New and Existing Structures.”

721.3.19.8 Waterproofing

721.3.19.8.1 The DOR must incorporate a waterproofing membrane on all Commuter Rail bridge decks.

721.3.19.8.2 Design commuter bridges for waterproofing using methods and materials in accordance with AREMA. The waterproofing must be retained by bond or anchorage in its original position to the surface to be waterproofed.

721.3.19.8.3 A spray elastomer waterproofing coating system may be incorporated. The spray elastomer bridge deck membrane used must be suitable for concrete deck surface and must utilize a polymer primer. The membrane system must be capable of sealing across expansion joints without the need for a separate gland and bonding agents on the membrane. Use of protective asphaltic panels with the spray elastomer bridge deck membrane is not required, but a film thickness test before accepting the deck membrane is required.

721.3.19.9 The design must address inspection and maintenance access needs of Sound Transit. The design must meet the following requirements, at a minimum:

Commentary: Reference to WSDOT BDM for inspection and maintenance access requirements

721.3.19.9.1 The design must provide a flat bench at least 2.5 feet wide along the exposed face abutments and wingwalls.

721.3.19.9.2 Reinforced concrete box and post-tension box girders (box girders) with inside clear height greater than 4 feet but less than 6.5 feet must have access, electrical receptacles, and ventilation provided inside each box girder cell containing utilities, longitudinal restrainers, and other components requiring inspection or maintenance.

721.3.19.9.3 Box girders with inside clear height greater than or equal to 6.5 feet must have access, electrical receptacles, and ventilation provided inside each box girder cell. Electrical receptacle requirements must conform to WSDOT Design Manual Chapter 1040. Air vents must conform to WSDOT BDM Figures 5.2.6-1 and 5.2.6-2, “Access Hatch Details and Air Vent Opening Detail.”

721.3.19.9.4 All spans and girder cells must be accessible, including the provision of openings through interior diaphragms for through-passage. The access hatch design must meet the following design requirements:

721.3.19.9.4.1 The design must provide access hatches at a spacing less than 400 feet.

721.3.19.9.4.2 Access hatch size must be at least 2 feet 6 inches by 2 feet 6 inches. The weight of each hatch lid must be at least 80 pounds.

721.3.19.9.4.3 Access hatches must be galvanized according to Sound Transit Standard Specification 05 05 13, “Shop Applied Coating for Metals.”

721.3.19.9.4.4 The design must locate access hatches, preferably in the deck slab for double-track superstructures, if the access avoids interfering with rail operation and trackwork. The design must locate access hatches in the soffit for single-track superstructures to avoid interfering with the rail operation and the trackwork.

721.3.19.9.4.5 Access hatches located in the deck slab must be watertight and must not be located at low point of deck drainage. The design must keep the access hatch frame at least 1 inch above the deck surface, to prevent deck drainage water from entering the interior space. Inside the girder interior on the deck slab soffit, the design must provide a drip groove around the access hatch frame perimeter within 2 inches from the frame edge.

721.3.19.9.4.6 The design must place the access hatches located in the soffit where the access does not impact traffic under the bridges. Access hatches located in the bridge soffit must be accessible with a ladder or a lift device from ground level and must swing into the box girder. To exclude unauthorized access, the access hatch must be located where ladders, as a minimum, are required to gain access and must be detailed to allow lock attachment.

721.3.19.9.4.7 Provide a fixed interior ladder (galvanized, painted, or aluminum) at each access hatch in the deck slab. Fixed ladder design must comply with the ANSI-ASC A14.3 standard. Fixed ladders must include a ladder safety system and storage for the ladder safety system travel guide. Ladder safety systems must comply with WAC 296-876-60080. The ladder must be equipped with a spring-assisted extendable ladder safety post at the top, or equivalent to be approved by Sound Transit Safety for safe mounting and dismounting of the fixed ladder. The post must extend at least 39 inches above hatch level.

721.3.19.9.4.8 The design must configure the inside of box girder to allow inspectors access to within 3 feet of the components requiring inspection or maintenance. The possible approaches include permanent walkways and/or ladders inside the box girders. The permanent walkway design must comply with WAC 296-880-40010 if the walkways are less than 4 feet above the lower level and with WAC 296-880-20005 if the walkways are 4 feet or more above the lower level.

721.3.19.9.4.9 Each hatch must be equipped with a sign permanently attached to its underside stating:

Figure 721-9: Hatch Warning Sign

Danger: Follow Confined Space Entry Procedure Before Entering

721.3.19.9.5 Parallel, separated elevated guideway structures must have a separation of no less than 7 feet to accommodate future inspection and maintenance.

721.3.19.9.6 Horizontal clearance between bottom flanges of steel girders and steel beams must be at least 12 inches for members 45 inches and less in depth and must be no less than 18 inches for members greater than 45 inches in depth.

721.3.19.9.7 Column silos are an acceptable technique to satisfy the balanced stiffness and frame geometry requirements in seismic design. The design must provide galvanized steel column silo access for inspection and maintenance from grade to the top of foundation, where the top of foundation is greater than 5 feet below finish grade. Column silos should be designed as permanent structures and detailed accordingly for a 100-year minimum service life. Due to the construction and inspection complications of column silos, the DOR must first attempt to meet balanced stiffness and frame geometry requirements by the other methods specified in Article 4.1.4 of AASHTO Guide Specifications for LRFD Seismic Bridge Design. If column silos are required, the DOR must design and detail column silos and its cover in accordance with the requirements in WSDOT BDM Article 7.3.4, “Column Silos,” with the additions herein.

721.3.19.9.8 The DOR must design the column silo for a 2-foot-7-inch minimum annular space, the clear space between the column and column silo. This will allow suitable inspection space through an access hatch at the silo cover and the implementation of ladder rungs, which must be installed along the steel casing conforming to ANSI A14.3-2008. The ladder rungs must standoff from the casing by 7 inches, leaving a 24-inch clear distance for inspection access. Each access hatch must have a clear opening of at least 2 feet by 2 feet. A minimum of two access hatches placed on opposite sides of the column must be provided to allow visual inspection to all sides of the column from outside the silo. The weight of each access hatch units must not exceed 80 pounds and must be detailed to allow lock attachment to the silo cover. The DOR is responsible to stipulate the pulley system to remove and restore column silo cover by maintenance and inspection personnel on the contract drawings. The design must provide a flat bench at least 2.5 feet wide around the silo. The vertical clearance above the silo cover must be at least 9 feet for the whole projected area of the cover.

721.3.19.9.9 The DOR is responsible for stipulating and specifying the davit system for confined space access and rescue purpose with the mounting location(s) and the mounting details for the davit system setup on the contract drawings. The davit system may be chosen to be capable of rotating to allow for better proximity to the hatches. Installation of the davit base must be included in the contract drawings and must either embedded to the structure or face mounted. The davit assembly can then be installed to the base and removed as necessary by Sound Transit. The davit assembly must be specified with a hand-controlled winch with a locking type stop to allow for retrieval of two individuals simultaneously. The DOR must provide calculations for design of the mounting showing sufficient resistance to withstand the anchorage forces specified by the davit system manufacturer. The davit system mounting must be designed by a Professional Engineer licensed in Washington State. The DOR must detail the covers on column silos to shed water and be watertight.

721.3.19.10 Support and Underpinning of Existing Structures

721.3.19.10.1 The DOR, in consultation with the Geotechnical Engineer of Record, must investigate all structures that remain over, or adjacent to, the work and must prepare all necessary designs for their protection or permanent support and underpinning.

721.3.19.11 Corrosion Control

721.3.19.11.1 Designs based on the use of metallic supports exposed to the environment, such as H or soldier piles, must include additional sacrificial wall thickness to the structural requirements for the pile based on the soil condition. See 721.3.18.3.3 for corrosion rate reference.

721.3.19.11.2 Transverse collector/bonding bars must be installed every 500 feet and be electrically continuous with top layer longitudinal reinforcing bars.

721.3.19.11.3 Transverse collector/bonding bars must be installed in the deck and tunnels and made electrically continuous with top layer longitudinal reinforcing bars at expansion joints, hinges, abutments, and intermediate locations not exceeding 500 feet.

Commentary: This requirement is applicable only to support piling systems that are to provide permanent support. Piling used for temporary support does not require corrosion control provisions.

721.3.19.11.4 Elevated Guideway Structures: Superstructure integral with Substructure with Direct Fixation

721.3.19.11.4.1 Provide electrical continuity by providing all the following.

721.3.19.11.4.2 Weld top layer reinforcing splice in the deck.

721.3.19.11.4.3 Provide collector/bonding bars in the deck.

721.3.19.11.4.4 Bridge electrical continuity over expansion joints and other electrical discontinuity.

721.3.19.11.4.5 Interconnect electrically continuous top layer deck reinforcing bars to the reinforcing bars in the bents/girders, piers, and foundation.

721.3.19.11.4.6 Provide stray current test boxes. See requirements Set 222 Stray Current Corrosion Control for additional information.

721.3.19.11.4.7 Consult the project corrosion engineer or cathodic protection specialist to ensure the above requirements are integrated into the design.

721.3.19.11.5 Elevated Guideway Structures: Superstructure non-integral with Substructure with Direct Fixation

721.3.19.11.5.1 Provide electrical continuity by providing all the following:

721.3.19.11.5.2 Weld top layer reinforcing splice in the deck.

721.3.19.11.5.3 Provide collector/bonding bars in the deck.

721.3.19.11.5.4 Bridge electrical continuity over expansion joints and other electrical discontinuity.

721.3.19.11.5.5 Interconnect electrically continuous top layer deck reinforcing bars to the reinforcing bars in the bents/girders.

721.3.19.11.5.6 Provide a ground electrode system between the superstructure and the substructure.

721.3.19.11.5.7 Provide stray current test boxes. Please see requirements Set 222 Stray Current Corrosion Control for additional information.

721.3.19.11.5.8 Consult the project corrosion engineer or cathodic protection specialist to ensure the above requirements are integrated into the design and for electrical isolation requirements at the bearing.

721.3.19.11.6 Elevated Guideway Structures with Tie and Ballast

721.3.19.11.6.1 Conform to the requirements from the corresponding structural systems in the above sections with the following exceptions.

721.3.19.11.6.2 Welding of reinforcing in the deck is not required.

721.3.19.11.6.3 Provide electrical isolation at the surface of the deck.

721.3.19.11.7 Consult the project corrosion engineer or cathodic protection specialist to ensure the above requirements are integrated into the design "Overhead Contact System (OCS) Pole Foundation Grounding"

721.3.19.11.7.1 All metallic components, inclusive of the pole baseplate, that will be partially embedded or be in contact with concrete surfaces must be hot dip galvanized or receive protective coating.

721.3.19.11.7.2 Consult the project corrosion engineer or cathodic protection specialist for detailed requirements of the OCS pole foundation grounding.

721.3.20 Fatigue

721.3.20.1 Detail categories for steel structure fatigue design must be as shown in AREMA MRE Table 15-1-9, Detail Categories for Load Induced Fatigue. Allowable fatigue stress ranges are shown in AREMA MRE Table 15-1-10, "Allowable Fatigue Stress Range." Fracture is not necessarily the result of fatigue, yet fatigue of a member can lead to fracture. As such, the DOR must avoid low-fatigue-resistant details on fracture-critical members (FCMs). The DOR must not use Detail Category E and Detail Category E' details on FCMs, and Detail Category D details are discouraged and used only with caution.

721.3.20.2 Reinforced concrete and prestressed concrete fatigue design must conform to AASHTO LRFD Bridge Design Specifications Article 5.5.3.

721.3.21 Seismic Design

721.3.21.1 Design Policy

721.3.21.1.1 Sound Transit has adopted a two-level earthquake hazard design approach, the ODE and MDE.

721.3.21.1.2 ODE is defined as an earthquake event that has a return period of 150 years. Such an event has a high probability of occurring during the 100-year facility design life. The probability of exceedance of this level of event is approximately 50 percent during the facility design life.

721.3.21.1.3 MDE is defined as an earthquake event that has a return period of 2,500 years. This event has a small probability of exceedance during 100-year facility life. The probability of exceedance for MDE is approximately 4 percent during the facility design life.

Commentary: The 2,500-year MDE remains a useful benchmark design earthquake level for all structure types on the Sound Transit system. From time-to-time a question regarding the use of a smaller-return-period event, such as the 1,000-year return period that the AASHTO SGS uses, arises. The use of the 2,500-year MDE earthquake ground motion is recommended for continued use in the future for Sound Transit elevated guideway, bridge, and tunnel design for several reasons.

Commentary: The Sound Transit light-rail system is a linear, non-redundant transportation facility that is viewed as a key part of regional mobility and a key system for recovery from large earthquake events in the region. Due to the lack of redundancy and the fact that a large portion of the system has already been designed and built to a 2,500-year event, that earthquake event should be continued to be used for design of the guideway facilities in the future.

Commentary: The Sound Transit light-rail system includes major structures, such as long-span bridges, tunnels, and other specialized infrastructure where it is difficult to implement high damage tolerant elements with conventional ductile lateral force-resisting systems. Designing to a higher ground motion, such as the 2,500-year event, helps ensure that the system is resilient to large MDE ground motions.

Commentary: The Sound Transit light-rail system includes numerous combined guideway and station structures. The stations, as governed by the IBC/ASCE 7, are designed for intermediate to life-safety and no-collapse performance levels under the 2,500-year ground motion. This design consists of the higher "seismic importance factor" used for the stations in accordance with ASCE 7 and the IBC. Therefore, designing the guideway portion of these stations to the 2,500-year ground motion is appropriate and ensures consistent system resilience.

721.3.21.1.4 Besides the structures that carry guideway and stations, all structures the failure or damage of which may impact guideway operations must be in accordance with the design policy in this section as well.

721.3.21.1.5 The DOR must assign each structure to a Seismic Design Category (SDC) in accordance with AASHTO Guide Specifications for LRFD Seismic Bridge Design.

721.3.21.2 Seismic Performance Objective

721.3.21.2.1 The goal of this objective is to protect life safety and the capital investment of the public represented by permanent stationary facilities of Sound Transit and to minimize interruption of Link operations caused by damage to systems or track support.

721.3.21.2.2 The intent of these criteria is to ensure that new Link facilities can withstand the effects of the ODE such that the Link will be able to resume operation in a reasonable amount of time, and the MDE for collapse prevention and life safety.

721.3.21.2.3 The system components needed for operations of Link (e.g., OCS power, communications) associated with the facility must be designed such that Link will be able to resume operations in a reasonable amount of time after an ODE event.

721.3.21.2.4 For the ODE, which is likely to occur more than once during the normal life expectancy, the DOR must design the structure to respond without significant structural damage, which can be repaired during normal operating hours.

721.3.21.2.5 For the MDE, which has a low probability of being exceeded during the normal life expectancy, the DOR must design the structure to survive the deformation imposed and induced on the structure and the foundation, to avoid major failure, and to maintain life safety.

721.3.21.2.5.1 The goal for conventional structures, such as those covered by the AASHTO Guide Specifications for LRFD Seismic Bridge Design (AASHTO SGS), as defined in Table 721-3 AASHTO Article 3.1, must be to provide adequate strength and ductility to prevent collapse or instability of the structure, including those demands from geotechnical seismic hazards such as liquefaction-induced deformations.

721.3.21.2.5.2 The goal for non-conventional structures, as defined in 721.3.21.5, must be as follows.

721.3.21.2.5.2.1 The structure can withstand seismic deformations, strains, and internal forces, consistent with the capability of the structure type and foundation type to tolerate such demands. This includes geotechnical seismic hazards, such as liquefaction-induced deformations. The criteria for damage tolerance and the analysis methods used to substantiate damage or lack thereof must be identified on a project-specific basis and must be approved by Sound Transit Structural Engineer or their Representative. See elsewhere for approval roles.

721.3.21.2.5.3 Initial criteria must be developed during preliminary design for the structure type considered. As the project advances, these criteria, including analysis methods, must be evaluated and updated as new information is developed, including alternate structural concepts that may emerge and as geotechnical information is advanced. Independent peer review and Requirements Set 721 owner (or his/her representative) review and approval are required. Expert panel participants performing the peer review are also subject to Sound Transit approval. The independent peer review team must be independent of the design team consultants. This section applies regardless of the project delivery method.

Commentary: The Peer Review Team must be independent from the design team and design team's organization and must be composed of engineers familiar with AASHTO.

721.3.21.2.5.3.1 Design criteria that are relevant to seismic damage tolerance on alternative delivery projects, such as design-build, including ATC, must also be approved by Sound Transit. Peer review must be used to substantiate the criteria and design approach. Peer review responsibilities and the entity providing such services must be established prior to contract award. Acceptance of ATCs by Sound Transit may be conditional, subject to peer review after contract award.

721.3.21.2.5.3.2 Additionally, for non-conventional structures, a life-cycle cost comparison with peer review must be conducted and approved by Requirements Set 721 owner (or his/her representative) and Operations. This assessment process is subject to the same protocols as described in the preceding sections. Elements that must be considered in the comparison are estimates of construction cost, schedule, repair/replacement cost, and potential downtime after a damaging event. Criteria for such non-conventional structures typically will require that material strain levels be kept within the elastic range of the materials and that analysis/assessment techniques be established such that material and geometric nonlinearities can be identified and controlled anywhere within the structure or its foundation. Linear elastic analysis approaches, such as response-spectrum analysis, are not adequate and nonlinear response-history (aka time-history) analysis using project and site-specific input acceleration or displacement histories must be applied. Accordingly, independent peer review of the approach, analysis, and results is required.

Commentary: Performance objectives and acceptable damage at MDE ground motion level may vary depending on the pursuit of conventional vs. non-conventional seismic design approach.

Commentary: Lacking detailed system risk assessment or cost data to the contrary, there is sufficient precedent for typical representative Sound Transit elevated structures be designed for a minimum of life-safety/no-collapse during the 2,500-year MDE. This seismic design approach for conventional structures is well covered by AASHTO SGS provisions. Note that the AASHTO provisions treat life safety and no-collapse essentially as the same performance level, unlike the building codes, which treat these as separate and distinct performance levels.

Commentary: However, most long-span, and therefore non-conventional structures are not capable of developing reliable substructure plastic hinging mechanisms, such as those the AASHTO SGS is based upon. Accordingly, non-conventional bridge systems should be designed using a seismic design approach for non-conventional structures where alternative acceptable damage mechanisms can be identified in support of prescribed performance objectives. Such an approach allows for tighter control of damage levels tailored to what the structure type can reliably sustain. Careful consideration of structural-system versus *damage-tolerance should be given to projects at the preliminary design phase, to appropriately inform development of design criteria, especially for alternative delivery, such as design-build.*

Commentary: Non-conventional structures often are high-value major structures where consideration of first cost vs potential repair costs and downtime—post-earthquake—is important. Repair and potentially replacement of major structures can take years, and the potential for such downtime where the light-rail system is unusable to passengers and is generating reduced or no revenue is likely unacceptable to Sound Transit. A high-level life cycle cost comparison must be conducted for peer review and Sound Transit approval which considers the construction cost, schedule, repair/replacement cost, remaining life, and downtime after a seismic design event, including the relatively low possibility of occurrence of the MDE event. Such an analysis should provide perspective on the elements listed above in an approximate manner that considers that such a seismic event may occur many years into the future.

Commentary: It is not possible to outline numerical damage limit criteria, such as damage locations, strain levels, damage-control devices, etc., for all types of non-conventional structure types. Even for conventional structures strain limits as related to damage levels can be subjective, as described in ATC-32 (1996). This is still the case, as outlined in The NCHRP Synthesis 440 (2013), where damage levels are linked to performance levels for several agencies and projects in Chapter 10 of the synthesis. Note, however, that the NCHRP 440 does not delineate between conventional and non-conventional structures, but rather uses owning organizations and projects, the implication being that non-conventional structures are typically the ones with project-specific criteria. Regarding non-conventional bridges, the NCHRP Synthesis 532 (2019) is another source of example seismic design criteria, design approaches, and other considerations for actual non-conventional bridge structures. Since these documents were published, additional project design data is available from other transit agencies and departments of transportation (e.g., Caltrans and WSDOT), and such data should be useful to inform specific structure-type designs.

Commentary: Beginning with ATC-32 and as currently outlined in the NCHRP 949 (2020) proposed guidelines, relatively consistent damage levels have been used. In their most general form, the levels follow five damage states from “no damage” to “collapse”. For design use, these have been condensed into three levels with slightly different terms to describe each of the three: (1) no-damage/minimal/very minor, (2) minimal/moderate/repairable, and (3) significant/major. The strain limits used for these three damage states vary by agency, bridge type, structural material, and bridge element; therefore, there is no universal set of limits. However, the lowest damage level corresponds to “essentially elastic” response, the highest damage state corresponds to “near collapse”, and the middle damage state is in-between. For the most part, the highest damage state is reserved for ductile-type structures for which a defined plastic mechanism can be relied upon for inelastic seismic loading. The lowest damage state is typically reserved for large structures that are not particularly damage tolerant, for example suspension and cable-stayed structures. However, some of these cable-supported systems have been designed to deliver moderate ductile response by including yielding elements in their support towers. Such devices are not typical and must be designed on a project-specific criteria basis developed specifically for the unique deformation absorbing elements provided in the structure.

721.3.21.2.6 Design any structure crossing or within the right-of-way of a guideway track or facility to meet the seismic performance objective for MDE established herein. The structure must not encroach on the train dynamic clearance envelope or prevent normal operation of the trains or system equipment during and after an ODE event.

721.3.21.3 Risk Acceptance

721.3.21.3.1 This seismic performance objective is based on flexible standards in which the degree of seismic design to meet the ODE requirements for any structure or facility will vary depending upon design and construction cost and the level of assumed risk. In some cases, it may be desirable to waive certain criteria when the additional risk is low, and cost of compliance is high. Sound Transit may consider variances to the performance criteria when rigorous adherence to them will significantly increase cost without commensurate increase in performance.

721.3.21.3.2 In such cases, the DOR must notify Sound Transit in writing with an action recommendation for a request for deviation. The DOR must include a discussion of the cost difference between the recommended action and the design criteria requirement and the difference in performance between the two actions. Sound Transit will review the deviation request and provide direction on the required action.

721.3.21.3.3 Content in this document must not be construed to allow design of new facilities to a level less than required by the applicable building codes, industry standards and guidelines or the current Sound Transit Design Requirements Manual. Further, nothing herein should be construed that Sound Transit guarantees any levels of service. Factors outside of Sound Transit's control (such as regional fires, damage to non-Link lifelines and infrastructure, etc.) may mean that these goals are not met. In no case must life safety be compromised.

721.3.21.4 Analysis and Design Procedures

721.3.21.4.1 Seismic design procedures and analysis of elevated structures and bridges except non-conventional bridges defined in 721.3.21.5 for ODE, an earthquake event that has a return period of 150 years, and MDE, an earthquake event that has a return period of 2,500 years, must be in accordance with the "AASHTO Guide Specifications for LRFD Seismic Bridge Design," except as supplemented or explicitly modified in Table 721-4 below.

Table 721-4: Additional Requirements and Deviations from AASHTO Guide Specifications for LFRD Seismic Bridge Design.

(See below).

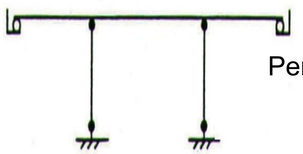
AASHTO Article	Subject	ODE Requirements	MDE Requirements
3.1	Applicability of the Specifications	AASHTO Guide Specifications for LRFD Seismic Bridge Design is applicable to the design of conventional bridges to resist the effects of earthquake motions. Seismic design requirements of non-conventional bridges, and bridges categorized as essential or critical (recovery) must be with the consultation of Sound Transit Engineers. See definition of non-conventional bridges and essential or critical (recovery) bridges in Section 721.3.21.5.	
3.2	Performance Criteria	Seismic design procedure and analysis of elevated structures and bridges for an earthquake event that has a return period of 150 years must be in accordance with the "AASHTO Guide Specifications for LRFD Seismic Bridge Design", except as supplemented or explicitly modified. Such an event can reasonably be expected to occur during the 100-year facility design life. The probability of exceedance of this level of event is approximately 50 percent during the 100-year facility design life. Design structure to respond without significant structural damage, which can be repaired during normal operating hours.	Seismic design procedure and analysis of conventional elevated structures and bridges for an earthquake event that has a return period of 2,500 years must be in accordance with the "AASHTO Guide Specifications for LRFD Seismic Bridge Design", except as supplemented or explicitly modified additional requirements and deviations from AASHTO Guide Specifications for LRFD Seismic Bridge Design. See Section 721.3.21.2.5 for the general guidance of non-conventional bridge performance objectives. The probability of exceedance of this level of event is approximately 4 percent during the 100-year facility design life.
3.3	Earthquake Resisting Systems (ERS) Requirements for SDC C & D	Permissible Global Seismic Design Strategies: Ductile Substructure with Essentially Elastic Superstructure. Elastic Superstructure and Substructure with a Fusing Mechanism between the two. This category is only permissible with approval from Requirements Set 721 owner. See Section 721.3.21.6 for general guidance. Permissible Earthquake Resisting System (ERS), see Figure 721-9. Permissible ERE, see Figure 721-10. Note that these two figures replace the referenced AASHTO SGS Article 3.3 Figures 3.3-1 and 3.3-2 in their entirety. ERS and ERE that require Sound Transit's Approval are noted in the replacement figures.	
3.4.1	Design Spectra Based on General Procedure	Derive Peak Ground Acceleration (PGA), Short Period Spectra Acceleration Coefficient (S_s) and Long Period Spectra Acceleration Coefficient (S_1) per Set 701 Geotechnical Engineering.	
3.4.3	Response Spectra Based on Site-specific Procedures	Use Site-Specified Procedure to develop design spectra of earthquake ground motions considering a 50% probability exceeding during the 100-year facility design life. The DOR must consider Near-Fault effect per Set 701 Geotechnical Engineering.	Use Site-Specified Procedure to develop design spectra of earthquake ground motions considering a 4 percent probability exceeding during the 100-year facility design life. The DOR must consider Near-Fault effect per Set 701 Geotechnical Engineering.
3.5	Selection of Seismic Design Category (SDC)	Design all structural in accordance with SDC C or D. Use Pushover Analysis to determine displacement capacity for both SDC C and D.	
3.6	Temporary and Staged Construction	The contract documents for temporary and staged construction must clearly indicate that structure is designed for reduced response spectra or show the Acceleration Response Spectrum used for design. See 721.3.21.7.	
4.1.2 / 4.1.3	Balanced Stiffness / Balanced Frame Geometry	The DOR must balance stiffness and balance frame geometry so to achieve the following limitations on the relative gap and angle movement between superstructure joints and rail stress: Maximum relative rotation about transverse axis at expansion joint: $\theta < 0.007$ rad. Maximum relative rotation about vertical axis at expansion joint due to lateral deflection: $\theta < 0.003$ rad. Axial rail stress limits: $\Delta\sigma = 24$ ksi. No complete closure is allowed at expansion	DOR must consider all techniques listed in Article 4.1.4 to satisfy Balanced Stiffness and Balanced Frame Geometry requirements for bridges in both SDC C and D. See 721.3.21.8 if these requirements cannot be satisfied.

AASHTO Article	Subject	ODE Requirements	MDE Requirements
		joints. Refer to 721.3.14 Rail Rotations and Stress Limits for additional information. Deviation from these requirements require approval from the Requirements Set 721 owner.	
4.2	Selection of Analysis Procedure to Determine Seismic Demand	Analysis Procedures: Procedure 1 (Equivalent Static Analysis): The DOR must not use. Procedure 2 (Elastic Dynamic Analysis): The DOR must use for all "regular" bridges with 2 through 6 spans and "not regular" bridges with two or more spans in SDC C or D. Procedure 3 (Nonlinear Time History): This procedure must only be used with the approval from the Requirements Set 721 owner. Use of this procedure must be in accordance with the guidance provided in 721.3.21.9	
4.9	Member Ductility Requirement for SDC C and D	Design must not allow in-ground hinging for drilled shaft and pile foundations. Ductility demand must not be greater than 1.0 in Superstructure.	Design may consider in-ground hinging upon the approval from the Requirements Set 721 owner. See 721.3.21.10 Ductility demand must not be greater than 1.0 in Superstructure.
4.11.1	Capacity Design	Foundation designs without full capacity protection must be approved by the Requirements Set 721 owner on a case-by-case basis. See 721.3.21.11	
4.13.1	Longitudinal Restrainers	Shock Transmission Unit (STU) may be considered where appropriate and must be subject to the approval of the Requirements Set 721 owner (or his/her representative).	
4.14	Superstructure Shear Keys	If transverse shear keys are used, they must be included in the analytical model. Design the Shear keys to remain elastic to resist the design force(s) for the level of earthquake under consideration except as described below. Breakaway (also called fusible or isolated) shear keys may be used for the MDE upon approval of the Requirements Set 721 owner (or his/her representative). The DOR may use the guidance provided in Caltrans Seismic Design Criteria (SDC) 2.0, Articles 6.3.4 and 6.3.5 on designing such shear keys.	
5.2	Abutment as Earthquake Resisting System (ERS)	Participation of abutment walls in the overall dynamic response of bridge systems during earthquake loading and in providing resistance to seismically induced inertial loads may only be considered in transverse direction. The DOR must not consider participation of the wingwall in the transverse direction in the seismic design of bridges.	
5.6.3	I_{eff} for Box Girder Superstructure	Use gross moment of inertia for box girder superstructure modeling.	
6.3.9	Foundation Rocking	The DOR must not use foundation rocking for the design of the structure for the ODE and the MDE.	
6.7.1	Longitudinal Direction Requirement	The DOR must exclude abutment contribution in longitudinal direction in Earthquake Resisting ERS. Although abutment soil resistance in the longitudinal direction is not permitted, knock-off (breakaway) backwalls may be considered in the MDE to limit other damage to the abutment upon approval from the Requirements Set 721 owner (or his/her representative).	
8.3.1	Seismic Design Categories B, C & D – Initial sizing of columns.	Perform initial sizing of columns using strength and service load combinations (Table 721-1).	
8.3.2	Force Demands for SDC's C & D	Seismic force demands must be per Extreme Event I in Table 721-1. The inertia effects of the LRV, without impact, with centrifugal, acting on one track only must be included in the dynamic analysis. The LRV mass must be the AW1 loading and must be considered acting along the centerline of track, at a height of 5 feet above the top of the low rail. Design must not consider the dynamic characteristic of the suspension system of the LRV in deriving the inertia effects of the LRV. To include this consideration in the dynamic analysis, the LRV can be modeled as a mass supported by (or attached to) the superstructure through a rigid link for both longitudinal and transverse direction. Where appropriate, the effects of the following considerations must be included: (1) the effects of continuous rails on distributing the longitudinal inertia force of the LRV to multiple bents, and (2) the limiting transferable forces between the LRV and the rails or between the rails and the superstructure.	

AASHTO Article	Subject	ODE Requirements	MDE Requirements
8.4.2	Reinforcing Steel Modeling	Maximum plastic strain of reinforcing steel must not exceed 0.005	Maximum plastic strain of reinforcing steel must not exceed the reduced ultimate tensile strain ε^R_{su} as defined in AASHTO Guide Specifications for LRFD Seismic Bridge Design Table 8.4.2-1
8.4.3	Prestressing Steel Modeling	For 250-ksi strands: $\varepsilon_{pp,EE}$ = 0.0076 For 270-ksi strands: $\varepsilon_{pp,EE}$ = 0.0086	Reduced ultimate prestress steel strain must be taken as the following: $\varepsilon^R_{ps,u}$ = 0.03
8.4.4	Concrete Modeling	Maximum unconfined concrete compressive strain must be limited to 0.0032	Ultimate unconfined concrete compression strain must be taken as equal to 0.005
8.6.7	Interlocking Bar Size	The longitudinal reinforcing bar inside the interlocking portion of column (interlocking bars) must be the same size of bars used outside the interlocking portion.	
8.8.2	Minimum longitudinal reinforcement	The DOR must use minimum longitudinal reinforcement of 1 percent of A_g for columns in SDC B, C, and D. The minimum longitudinal reinforcement in the shafts must be in accordance with Section 16.3 of “Drilled Shafts: Construction Procedures and LRFD Design Methods” (FHWA Publication No. FHWA-NHI-10-016). The clear spacing between longitudinal reinforcement of shafts must not be less than 6 inches. Design must provide longitudinal reinforcement for the full length of the shafts.	
8.8.3	Splicing of Longitudinal Reinforcement in Columns Subject to Ductility Demands for SDC C and D	The splicing of longitudinal column reinforcement outside the plastic hinging region must be accomplished using mechanical couplers that are capable of developing the expected tensile strength of the spliced bar. Splices must be staggered at least 2 feet. Design must not use lap splices. The DOR must clearly identify the locations where splices in longitudinal column reinforcement are permitted on the plans.	
8.8.10	Development length for Column Bars Extended into Oversized Pile Shafts for SDC C and D	Column longitudinal reinforcement in drilled shafts is typically straight. Embedment must be a minimum length equal to $l_{ns} = l_s + s$ (per TRAC Report WA-RD 417.1 titled “Noncontact Lap Splices in Bridge Column-Shaft Connections”) and the WSDOT BDM. Same size column-shaft must not be permissible.	
8.11	Superstructure Capacity Design for Transverse Direction (Integral Bent cap) for SDC C and D	For SDC C and D, the longitudinal flexural bent cap beam reinforcement must be continuous. Splicing of cap beam longitudinal flexural reinforcement must be accomplished using mechanical couplers that are capable of developing the expected tensile strength. Splices must be staggered at least 2 feet. Design must not use lap splices.	
8.12	Superstructure Design for Nonintegral Bent Caps for SDC C and D	Design must not use nonintegral bent caps for continuous concrete bridges in SDC C and D, except at the expansion joints between superstructure segments.	
8.16.2	Cast-in-Place Concrete Piles	The minimum longitudinal reinforcement in the shafts must be in accordance with Section 16.3 of “Drilled Shafts: Construction Procedures and LRFD Design Methods” (FHWA Publication No. FHWA-NHI-10-016). The clear spacing between longitudinal reinforcement of shafts must not be less than 6 inches. However, 5-inch minimum spacing may be considered for dry installation on a case-by-case basis as permitted by above FHWA publication.	

Figure 721-10: Permissible ERS

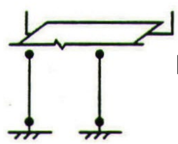
1 Longitudinal Response



Permissible As Noted

- Plastic hinges in inspect able locations
- Abutment resistance not required as part of ERS
- Knock-off backwalls permissible upon approval by Sound Transit Structural Engineer.

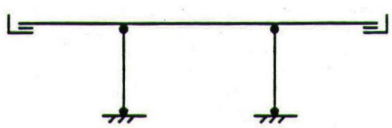
2 Transverse Response



Permissible As Noted

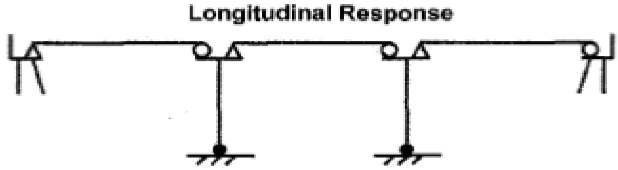
- Plastic hinges in inspectable locations
- Abutment not required in ERS,
- Breakaway shear keys permissible upon approval by Sound Transit Structural Engineer.

3 Longitudinal and Transverse Response



- Plastic hinges in inspectable locations
- Isolation bearings with or without energy dissipaters to limit overall displacements

Longitudinal Response

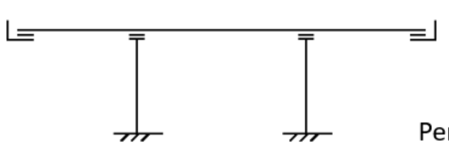


Permissible

4
- Multiple simply-supported spans with adequate support lengths
- Plastic hinges in inspectable locations

Longitudinal and Transverse Response

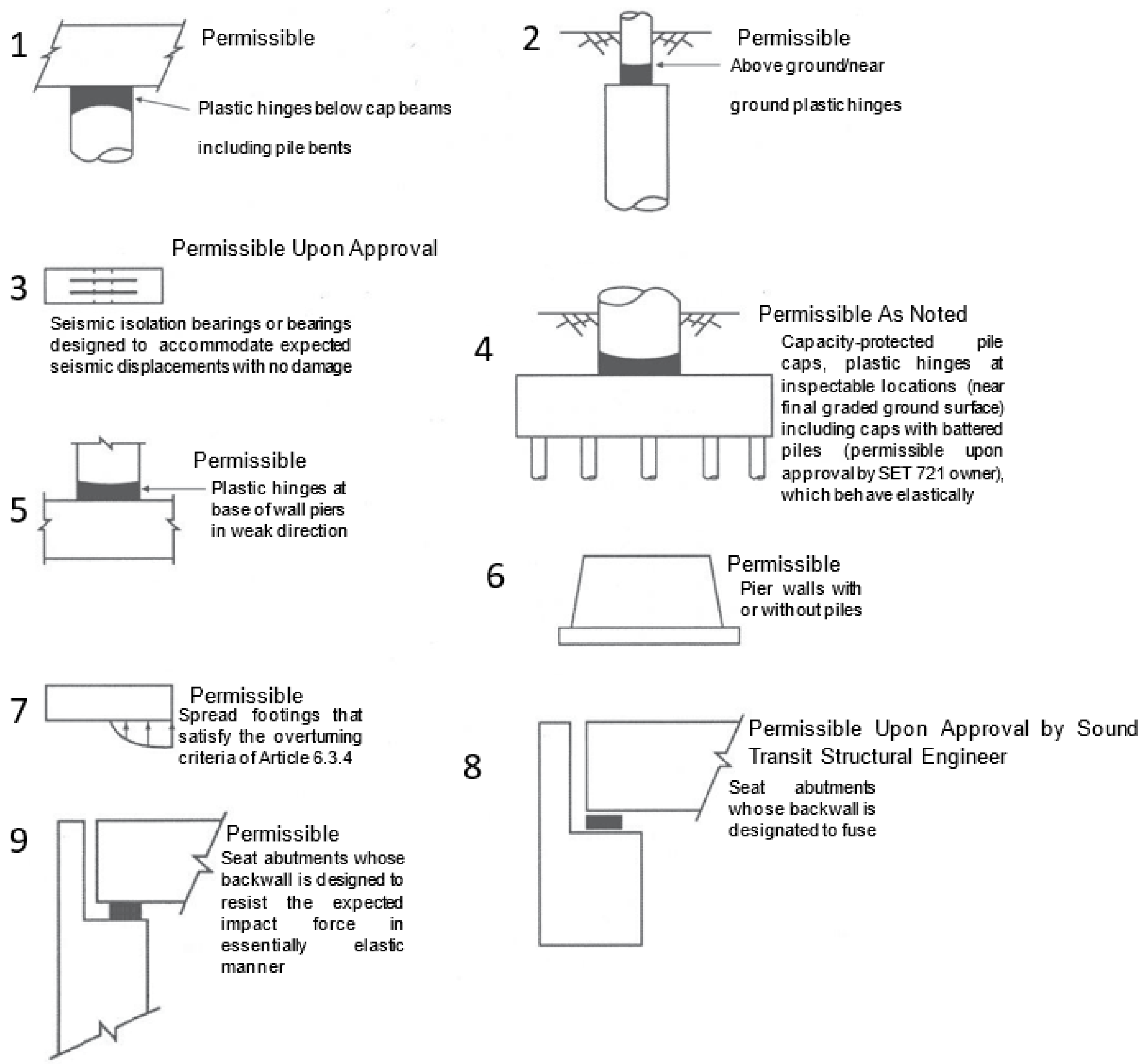
5



Permissible Upon Approval

- Isolation bearings accommodate full displacement
- Abutments not required as part of the ERS

Figure 721-11: Permissible ERE



721.3.21.5 Definitions of Conventional, Non-Conventional, Critical and Essential (Recovery) Bridges

721.3.21.5.1 Non-conventional bridges, also called "elevated guideway structures", (a term used synonymously with bridges in the DCM), with respect to seismic performance and design, are defined as bridges that seismically cannot be designed to conform to the AASHTO SGS using its capacity design limit-state approach. Such structures include, but are not limited to suspension bridges, cable-stayed bridges, longer-span extradosed bridges, arch-type bridges, including tied arches, longer-span segmental bridges, larger truss superstructure bridges, moveable bridges, and bridges not meeting the balanced-stiffness requirements. The outline below may be used to identify non-conventional bridges. Non-conventional bridges require seismic criteria that address the special character of the bridge type. Because Sound Transit's seismic criteria includes a two-level-hazard design approach with operational (ODE) and safety (MDE) performance objectives defined for each level, the SGS terms "critical" and "essential" in the SGS do not apply. Instead, individual non-conventional structures must be designed using criteria that address Sound Transit's tolerance for damage and repair costs following MDE design ground motion. Such criteria must be identified and approved by the Requirements Set 721 owner (or hi/sher representative) at the preliminary design phase. Combined elevated guideway and station structures where the SGS and ASCE 7 must be reconciled for seismic design, refer to Set 720 Building Structures. Separation between the structures must exceed the MDE displacements calculated with the square root of the sum of the squares procedure. Estimated differential settlement between the structures must be mitigated through site soil improvement, deep foundations, or grade beams between foundation elements. For bridges not meeting the balanced stiffness requirements of the SGS, refer to 721.3.21.8.

721.3.21.5.2 The outlined logic for identifying conventional versus non-conventional elevated structures with respect to seismic performance and design is as follows.

721.3.21.5.2.1 Is the structure type and capacity design-based seismic behavior explicitly covered by AASHTO SGS (for instance, a Type 1 GDS)? If "yes," use SGS filling in any minor criteria gaps. If "no," go to the next step.

721.3.21.5.2.1.1 Elevated guideway on conventional reinforced-concrete ductile piers.

721.3.21.5.2.1.2 Shorter span extradosed structures that meet GDS Type 1 behavior.

721.3.21.5.2.1.3 Shorter span segmental structures that meet GDS Type 1 behavior.

721.3.21.5.2.1.4 Isolated structures (gaps addressed with AASHTO isolation guide specifications).

721.3.21.5.2.1.5 Partially isolated structures (gaps addressed with AASHTO isolation guide specifications).

721.3.21.5.2.2 Structures not covered by AASHTO SGS because capacity design-based seismic behavior is not feasible for the structure – Project-specific criteria must be developed.

721.3.21.5.2.2.1 Cable-supported structure

721.3.21.5.2.2.1.1 Cable-stayed

721.3.21.5.2.2.1.2 Suspension

721.3.21.5.2.2.1.3 Longer-span extradosed structures

721.3.21.5.2.2.2 Arch structures

721.3.21.5.2.2.3 Longer-span segmental structures

721.3.21.5.2.2.4 Larger truss superstructures, particularly continuous trusses

721.3.21.5.2.2.5 Moveable bridges

721.3.21.5.2.2.6 Structures not meeting the SGS Balanced Stiffness requirements

721.3.21.5.2.3 Alternate delivery contract? (For example, Design-Build)? If "yes:"

721.3.21.5.2.3.1 Sound Transit develops additional project criteria or design methodology beyond that contained in the SGS as specified in the request for proposal stage.

721.3.21.5.2.3.1.1 Clear performance criteria

721.3.21.5.2.3.1.2 Identification of gaps to be addressed

721.3.21.5.2.3.1.3 Structural design peer review or independent check required

Commentary: This commentary is to provide further clarifications on the definition of Conventional, Non-Conventional, Critical, and Essential (Recovery) Bridges.

Commentary: Non-Conventional versus Conventional Bridges: Most of Sound Transit's conventional elevated guideway (aerial) structures can be designed using the seismic design approach outlined in the AASHTO SGS approach without significant changes for the MDE. In the sense that the term "bridges" is used in the DCM, the term is synonymous with aerial or elevated structures. For non-conventional bridge types that are not covered by the SGS, project-specific criteria must be developed to address the physical ability of such bridge types to resist lateral loading with response appropriate for the special characteristics of the bridge type. In many cases, this means that response in the MDE will be limited to less inelastic action than conventional bridges are permitted to experience. Many non-conventional bridge types simply cannot endure the significant inelastic substructure response that smaller, simpler bridges can withstand. For example, a cable-stayed structure is not likely able to endure full plastic hinging at the base of the pylons; therefore, the strain levels permitted in the pylon may only permit minor inelastic deformations, if any. Additionally, such non-conventional structures may be controlled by other loadings (e.g., wind) instead of seismic loading, and this further complicates design methodologies that pre-suppose that seismic loading controls.

Commentary: An outline, provided above, uses a high-level decision process to determine whether a bridge is non-conventional or not and whether project-specific criteria or additions to the SGS are needed. At a more detailed level, this process requires the engineering team to clearly identify the seismic load resisting system using the conceptual framework of the ERS and ERE as outlined in the AASHTO SGS and as modified by this DCM. The SGS is based on bridge types that can develop a full plastic mechanism in its substructure under seismic lateral loading (Type 1 GDS) or types that can tolerate seismic loading and displacements using seismic isolation techniques (Type 3 GDS). A non-conventional bridge will typically fall outside of the systems and elements described in the SGS. However, some bridges that classify as non-conventional in the outline provided may be able to be designed using the SGS with additional criteria that reconcile the bridge type with the capacity design approach provided in the SGS.

Commentary: In earlier versions of seismic design criteria and scope of specification coverage, dimensions were often listed as objective criteria to determine whether the bridge fell within the scope of the specifications. Span lengths beyond which the specifications should not be applied are an example. However, in recent years, the industry trend has been to use behavior rather than hard dimensions to delineate applicability of the specifications, and that is the approach taken in this manual, as described in the following paragraphs. The outline provided includes qualitative terms, such as "longer-span" in reference to various structures, and the use of this term is meant to address two possible attributes of structures. One attribute relates to elevated structures whose spans become sufficiently long that the substructure supports high amounts of gravity load and can no longer be designed to sustain inelastic action that can be controlled by capacity design principles as the SGS outlines. Another attribute relates to elevated structures whose proportions are such that the superstructure is too flexible or otherwise unable to restrict inelastic action to the substructure. The delineation between where capacity design as outlined by the SGS applies and where capacity design cannot be met depends on a number of variables and details that elude a simple outline or table. Therefore, the logic of where a bridge becomes "non-conventional" depends more on seismic behavior and less on absolute dimensions.

Commentary: Bridge types not covered by the SGS will require the engineering team to define ERS and ERE that are not provided currently in the SGS. Additionally, bridge types that cannot develop a full plastic mechanism or are constrained by performance limits to limit plastic behavior should have their own, project-specific lateral system and design objective for that system clearly defined. Criteria definition must outline where limited inelastic damage is permitted within the structure and where no damage should occur in the structure. Definition of permitted location and limits on inelastic response will control member proportions and design of the bridge such that the seismic performance of the bridge should be as the designer intends. Bridge-type-specific criteria avoids simply meeting a set of code-based design requirements that may not rationally apply to a non-conventional structure.

Commentary: Additionally, bridges that include additional damping devices, such as but not limited to isolation bearings acting in tandem with plastic hinging of columns, will need additional project-specific criteria beyond what the SGS provides. This type of structure, known as a partially isolated structure, is a hybrid ERS type, which could reasonably blend the SGS with the Seismic Isolation Guide Specifications. Another type of bridge that can typically use criteria in tandem with the SGS is truss-superstructure bridges. Normally, inelastic action can be restricted to the substructure, but the superstructure may require additional criteria beyond the SGS to ensure that capacity protection is effective and to account for the dynamic response and deformations of the truss, particularly for larger trusses.

Commentary: Another aspect of bridge types that do not fit the basis of the SGS (i.e., development of a full plastic mechanism and the associated capacity protection of elements that are not intended to behave inelastically) is that capacity protection may not be appropriate. The requirement for capacity protection may be waived if advanced analysis, such as NLTHA is used to evaluate the expected damage level in the full system and if a complete plastic mechanism is not anticipated in the MDE. Such analysis must assess all potential nonlinear damage locations by including analytical elements that can model damage. Often such damage will be limited to low inelastic-strain performance. Due to the probabilistic nature of material strengths and member configuration, the designer must consider and demonstrate that inelastic action will not occur in unintended locations in the MDE. This potential waiver also recognizes that the MDE has a low probability of occurrence at 4 percent in 100 years (2,500-year return period) and that typically, bridges designed using this approach have limitations on damage due to both the bridge's operational classification and structure type.

Commentary: Non-conventional bridges often represent a significant investment by Sound Transit and, therefore, the likelihood of significant repair costs and down time following a large earthquake should be considered in the development of the project-specific criteria. Whereas conventional structures may be designed such that structural collapse is avoided in the upper-level (MDE) seismic event, thus preserving life safety, a large non-conventional structure may warrant more restrictive design criteria simply to preserve the structure's investment value and help ensure subsequent re-use of the bridge following a major seismic event. This subjective evaluation cannot be established as a global design criterion but must be made by Sound Transit on a project-specific basis.

Commentary: Additional useful guidance may be found in the recently published AASHTO Guidelines for Performance-Based Seismic Design of Highway Bridges (PBSD Guidelines).

Commentary: Critical and Essential (Recovery) Bridges: The AASHTO operational classifications of Critical, Essential (Recovery in the PBSD Guidelines), and other bridges are based upon the facility's availability for emergency vehicle use, security/defense use, or all vehicle use. Because the Sound Transit elevated guideway structure is part of a continuous light-rail system that may not be operable after a large seismic event, such as the MDE, there is little need for an individual bridge in the system to be available for immediate use. Therefore, the designations of critical and essential (recovery) do not have the same significance that they would in a redundant highway network where post-earthquake use of a bridge would be possible from a variety of surface roadways.

Commentary: Furthermore, Sound Transit uses a two-level seismic design approach where the ODE defines structural operability post-earthquake for a lower-level event. All bridges in the Sound Transit system are required to meet the performance objective for the ODE; thus, no one bridge is classified above or below other bridges for purposes of the ODE.

Commentary: However, non-conventional bridges are often major structures that represent a significant investment for the region and Sound Transit. Therefore, the ability of a major structure to be inspected, repaired, and returned to service in a short time frame is still an important consideration for the agency. Replacement of a major structure could take many years and take longer than the replacement of smaller structures. For these reasons, major structures may be designated by Sound Transit as Critical or Essential (Recovery).

Commentary: Thus, from an economic perspective, non-conventional major bridges should be considered for conservative seismic design criteria that would lead to minor but repairable damage following an MDE-type earthquake. Such criteria would limit material strains such that future use after a large earthquake would be feasible. Using the approach in the PBSD Guidelines, non-conventional major bridges would be designed as "Recovery" bridges, with Performance Level 3 – Fully Operational performance in the ODE and Performance Level 2 – Operational performance in the MDE. In accordance with the PBSD Guidelines, project-specific criteria appropriate for the non-conventional bridge type would still need to be developed and specified.

Commentary: The third category in the outline, which focuses on project delivery, is included to reinforce the idea that the requirements that are included in an alternative delivery procurement of a structure must address performance criteria and the development of project-specific seismic criteria that are commensurate with the types of structure anticipated and allowed in the project.

721.3.21.6 Seismic Isolation

721.3.21.6.1 The DOR must design seismic isolation ERS in accordance with the AASHTO Guide Specifications for Isolation Design, and in addition to the requirements of that guide specification, the design must meet the operational requirements of the ODE, including operability of rail systems and other systems that cross the movement joints. These considerations will require project-specific criteria, along with the designer's justification for use and subsequent approval from the Requirements Set 721 owner for use.

Commentary: Seismic isolation technology may offer performance advantages for the MDE, such as reducing or eliminating damage to the substructure, but isolation element use may also pose problems for rail and other systems that cross the movement joints where the isolated structure transitions to non-seismically isolated structure or track. In as much as forces in the superstructure and substructure are reduced when using isolation technology, the interface displacements increase. The DOR must carefully consider how such seismically isolated systems can address both ODE and MDE performance. Isolation with trackwork crossing relatively large-movement interfaces will require project-specific criteria.

721.3.21.7 Staged Construction and Temporary Structures

Commentary: The extent to which earthquake loading is considered during construction can vary considerably. Traditional contracts treat construction-phase earthquakes as force majeure events (i.e., extreme and unforeseeable). As such, the Contractor provides no seismic design of temporary works. In order to mitigate that risk, recent large projects have specified a construction earthquake for the Contractor to design temporary and staged works against. Selected examples follow.

i. *The East Span of the San Francisco to Oakland Bay Bridge was "designed to resist an equivalent static loading of 0.1g for configurations occurring under the assumed construction sequence" (CalTrans, 2001).*

ii. *Temporary and staged construction of the Gerald Desmond Bridge was designed using a spectrum based on a 10 percent probability of exceedance in 10 years" (CalTrans, 2011).*

iii. *Temporary and staged construction of California High Speed Rail Construction Package 2-3 was designed using the greater of 125 percent of the specified Operating Basis Earthquake, OBE (to approximate a 75-year return period), or the OBE spectra scaled to a 0.1 g peak ground acceleration (California High Speed Rail Authority, 2014).*

Commentary: In recent years, codes have sought to formally incorporate construction-phase earthquakes. For example, Article 3.6 of the AASHTO Guide Specifications for LRFD Seismic Bridge Design requires *temporary structures in place for more than five years be designed as if they were permanent structures. Conversely, temporary structures in place less than five years can be designed using a reduced acceleration response spectrum, by dividing the 1,000-year spectra by a factor of up to 2.5 (up to a 60% reduction).*

Commentary: The WSDOT BDM adopts Article 3.6 of the AASHTO guide specification and clarifies that temporary bridges are not required be to designed against liquefaction. Furthermore, WSDOT adopts the associated commentary wherein the seismic design criteria for temporary and staged construction must be included in the contract documents.

Commentary: A potential shortcoming of each approach described above is it results in an inconsistent risk exposure. If earthquake events are assumed to follow a Poisson distribution, a probabilistic approach could be taken to arrive at the return period for a risk-consistent construction earthquake:

$$RP = -\frac{W}{\ln(1-PE)}$$

Where:

RP = earthquake return period, years

W = construction exposure window (or design life), years

PE = probability of exceedance, decimal

Commentary: Sound Transit designs MDE for the ground motions considering a 4 percent probability exceeding (PE) during the 100-year facility design life. It is rational to assume a PE no less than this value and the same performance objective of Life Safety and Collapse Prevention for seismic design within a given construction window.

Commentary: The Poisson equation reveals the ratio of RP to W is a constant, as reflected in Table 721-4, which lists risk-consistent (i.e., 4 percent probability of exceedance) construction earthquake return periods for varying construction windows. The ODE (150-year event) is consistent with a six-year construction window. To clarify, if the ODE was defined as the de facto construction earthquake, it would be conservative (relative to the scaled MDE) up to a six-year construction window, and not conservative thereafter. Note that Sound Transit requires to design a temporary structure as a permanent structure if the construction window is longer than five years.

Commentary: In application, the DOR would choose to either use ODE for a construction window that is not longer than five years or adopt a third design earthquake, and the contract would specify the maximum construction window and provide the associated construction earthquake return period and acceleration response spectra. The designer would design the temporary works using the contract-specified construction acceleration response spectra. For example, if the contractor commits to a shorter construction window, they could conceivably be allowed to design to an earthquake with 100-year return period while preserving the 4 percent probability of exceedance. In so doing, risk-consistency is maintained in the seismic design of temporary works.

Commentary: It should be noted that the construction window is not the same as the contract duration. The construction window is the length of time a particular temporary work is in service, whereas contract duration typically begins at notice-to-proceed and ends at substantial completion. To avoid confusion, the construction window would require careful definition in the contract.

Commentary: Additional considerations for the construction earthquake include analysis methods and liquefaction. It would seem reasonable to limit the analysis to response spectrum and equivalent static analyses (depending on structure type) and to not consider liquefaction (similar to the WSDOT approach). Sound Transit can always require more stringent analyses on a case-by-case basis, depending on the complexities of the projects.

721.3.21.7.1 If the service life of a temporary shoring system is one year or less, the shoring system design need not consider seismic loading. Similarly, the design need not mitigate geologic hazards such as liquefaction, for temporary shoring systems with a service life of one year or less.

721.3.21.7.2 For temporary structures expected to be in service between one and five years, the DOR must design the temporary structures for the ODE event or for the construction earthquake that is corresponding to the specified construction window as shown in Table 721-5. The DOR should consider potential delays to construction that may lengthen construction duration, in which case designing for a higher return period earthquake may be appropriate. Use linear interpolation to find the construction earthquake return period when other construction windows are specified. The contract plans must show the Acceleration Response Spectrum (ARS) used for design. The design doesn't require liquefaction assessment unless otherwise specified.

Table 721-5: Risk-consistent Construction Earthquake Return Periods

Construction Window (years)	Construction Earthquake Return Period (years)
1	25
2	50
3	75
4	100
5	125

721.3.21.7.3 For any temporary structure that is to remain in service beyond five years, the DOR must design it as a permanent structure.

721.3.21.7.4 The requirements apply to each key stage of bridges constructed in stages.

721.3.21.7.5 These requirements also apply to tunnels and buried stations.

721.3.21.8 Balanced Stiffness and Balanced Frame Geometry Requirements

721.3.21.8.1 When the requirements of AASHTO Guide Specifications, Article 4.1.2 or 4.1.3 cannot be met, the DOR must satisfy these requirements in numerical order, and the Requirements Set 721 owner (or his/her representative) must approve each step before moving to the next step. As the DOR proceeds through the following steps, they must follow the modeling approach described in Article C4.1.3. If the structure meets the requirements of a particular step, then further steps do not require evaluation. All references to "Articles" are to those of the AASHTO Guide Specifications.

721.3.21.8.1.1 The DOR must show that the structure meets AASHTO Guide Specifications Article 3.1, "Applicability of the Guide Specifications." If the structure does not meet the criteria, then the DOR must develop project-specific seismic design criteria for review by the Sound Transit Structural Manager. These balanced-stiffness-and mass requirements only apply to Type 1 systems as listed under Article 3.3 and only to bridges with reinforced concrete substructures. The DOR must include the following modifications to the AASHTO Guide Specifications: the prequalifier to Equation 4.1.2-1 to read, "Constant width and constant mass frames", the prequalifier for Equation 4.1.2-2 to read, "Variable width or variable mass frames", modify the prequalifier to Equation 4.1.2-3 to read, "Constant width and constant mass frames:", the prequalifier for Equation 4.1.2-4 to read, "Variable width or variable mass frames:"

721.3.21.8.1.2 The DOR must, at a minimum, use Procedure 2: Elastic Dynamic Analysis (EDA) as outlined in Article 5.4.3. The DOR must check that local displacement demands against capacities using the nonlinear static procedure of Article 4.8.2, regardless of Seismic Design Category (SDC). The DOR must construct the EDA model using the actual three-dimensional geometry of the bridge. Spine models are permitted for determining seismic displacement demands.

721.3.21.8.1.3 The DOR must provide calculations for all the techniques of Article 4.1.4 of the AASHTO Guide Specifications demonstrating that Articles 4.1.2 and/or 4.1.3 cannot be met.

721.3.21.8.1.4 If the stiffness ratio is less than 75 percent between adjacent bents or columns as defined in Article 4.1.2, but otherwise complies with that article and with Article 4.1.3, then the following limits apply. The DOR must demonstrate compliance in the calculations using these reduced limits, which apply to the entire frame.

721.3.21.8.1.4.1 The DOR must use displacement capacities for all inelastic elements limited to 90 percent of that otherwise permitted by the AASHTO Guide Specifications and determined by the nonlinear static procedure of Article 4.8.2.

721.3.21.8.1.4.2 The DOR must meet the P-Delta requirements defined by Article 4.11.5, but is limited to 90 percent of that permitted by the article.

721.3.21.8.1.4.3 The ductility limits for SDC D must apply also to SDC C, and the DOR must use the ductility limits for both SDC C and SDC D reduced to 90 percent of that otherwise permitted.

721.3.21.8.1.4.4 The DOR must increase the support lengths as determined by the requirements of Article 4.12 by 1/0.90 of AASHTO SGS prescriptive values, and the DOR must increase joint widths with the same increase applied to calculated displacements or find alternative methods in reducing the stiffness.

721.3.21.8.1.5 If the stiffness ratio is less than 50 percent as defined in Article 4.1.2 or the fundamental period ratio is less than 70 percent as defined in Article 4.1.3, then the following limits apply, provided the stiffness ratios are greater than or equal to 0.25 and the period ratios are greater than or equal to 0.5. The DOR must demonstrate compliance in the calculations using these reduced limits, which apply to the entire frame.

721.3.21.8.1.5.1 The DOR must use displacement capacities for all inelastic elements limited to 75 percent of that otherwise permitted by the AASHTO Guide Specifications and determined by the nonlinear static procedure of Article 4.8.2.

721.3.21.8.1.5.2 The DOR must meet the P-Delta requirements defined by Article 4.11.5 but limited to 75 percent of that permitted by the article.

721.3.21.8.1.5.3 The ductility limits for SDC D must also apply to SDC C, and the DOR must use the ductility limits for both SDC C and SDC D reduced to 75 percent of that otherwise permitted.

721.3.21.8.1.5.4 The DOR must increase the support lengths as determined by the requirements of Article 4.12 by 1/0.75 of AASHTO SGS prescriptive values, and the DOR must increase joint widths with the same increase applied to calculated displacements or find alternative methods in reducing the stiffness.

721.3.21.8.1.6 If the DOR cannot satisfy criteria of any of the previous steps, then the DOR may change analytical approach and perform “direct displacement-based design” (DDBD) as outlined in detail in Priestley, et al. (2007) and as included in the Appendix A of NCHRP Report 949. In Priestley, et al., Chapter 3 outlines the fundamentals of the method, Chapter 10 addresses bridge design. The DOR must use “thin Takeda (TT)” hysteresis and tangent-stiffness damping. The reduced limits outlined in 721.3.21.8.1.4 and 721.3.21.8.1.5, do not apply in this step. All limits may be reset to the AASHTO SGS limits for this step. This effort must also be accompanied by peer review (refer to the pending peer review requirements).

721.3.21.8.1.7 If the DOR cannot satisfy criteria of any of the previous steps, then the DOR must perform NLTHA as a verification check of the proposed design. The DOR must develop for review and approval by Requirements Set 721 owner (or his/her representative) a project-specific seismic analysis plan and basis of design, and this effort must also be accompanied by peer review (refer to the pending peer review requirements). All limits may be re-set to the AASHTO SGS limits for this step.

Commentary: A flowchart of the steps listed in the requirements is provided in Figure 721-12. This methodology only applies to bridge/guideway structures with an earthquake resisting system based on inelastic plastic hinging of substructure elements and elastic capacity protected superstructures. The approach is not appropriate for other types of structures, such as cable-supported or arch structures, where the substructure typically remains essentially elastic.

Commentary: The balanced-stiffness requirements in AASHTO were originally developed by Caltrans to mitigate adverse performance associated with unusual geometry, stiffness, or mass distributions in bridges.

Commentary: The behavioral objectives for the balanced stiffness requirements include reduction in pounding between frames, relative inelastic displacements between columns, relative displacements between frames, and torsion about a vertical axis which can unseat spans. These behavioral objectives can seem removed from the balanced-stiffness requirements, making the requirements seem arbitrary.

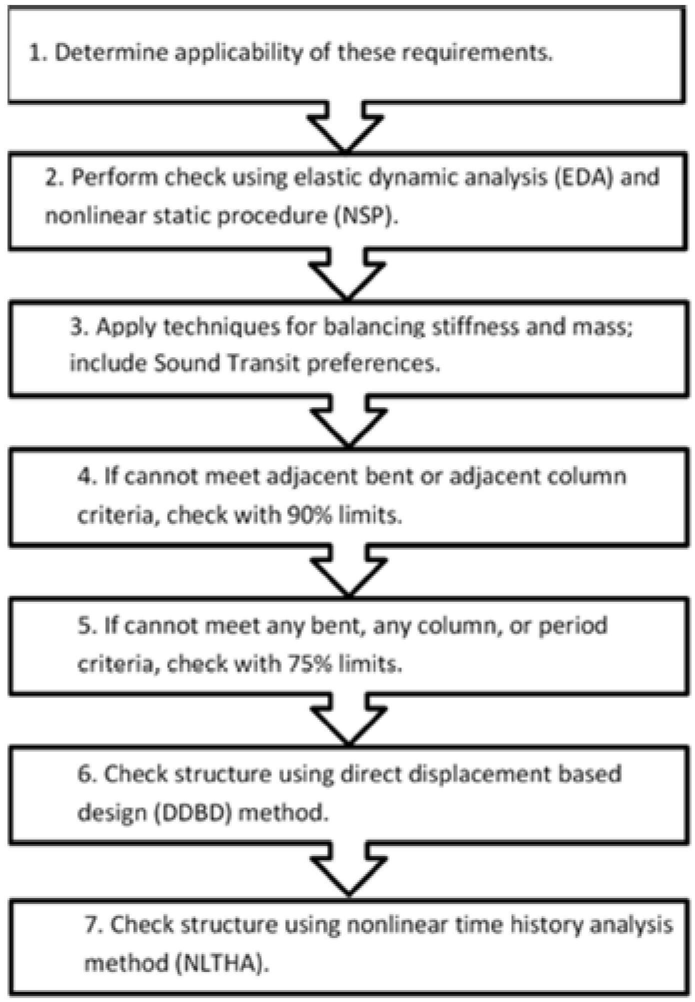
Commentary: When it is not possible to meet the balanced-stiffness requirements, it is necessary to address the behavioral objectives for which the requirements exist and check relevant response parameters, rather than addressing the requirements themselves. This is the focus of 721.3.21.8.1.4 to 7.21.3.21.8.1.7 of the requirements, provided above.

Commentary: Understand that designers typically rely on a fully elastic analytical model to estimate the actual inelastic response of the bridge. Standards allow significant damage to bridge substructures, inelastic action, under the MDE loading. This approach works well when the actual bridge response is similar to the elastic model response, such as when inelastic demands are low and the distribution of stiffness and mass in the bridge is nearly uniform. However, when unbalanced stiffness or mass conditions are present and significant, internal redistribution of inertial forces may occur relative to those predicted by the fully elastic model. Additionally, unbalanced structures may develop seismic displacement profiles that are not predicted by the fully elastic model, which can lead to unwanted and unanticipated seismic response.

Commentary: For the reasons given in the commentary sections above, strategies for designing bridges with unbalanced stiffness and/or mass must follow one of two approaches: (1) Develop more conservative designs as required by 721.3.21.8.1.4 and 721.3.21.8.1.5 above, or 721.3.21.8.1.2. (2) Use analytical tools that are better suited to estimate the inelastic forces and displacements. 721.3.21.8.1.6 and 721.3.21.8.1.7 follow this path.

Commentary: The DDBD method estimates the unbalanced structure displacements and internal forces carried by various inelastic substructure elements more accurately than the “equal displacement” method included in the AASHTO Guide Specification. This is the Priestley et al. (2007) preferred method of addressing inelastic response as estimated using elastic response. The method may be included in elastic multi-mode dynamic analysis; however, iteration of the model will be required to obtain appropriate stiffnesses and damping ratios. Note that this method may predict displacements larger than the Caltrans or AASHTO method because tangent-stiffness damping is used. This type of damping is generally accepted as a better damping model to use.

Figure 721-12: Flowchart for checking adequacy of structures that do not meet the balanced stiffness and balanced frame geometry requirements of the AASHTO Seismic Guide Specifications



Commentary: Where the conventional AASHTO analysis methods use elastic dynamic-analysis models based on initial (first-yield) stiffnesses of the bridge substructure with five percent assumed damping, the DDBD method uses a secant stiffness method with adjusted damping. The secant stiffness is indicative of the inelastic column stiffness calculated using the shear force in the column at the maximum displacement, not first yield. This is a more flexible system than one based on first-yield stiffness. The increased damping is indicative of energy dissipated by inelastic action and is typically greater than five percent. These attributes of the DDBD model provide an alternate and more realistic method for calculating inelastic displacements and for assessing the internal forces experienced by the actual bridge.

Commentary: In addition to modeling the bridge structure itself, the estimates of the foundation-soil stiffness are included. These stiffnesses are also represented with secant stiffness in either the AASHTO method or the DDBD method. While seeming contradictory, this is simply a function of the approach that each method uses to estimate inelastic bridge displacements.

Commentary: The other analytical tool used to estimate inelastic dynamic response of bridges is the NLTHA method. This is the most rigorous method for determining inelastic bridge response due to earthquake loading. It can always be used to provide accurate response estimates, but the method requires more input *data, including acceleration or displacement histories, member hysteresis models, and other information that make this potentially cost prohibitive and a time-consuming alternative.*

721.3.21.9 Guidance for Use of Seismic Time History Analysis

721.3.21.9.1 When time history analysis is used for structural performance assessment, the provisions of the AASHTO Guide Specifications for LRFD Seismic Bridge Design (SGS) Article 5.4.4 must be followed. Additional guidance is included in the AASHTO Guidelines for Performance Based Seismic Design of Highway Bridges and its companion NCHRP Research Report 949 (PBSD Guidelines). This guidance is mandatory, and subject to the approval of the Requirements Set 721 owner (or his/her representative) for the project and will take precedence over the SGS provisions where conflicts occur.

721.3.21.9.2 The AASHTO SGS must be augmented to address the lower-level ODE event. The bridge is expected to perform “without significant structural damage.” Therefore, either Linear Elastic Time History Analysis or Response Spectrum Analysis may be appropriate for ODE analysis if the structure and affected soil responds essentially elastically. For the MDE, NLTHA is required for the structural and foundation analysis.

721.3.21.9.3 When NLTHA is used for non-conventional bridges, the Article MDE performance objective may be more stringent than AASHTO SGS because the SGS is based upon ordinary bridges. The PBSD Guidelines provides for two-level design performance objectives. Unless directed otherwise by Sound Transit, the criteria for the “Recovery” Operational Category must be used. Where NLTHA is used on conventional bridges, the criteria for the Ordinary Operational Category may be used only with the approval from the Requirements Set 721 owner.

721.3.21.9.4 When NLTHA is used, a seismic analysis plan must be developed and subject to the review and approval of the Requirements Set 721 owner (or his/her representative). Both the Geotechnical and Structural Engineers of Record must be responsible for the plan.

721.3.21.9.4.1 The seismic analysis plan must address all NLTHA aspects, including geophysical, geotechnical (including soil-structure interaction), and structural analysis features and constraints. This includes the development of the regional hazard if not code-based (source characterization; ground motion prediction equations; decision tree weighting factors), consideration of near-fault effects, consideration of fault-rupture effects, consideration of basin effects, determination of target response spectra (including conditional mean, source-specific, and vertical as appropriate), selection of seed time histories, method of spectral matching and acceptance, method of confirming rotational independence, method for modelling soil and rock constitutive behavior (including excess pore pressure effects, hysteretic damping, and radiation damping), method for establishing boundary conditions, and method for computing free-field ground motions used to excite structural response.

721.3.21.9.4.2 Structural modeling items appropriate for the site and consistent with the type of bridge and foundations include the types and location of structural nonlinearity to be used in the model, the type of structural model (spine, grid, shell, solid), the approach to inclusion of damping, the approach for consideration of rail/trackwork-bridge interaction, the concurrent non-seismic loads, the mass confirmation approach, the range of model variations to be investigated, the proposed method of tracking and presenting results, the method for demand vs. capacity assessment (including average vs. maxima, assessment internal to model vs. post-processed assessment), the proposed interpretation strategy for reasonableness (individual direction analysis followed by full three-dimensional analysis, comparison with other models, etc.).

721.3.21.9.4.3 The seismic analysis plan must outline the specific quality assurance and quality control procedures to be used to ensure reasonable results of the NLTHA.

721.3.21.9.4.4 The seismic analysis plan must include software validation. Validation may include vendor-supplied benchmarking but must include project-specific benchmarking against other known or calculated solutions, including parametric studies to determine sensitivities.

721.3.21.9.5 Sound Transit will require an independent Peer Review performed by an expert panel for NLTHA. Sound Transit must approve the expert panel participants and based on the project, may contractually engage the panel. For alternative delivery projects, such as design-build, Sound Transit may elect to have the contractor contractually engage the expert panel and will impose conditions on the Contractor to ensure their independence.

721.3.21.9.6 Final NLTHA results, interpretations and conclusions must be documented in reports and are subject to the approval of the Requirements Set 721 owner (or his/her representative). Key response results, including anticipated damage locations and damage levels, must be documented in the reports, and added to the project documents.

721.3.21.9.7 An independent peer review must be performed for any non-conventional structure for all aspects of the design. Independent structural design checks and software verification are required for a quality control and quality assurance program when using NLTHA.

Commentary: NLTHA are assessment tools used to confirm adequate performance of a proposed design. NLTHA requires specialized software to quantify nonlinear phenomena important for the structure and project. Example nonlinear effects are inelasticity due to extreme seismic events and geometric nonlinearities where internal forces are a second-order function of member deformations. Cable-supported structures and tall slender structures typically require direct consideration of geometric nonlinearities. Not all structural software can address all nonlinearities. Accordingly, expertise and experience with a particular software is essential.

Commentary: As a practical matter, geotechnical considerations that are structure-independent can be housed in a stand-alone document. For example, if a project-specific probabilistic seismic hazard assessment is conducted, those items could be placed in a separate document that is cited by or appended to the seismic analysis plan.

Commentary: Selection of the appropriate software must consider which nonlinearities the software can and cannot handle, as well as the solving algorithm's ability to reliably converge to a solution. For these reasons, it is not possible to simply provide a list of acceptable software packages that may be used. Through the seismic analysis plan, the DOR must identify and qualify the project-specific software to be used.

Commentary: If the chosen software is unable to address all nonlinear behavior important to structural performance, then parallel analyses using a different software package must be made to bound predicted behavior. Bounding may also be achieved using the same software with different input data. Exploring ranges of behavior and using bounding analyses is an effective way to better understand structural performance.

Commentary: One challenge of NLTHA is the voluminous amount of output data can make it difficult to interpret the results in a meaningful way. For example, running three simultaneous directions of input histories into a complex model may produce response outputs that are difficult to interpret and validate. Thus, intermediate steps such as using a single direction of input histories is a useful way to build confidence in the results and determine whether the structural response is reasonable or not.

Commentary: The selected software and model configuration must be able to represent both the expected structural and geotechnical response. For example, the pre-determined mechanisms of inelastic behavior are the only locations warranting inelastic modeling. The other elastically modeled elements need to be checked to ensure that they are not strained into the inelastic range. Furthermore, if pre-determined mechanisms of inelastic behavior are widely distributed, then the entire bridge may require inelastic elemental modeling. Depending upon the bridge specifics, the level of modeling rigor can vary when using NLTHA.

Commentary: Nonlinear input data for NLTHA can be more complex than for standard elastic analyses and requires significant time and effort to develop and validate. Elastic input data for common structural components is reasonably well defined within AASHTO SGS and the PBSD Guidelines. However, defining inelastic input such as member hysteretic behavior requires more rigor. Geotechnical input data is typically site-specific and requires significant field exploration, laboratory testing, and interpretive effort to define.

Commentary: Another critical input modeling parameter is material damping. The PBSD Guidelines provide important guidance on damping within NLTHA. The assumption that a constant level of material damping (e.g., five percent of critical) is valid for all time steps and deformation stages of the structure is known to be erroneous and can lead to underprediction of structure response.

Commentary: As structures incur significant concentrated inelastic response and plasticity, damping at regions remote from the inelasticity can trend towards zero or a very low value. This occurs when a plastic mechanism forms and adjacent regions tend toward rigid body movement and thus lowers material damping.

Commentary: When NLTHA is used, Sound Transit may seat an Expert Panel, who is intended to guide Sound Transit in review of the proposed project-specific software and modeling techniques to help ensure an appropriate and reasonable solution is reached. Parallel assessments, independent structural design checks, and software verification are all necessary parts of a practical quality assurance program when using NLTHA.

721.3.21.10 In-ground Plastic Hinging

721.3.21.10.1 In-ground plastic hinging is not permitted except under the special MDE load case that includes liquefaction-induced lateral spreading. In such cases, and upon approval by the Requirements Set 721 owner, the localized (equivalent cantilever versus entire system) displacement ductility demand must be limited to no greater than 4. Strain limits for confined concrete and reinforcing steel must be as outlined for AASHTO Articles 8.4.2 and 8.4.4 in this table. In-ground plastic hinging lengths must be established in accordance with AASHTO SGS, Article 4.11.6 and must be specified on a project-specific basis considering the soil properties and stratigraphy conditions of the site.

721.3.21.10.2 Where in-ground plastic hinging is expected in the foundation elements, a nonlinear static procedure (pushover) must be used to substantiate the displacement capacity and ductility limit compliance of the foundation. Compatible soil and structural deformations, equilibrium, and associated constitutive properties must be enforced. Both structural and geotechnical Engineers of Record must coordinate their teams to achieve this compliance. Conservative bounding may be used. Capacity protection of non-yielding elements is required when in-ground inelastic response is expected, just as with plastic mechanisms that correspond to load cases that do not involve lateral soil movement. Independent peer review, as discussed elsewhere in this set, is required. Where in-ground plastic hinging is anticipated in the foundations under MDE ground motions, instrumentation as described in the commentary must be installed.

721.3.21.10.3 Alternatives to reliance on in-ground plastic hinging to accommodate lateral soil movement must be considered. Site ground improvement may be used in conjunction with reliance on in-ground plastic hinging, or site improvement alone may be used.

721.3.21.10.4 Feasibility, cost, and structural performance must be included in such study of alternatives for accommodating or eliminating permanent lateral ground movement. The selected design approach must be submitted to the Sound Transit Set 721 owner for approval.

721.3.21.10.5 Deep foundations designed with in-ground plastic hinging must be accompanied by permanent instrumentation so that Sound Transit can confirm post-earthquake performance. The DOR must use the strain and displacement demands to inform a permanent instrumentation program defined in 721.3.21.12.

Commentary: Sound Transit's policy regarding in-ground plastic hinging is to prohibit such behavior and restrict plastic hinging to locations where such inelastic action can be detected through visual inspection *and repaired if necessary. This is a reasonable requirement for cases where liquefaction does not occur. It may also be reasonable where liquefaction reduces soil lateral stiffness and strength, but no lateral movement of the soil occurs. These two conditions correspond to the two bulleted items that the SGS Article 6.8 outlines. A third case where "liquefaction-related permanent lateral ground displacements" occurs is treated as a third site-specific load case. The potential for permitting in-ground plastic hinging in the foundation only applies to this third case. However, in cases where liquefaction-induced lateral spreading, lateral flow, or slope instability occurs, prohibiting in-ground plastic hinging may not be feasible.*

Commentary: By developing a design that prevents in-ground plastic hinging in the two bulleted items in the SGS Article 6.8, as the DCM requires, a fully capacity protected design of the foundation for these two load cases must be provided. This is the starting point for the design of a site, structure, and foundation that can tolerate permanent lateral movement of soil, a design that represents a third load case. Based upon the site, the seismic hazard and its disaggregation into shorter duration (crustal and deep interface) events and longer duration (subduction zone events), the sequencing of "kinematic" lateral soil movement relative to "inertial" vibratory shaking deformations will require coupling of the two types of loading. The appropriate amount of coupling (i.e., the amount of inertial loading to consider simultaneously with the kinematic loading) will be site- and project-specific, and the WSDOT Geotechnical Design Manual provides additional guidance on this matter.

Commentary: Because the structure above ground will tend to respond cyclically to the inertial ground shaking input, the coupled structure-ground analyses will need to consider two conditions, and these conditions will be used with the nonlinear static analysis. One condition is the structure is responding in-phase (same direction) as the ground movement, with the soil acting to push the structure laterally. The second condition is the structure is moving out-of-phase (opposite to) with the ground movement. In this condition, the lateral soil movement and load acts as resistance to the structural inertial movement. These two conditions will likely lead to different plastic hinging mechanisms forming at the time of these respective movements.

Commentary: The plastic mechanism(s) configuration will typically vary with foundation type. If a pile cap with multiple piles supports a column, for example, independent plastic mechanisms may form above and below the pile cap. On the other hand, a single column supported by a capacity protected oversize drilled shaft may form two separate mechanisms, one for the out-of-phase case with plastic hinging above the shaft, and one for the in-phase case where the plastic hinge forms below ground in the shaft. For a cantilever column and shaft, this single plastic hinge could define the plastic mechanism. For an integral cap, the mechanism would be composed of plastic hinges both at depth and at the top of the column. These descriptions provide conceptual examples of the structural-foundation inelastic behavior in the presence of lateral soil movement, but these examples are not exhaustive. Note that just as with typical design covered by the SGS, the non-overstrength forces and deformation relationship arising from the nonlinear static analysis will be used to show adequate displacement capacity, but capacity protection is also required to ensure the intended plastic mechanism forms.

Commentary: NLTHA could conceptually be used to analyze such loading and response but developing an appropriate combined geotechnical and structural model and running sufficient input histories will typically be time and cost prohibitive and is not recommended. If NLTHA were to be used with a system that is expected to form a plastic mechanism, capacity protection of non-inelastic members must still be used as required by the SGS.

Commentary: It is widely accepted and observed in limited cases (Kramer, 1996) that lateral spreading may cause lateral deformations of the ground and bridge foundations in that ground. Foundations that undergo inelastic deformations (plastic hinging) that are limited to the strain limits used for MDE design conditions will likely not lead to collapse. The foundation ductility limit of 4 is taken from the AASHTO SGS and WSDOT BDM. However, the foundations may not be reusable and may need to be replaced, because repair of in-ground damage may not be repairable due to access limitations. The foundation may have significant permanent displacement, which would require post-earthquake evaluation regarding re-use in its displaced position.

Commentary: Reduced strain limits to limit foundation damage and perhaps permit re-use should be part of the alternatives study required to develop solutions that may incorporate ground improvement strategies. Reduced strain limits are included in the SGS for this case, but they may not provide the deformation capacity required to control or endure the lateral soil movement.

Commentary: For the case with lateral flow or spreading, the development of a full plastic mechanism in the deep foundations may be physically necessary. It is often impossible to resist the movement of the soil, particularly when a non-liquefied crust impinges on the foundation resulting in lateral deformation of the foundation elements occurring. The soil movements often may be larger than the foundations can tolerate, even at the full plastic-mechanism level. To address such a case and to limit soil movements, ground improvement strategies may be required. The performance objective typically would be to obtain no-collapse of the structure and seek a displacement-compatible design solution of combined soil improvement and permitted inelastic deformation in the foundation. Bounding analysis of the site soil movement, foundation deformation, and bridge stability will be required. As indicated above, reuse of the foundations may be impossible. The development of an acceptable solution is highly dependent on the combination of site conditions, seismic hazard levels, bridge configuration, and bridge performance objective.

Commentary: The in-ground analytical plastic hinging lengths that are given in the AASHTO SGS provide reasonable estimates of such lengths, but those expressions are not specifically applicable for the type of plastic hinging mechanism (completely subsurface) expected with liquefaction-induced lateral spreading or flow. Generally, the plastic hinging mechanism will form, constrained only by soil, and the soil will provide a "softer" lateral constraint to a structural element (pile or shaft) than a directly attached structural member will provide. Consequently, longer plastic hinge zones may develop, and the upper limit of the analytical plastic hinge lengths related to the member cross-sectional dimension (1.5D for non-cased piles and shafts, and 2D concrete-filled steel pipe piles) given in the SGS apply. This should be verified based on the site conditions at hand. At lower strains, reinforcement plasticity can extend over relatively long lengths. However, as inelastic strains increase, concentration of plasticity will gradually occur, especially as bar buckling begins. For this reason, using the limits in terms of foundation element diameter quoted above from the SGS are reasonable.

Commentary: Longer plastic hinge lengths may form in weak, loose soil with no significant stiff layers. Foundation analysis methods that consider ground displacement profiles coupled to inelastic foundation pile elements using nonlinear p-y springs can provide useful insight into pile internal force distributions and inelastic strain distributions. Such analyses can provide estimates of plastic strain distributions along piles or shafts. However, once large inelastic deformations begin, the distribution of plastic strains may concentrate into a shorter length. For this reason, the SGS in-ground plastic hinge lengths are recommended.

Commentary: However, in cases where piles are socketed into rock or hard till, or are otherwise significantly restrained, a shorter analytical plastic hinge length may be warranted, and these may be estimated using the SGS Equation 4.11.6-1 for elements framing into stiffer elements. Analytical fiber-based models of inelastic reinforced concrete elements could be used to estimate plastic hinge lengths for unusual situations, but they are unlikely to provide significant accuracy given the imprecisely characterized nature of the subsurface stratigraphy where sharp transitions in soil restraint occur.

Commentary: Plastic mechanisms that are caused by lateral soil movement also create the need for capacity protection of non-yielding elements. Capacity protection is necessary to ensure that the intended plastic mechanism forms and that non-ductile elements do not experience damage. The use of overstrength factors for design of capacity protected elements is necessary. Examples of capacity protected elements are shear resistant action in foundation piles and shafts along with pile cap elements. Due to the design for non-liquefied and liquefied-no-spreading conditions foundation, elements should already have significant strength. Shear strength associated with the in-ground plastic overstrength forces must be assured. This may control transverse steel requirements relative to confinement requirements, as is typical with columns. Detailing and design of foundation elements expected to develop in-ground plastic hinging is covered by the SGS.

Commentary: It is difficult to develop a one-size-fits-all criteria that covers all situations. As a result, criteria, mitigation approaches, and analytical assessment techniques must be developed on a project-specific basis. These considerations and project-specific criteria should be evaluated at the conceptual and preliminary design phases and should include appropriate geotechnical site investigation and analysis that reliably informs subsequent design phases.

721.3.21.11 Foundation Designs without Full-capacity Protection

721.3.21.11.1 For non-conventional bridge structure design in which capacity design-based seismic behavior in foundations is not feasible, the DOR must confirm the structure does not collapse under MDE loading using rational analysis on ODE and MDE strain and displacement demands for non-capacity protected "Rational analysis" indicates physically based numerical analysis, not empirical analysis. The DOR must use the ODE and MDE strain and displacement demands to inform a permanent instrumentation program defined in 721.3.21.12.

Commentary: Capacity protection is a central theme of the AASHTO Guide Specifications for LRFD Seismic Bridge Design. However, it can be difficult to ensure capacity protected foundations in some cases. One example is foundations that support cable stayed bridge piers. The overstrength moment of the pier dwarfs the geotechnical capacity of typical supporting foundations. Another example is foundations subjected to significant lateral spread deformations. The imposed deformation field creates plastic hinging in the foundations. In these cases, it is advantageous for Sound Transit to accept some level of inelastic behavior within the foundation, so long as life safety performance measures are maintained. This requires the DOR to quantify the location and degree of inelastic behavior, confirm structural stability, and develop an instrumentation approach to provide post-earthquake confirmation of bridge performance.

721.3.21.12 Permanent Instrumentation Program

721.3.21.12.1 Deep foundations designed without full capacity protection or with in-ground plastic hinging must be accompanied by permanent instrumentation so that Sound Transit can confirm post-earthquake performance. The DOR must prepare an instrumentation and monitoring plan for Sound Transit review and acceptance. The instrumentation plan must describe the types, locations, use, and maintenance of the permanent instrumentation. Instrumentation must consider cost and practicality. Instrumentation must consider both manually read and automatically recorded sensors. Instrumentation must consider in-foundation and near-field slope inclinometers, substructure and near-field survey targets, substructure tilt meters, substructure and in-foundation strain gages, near-field settlement arrays, substructure and near-field accelerometers, and near-field pore-pressure transducers.

Commentary: In order to confirm post-earthquake resiliency, a robust instrumentation system is required to quantify damage location and extent. The instrumentation plan should be jointly developed by geotechnical and structural designers to capture the salient features of inelastic behavior. The instrumentation system should be designed with an eye towards redundancy, ease of collection, and security.

Commentary: Electrical or electromechanical instrumentation placed in the foundation is likely not robust enough to potentially last for years before use. Therefore, such instrumentation is not recommended. Slope inclinometer casing coupled with survey targets provide an acceptable balance of practicality and economy. Survey targets are inexpensive and can be read at any time. They provide confirmation of earthquake-induced superstructure movement that would be useful to interpret foundation deformation data. Standard slope inclinometer casing installed within the foundation (similar to CSL casing) would show permanent displacements and rotations after an earthquake. The data could then be used to estimate foundation strains. The casing would eliminate the need to install permanent below-ground sensors that are difficult to maintain and may require replacement during the life of the structure. In landslide applications, slope inclinometer casing is often damaged and rendered impassable by the recording instrument at well-defined shear planes with large offset movements. However, it is expected that foundations designed to allow for modest ductility would not impose similar deformations on inclinometer casing. Nevertheless, such a blockage would reveal a foundation deformed beyond its as-designed capacity.

721.3.21.13 Settlement

721.3.21.13.1 Under an ODE event, provided dynamic envelope clearance and other operational criteria are maintained, the permissible permanent settlement at each pier must be no greater than 2 inches.

Commentary: This requirement is to allow track realignment within a reasonable amount of time after the event.

721.3.21.13.2 Under an MDE event, design the elevated structures such that the superstructure remains essentially elastic when subject to the calculated differential settlement between adjacent piers and the total settlement at each pier. The differential settlement must not cause an angular distortion greater than 0.008 (RAD) in simple spans and 0.004 (RAD) in continuous spans.

Commentary: Reference to WSDOT BDM Section 4.3.5, "Design and Detailing Considerations." This requirement is to ensure structural stability and safety after the event.

721.3.21.14 Elevated Station

721.3.21.14.1 The elevated station primary structure seismic design must be in accordance with the AASHTO Guide Specifications for LRFD Seismic Bridge Design. Additionally, the design must meet the performance requirements in Set 720 Building Structures.

721.3.21.14.2 The seismic design of canopy structure and its connection to platform must be in accordance with requirements in Set 720 Building Structures.

721.3.21.15 Reinforced Concrete Box Structures

721.3.21.15.1 See Set 722 Tunnel and Underground Structure Design.

721.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

721.4.1 System Breakdown Structure

721.4.2 System Sites and Locations

721.5 SYSTEM INTERFACE REQUIREMENTS

Table 721-6 lists requirement sets that are typically coordinated and may have dependencies with this set.

The description of the interfaces below is provided to highlight only the major interface elements between Structures and the other discipline Sets. The list is not intended to capture all interface elements. The DOR must review and coordinate all interface requirements between Structures and the other disciplines at each phase of the design and/or construction.

Table 721-6: Interface Between Structures and Other Disciplines

SET SERIES	SET NAME	SET 721 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	X
500	Track	X
600	Fire/Life Safety	
700	Structures	
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	
1100	Technology	
1200	Security	

721.5.1 Traction Electrification

721.5.1.1 Coordinate guideway OCS pole, foundation, and anchorage design with Set 221 Overhead Contact System.

721.5.1.2 Coordinate structural design affected by stray current requirements of Set 222 Stray Current Corrosion Control.

721.5.2 Vehicles

721.5.2.1 Coordinate structural design for live load of LRV or commuter train.

721.5.3 Track

721.5.3.1 Coordinate track clearances.

721.5.4 Architecture

721.5.4.1 Coordinate fall protection design with Set 804 Fall Protection.

721.5.5 Civil

721.5.5.1 Coordinate bridge drain and its drainage pipe with Set 901 Storm Drainage.

721.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

721.7 ENGINEERING MANAGEMENT REQUIREMENTS

721.7.1 Interface and Integration Management

721.7.1.1 System Interface Requirement Sets (Not Used)

721.7.2 Design Management (Not Used)

721.7.3 Manufacturing and Construction Management (Not Used)

721.7.4 Installation Management (Not Used)

721.7.5 Inspection and Testing Management (Not Used)

721.7.6 Training, Pre-Revenue Operations (Not Used)

721.7.7 Certification Management (Not Used)

721.8 APPENDICES (NOT USED)

END SET - 721

722 TUNNEL AND UNDERGROUND STRUCTURE DESIGN

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SET - 722 GENERAL

722.1 INTRODUCTION

722.1.1 Document Scope

722.1.1.1 This set covers the structural design criteria for tunnels and underground structures (including lining for shafts, tunnels, associated interior structures and other structural elements within cut and cover, and mined or bored tunnel structures) for use by LRV or to access LRVs.

722.1.1.2 For underground stations, their structural design must follow the design requirements herein.

722.1.1.3 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Sound Transit Design Requirements Set 722 owner to determine the technical source for the design criteria.

722.1.2 Regulations, Codes, Standards, and Guidelines

722.1.2.1 The DOR must determine and present for review by the Requirements Set 722 owner any additional design criteria necessary to supplement the design criteria presented herein. The DOR must provide the additional criteria along with the source design codes or guidelines and the reason why they are applicable. All additional design criteria are subject to approval of the Requirements the Set 722 owner. The design must use the latest code version if this set does not specify the code version. If there is any difference between the latest code edition and what is specified in this set, the DOR must consult with Sound Transit structural engineer or its representative for further clarification.

722.1.2.2 International Regulations, Codes, Standards, and Guidelines

722.1.2.2.1 International Building Code (IBC) with local amendments.

722.1.2.3 Federal and National Regulations, Codes, Standards, and Guidelines

722.1.2.3.1 American Association of State Highway and Transportation Officials (AASHTO) Guide Specifications for LRFD Seismic Bridge Design (AASHTO LRFD).

722.1.2.3.2 American Association of State Highway and Transportation Officials (AASHTO) LRFD Road Tunnel Design and Construction Guide Specifications (2017) (AASHTO 2017).

722.1.2.3.3 American Association of State Highway and Transportation Officials (AASHTO) Technical Manual for Design and Construction of Road Tunnels- Civil Elements (2010) (AASHTO 2010).

722.1.2.3.4 AASHTO Guide Specifications for Bridges Carrying Light Rail Transit Loads, 1st Edition, 2018 (AASHTO Light Rail).

722.1.2.3.5 American Concrete Institute. (ACI) Building Code Requirements for Structural Concrete (ACI 318) and Commentary.

722.1.2.3.6 ACI 506.5R Guide for Specifying Underground Shotcrete.

722.1.2.3.7 ACI 533.5R-20 Guide for Precast Concrete Tunnel Segments.

722.1.2.3.8 ACI 544.7R-16 Report on Design and Construction of Fiber-Reinforced Precast Concrete Tunnel Segments.

722.1.2.3.9 ACI 365.1R Report on Service Life Prediction.

722.1.2.3.10 American Institute of Steel Construction (AISC). Design Manual.

722.1.2.3.11 American Institute of Steel Construction (AISC) Specification for Structural Steel Buildings (AISC 360).

722.1.2.3.12 AISC 303: Code of Standard Practice for Steel Buildings and Bridges.

722.1.2.3.13 American Railway Engineering and Maintenance-of-Way Association (AREMA).

722.1.2.3.14 American Society for Testing and Materials (ASTM).

722.1.2.3.15 ASTM C1609 Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam with Third-Point Loading).

722.1.2.3.16 American Society of Civil Engineers – Structural Engineering Institute (ASCE SEI). Minimum Design Loads for Buildings and Other Structures.

722.1.2.3.17 American Welding Society (AWS).

722.1.2.3.18 BS EN 14651:2005 Test method for metallic fiber concrete - Measuring the flexural tensile strength (limit of proportionality [LOP], residual).

722.1.2.3.19 Federal Highway Administration and the National Highway Institute (FHWA-NHI). Technical Manual for Design and Construction of Road Tunnels: Civil Elements.

722.1.2.3.20 National Fire Protection Association (NFPA) Standard for Fixed Guideway Transit and Passenger Rail Systems (NFPA 130).

722.1.2.3.21 Precast/Prestressed Concrete Institute (PCI) Design Handbook.

722.1.2.4 State and Local Regulations, Codes, Standards, and Guidelines

722.1.2.4.1 Washington State Department of Transportation (WSDOT) Bridge Design Manual.

722.1.2.4.2 WSDOT Geotechnical Design Manual (WSDOT GDM).

722.1.2.5 Industry Regulations, Codes, Standards, and Guidelines

722.1.2.5.1 Wood, M., 1975. “The circular tunnel in elastic ground,” Geotechnique 25, No. 1, pp. 115-127.

722.1.2.6 Other Jurisdictions (Not Used)

722.1.3 Abbreviations and Acronyms

722.1.3.1.1 AP–air pressure

722.1.3.1.2 BF–braking force

722.1.3.1.3 BL–blast loading

722.1.3.1.4 CE–centrifugal force

722.1.3.1.5 CR–force effects due to creep

722.1.3.1.6 CS–construction loadings

722.1.3.1.7 DC–dead load of structural components and nonstructural attachments

722.1.3.1.8 DD–downdrag load

722.1.3.1.9 DE–light rail derailment load

722.1.3.2 DOR–designer of record

722.1.3.2.1 DW–dead load of wearing surfaces and utilities

722.1.3.2.2 EH–horizontal earth pressure load

722.1.3.2.3 EQ–earthquake load

722.1.3.2.4 ES–earth surcharge load

722.1.3.2.5 EV–vertical pressure from dead load of earth fill

722.1.3.2.6 FI–force effect due to fire

722.1.3.2.7 FRC–fiber-reinforced concrete

722.1.3.2.8 IA–attachment dynamic load allowance

722.1.3.2.9 IM–dynamic load allowance due to vehicles other than light rail vehicles and commuter rail vehicles

722.1.3.2.10 IMR–light rail vehicle dynamic load allowance including both vertical and horizontal components

722.1.3.2.11 LF–longitudinal force

722.1.3.2.12 LL–live load due to vehicles other than light rail vehicles

722.1.3.2.13 LRV–light rail vehicle (live load)

722.1.3.2.14 LS–live load surcharge

722.1.3.3 MDE–maximum design earthquake

722.1.3.4 ODE–operating design earthquake

722.1.3.4.1 PI–loads due to piping systems inside the tunnel

722.1.3.4.2 PL–pedestrian live load

722.1.3.4.3 PS–secondary forces due to post-tensioning

722.1.3.4.4 RB–rail-break force

722.1.3.5 ROW–right-of-way

722.1.3.5.1 SE–effect of settlement of tunnel structure

722.1.3.5.2 SH–force effects due to shrinkage

722.1.3.5.3 TG–force effect due to temperature gradient

722.1.3.5.4 TU–force effect due to uniform temperature

722.1.3.6 SOE–support of excavation

722.1.3.7 TBM–tunnel boring machine

722.1.3.7.1 WA–water load

722.1.3.7.2 WAf–water load due to flooding

722.1.3.7.3 WAt–transient water load

722.1.3.7.4 WAtsu–water load due to tsunami

722.1.4 Definitions and Classifications

722.1.4.1 Bored tunnels: Those constructed using specialized equipment known as TBMs. The excavation process may be performed at atmospheric pressures or may require a pressurized face depending on the specific ground and groundwater conditions. It excavates a tunnel by drilling out the heading to fill size in one operation. In soft ground conditions, the tunnel final lining will consist of bolted and gasketed segmental concrete lining, which is erected during tunnel excavation.

722.1.4.2 Cut-and-cover tunnel structures: Include box structures, sump pump structures, stations, ventilation structures, and other structures that are constructed using cut-and-cover method and generally using temporary support of excavation and final cast-in-place concrete lining structures.

722.1.4.3 Mined tunnels: Those constructed utilizing mechanical excavation equipment or drill and blast method. The choice of mechanical excavating equipment or drill and blast depends upon the ground conditions being excavated. The shape of the excavation is customized to the ground conditions and specific geometric functional requirements of the tunnel. The excavated ground typically requires initial support prior to the construction of a permanent final lining.

722.1.4.4 Shafts: Vertical or inclined openings connecting the surface and the underground structure that when used during construction serve the same purpose as portals. They can function as ventilation shafts or as a part of the station entrance and appendage, such as to accommodate elevators, stairways, or both. They are constructed from ground surface with Support of Excavation (SOE) in overburden and drill and blast in rock with ground initial supports. Their final lining is generally formed by cast-in-place concrete lining, though precast segmental lining can be used as well.

722.1.5 References (Not Used)

722.2 STAKEHOLDER NEEDS

722.2.1 Passenger Experience (Not Used)

722.2.2 Operational Needs

722.2.2.1 Concrete durability, corrosion control, and corrosion protection to ensure design life and operability.

722.2.2.2 Watertightness criteria to ensure long term durability and operability.

722.2.2.3 Seismic design to ensure minor repair that can be made during normal operation hours after ODE.

722.2.3 Maintenance Needs

722.2.3.1 Refer to AASHTO 2017 and AASHTO 2010 for maintenance needs.

722.2.4 Safety Needs

722.2.4.1 Seismic design to ensure no collapse during an extreme seismic event.

722.2.5 Security Needs

722.2.5.1 See 722.3.1.2.

722.2.6 Reliability, Availability and Maintainability Needs (Not Used)

722.2.7 Environmental and Sustainability Needs (Not Used)

722.3 SYSTEM REQUIREMENTS

722.3.1 Loads and Conditions

722.3.1.1 Regardless of the type of analysis employed, the design must satisfy Eq. 1.3.2.1-1 of AASHTO LRFD Bridge Design Specifications for all specified force effects and combinations thereof, unless otherwise specified. The design must evaluate the following minimum loads and load combinations listed elsewhere in this set.

722.3.1.2 The design must prevent terrorist attacks, including explosives, by applying deterrence and detecting mechanism (such as CCTV) in lieu of structural hardening. The design must incorporate the elements in Safety and Security Analysis. See Set 1202 Closed Circuit Television (CCTV) and Track Intrusion Detection System for more information.

722.3.1.3 Load Factors and Combinations - Load factors and combinations must follow Table 722-1:

Commentary: Refer to AASHTO LRFD Road Tunnel Design and Construction Guide Specifications, 1st Edition, 2017 (AASHTO 2017), AASHTO Technical Manual for Design and Construction of Road Tunnels – Civil Elements (AASHTO 2010), AASHTO Guide Specifications for Bridges Carrying Light Rail Transit Loads, 1st Edition, 2018 (AASHTO Light Rail), and AASHTO LRFD Bridge Design Specifications 9th Edition, 2020.

Table 722-1: Load Factors and Combinations

Load Combination Limit State	DC DD DW EH EV ES PI PS CR SE SH	LL LRV IM IMR CE BR IA PL LS LF	WA WA_t	AP	TU	TG	CS	Use One of These at a Time						
								EQ	BL	RB	DE	FI	WA_f	WA_{tsu}
Strength T-I	γ_p [a]	1.75	1.00	1.00	0.50/ 1.20	γ_{TG} [a]	-							
Strength T-II	γ_p [a]	-	1.00	-	-	-	1.30							
Extreme Event T-I	γ_p [a]	0.50[b]	1.00	0.50	-	-	-	1.00						
Extreme Event T-II	γ_p [a]	0.50	1.00	0.50	-	-	-		1.00	1.00	1.00	1.00		
Extreme Event T-III	0.90	-	-	-	-	-	-						1.10	1.10
Service T-I	1.00	1.00	1.00	1.00	1.00/ 1.20	γ_{TG} [a]	-							
Service T-1A	γ_p [a]	-	1.10	-	-	-	-							
Service T-II	1.00	-	1.00	-	-	-	1.00							
Fatigue T-I LRV, IMR & IA only	-	1.50	-	1.10	-	-	-							

Notes:

a. See Table 3.4-2 of AASHTO 2017 for γ_p except as noted herein. Maximum value of γ_p must be 1.5 for ES except for Service T-1A Limit State. See Article 3.4.1 of AASHTO LRFD Bridge Design Specifications for γ_p value for DD and γ_{TG}.

b. Associated mass of LL need not be included in the dynamic analysis. Mass of LRV is required to be included in the dynamic analysis.

c. Apply these loads separately because the joint probability of these events is extremely low.

Commentary: In Table 722-1 Note a, the maximum γp factor of 1.5 for ES is from AASHTO LRFD Table 3.4.1.2. This table is referenced by AASHTO Guide Specifications for Bridges Carrying Light Rail Transit Loads, 1st Edition, 2018 (AASHTO Light Rail) Table 2.3-1.

722.3.1.4 Permanent Loads: DC, DD, DW, EV, EH, ES, WA, and PI

722.3.1.4.1 Permanent loads must follow Article 3.5 of AASHTO 2017, except as supplemented or modified in this section and Set 721 Bridges and Elevated Structures.

722.3.1.4.2 The DOR is responsible for determining any additional loads and forces on the structure. The DOR must use the minimum material densities shown in Set 721 Bridges and Elevated Structures. For buoyancy calculation, see section 722.3.2.6. 722.3.2.6

722.3.1.4.3 Downdrag Load (DD)

722.3.1.4.3.1 DD must consider the vertical force applied to the exterior of the lining that is resulted from the subsidence of the surrounding clayey soil due to the subsidence of the in-situ soil below the bottom elevation of the tunnel.

722.3.1.4.4 Earth surcharge, including foundation surcharges, ES.

722.3.1.4.4.1 Earth surcharge load must consider the vertical earth load due to fill over the structure placed above the original ground line, loads from existing building and other infrastructure foundations, loads from construction activities, or loads from planned or future development.

722.3.1.4.4.2 The DOR must use the minimum surcharge load of 400 pounds per square foot at top of ground for design of underground structures inside the ROW if future development is not a possibility according to the latest city zoning code.

722.3.1.4.4.3 For land outside the ROW and adjacent to the underground structures, if there is a potential for future development, the DOR must use the surcharge from the actual development, or the best estimate based upon the latest zoning codes in the design of the structure. The DOR can assume 20 pounds per cubic foot of building volume in building weight calculation. If no well-defined loading is available, the surcharge value must not be less than 1,000 pounds per square foot and apply at the top of the subsurface easement box.

722.3.1.5 Live Loads: LL, LS, LRV, IM, IMR, CE, BR, IA, PL, LS, LF, and DE

722.3.1.5.1 Live loads must follow Article 3.6 of AASHTO 2017, except as supplemented or modified in this section and Set 721 Bridges and Elevated Structures. For the underground structures similar to buildings, such as, entrance shafts, ventilation shafts, and underground stations, the DOR must consider relevant live loads in Set 720 Building Structures.

722.3.1.5.2 Live Load Surcharge (LS)

722.3.1.5.2.1 For future traffic loads, the design must use an area surcharge applied at the ground surface both over and adjacent to underground structures to simulate possible roadway and sidewalk live loads. This surcharge must also simulate conditions during future construction activities adjacent to the underground structures. Such construction may result in permanent loads, or in temporary loads from construction equipment, from the stockpiling of construction materials, from the deposition of excavated earth, or from hauling trucks that applied inadvertently to the underground structures.

722.3.1.5.2.2 The DOR must apply an area surcharge at the ground surface both over and adjacent to underground structures inside the ROW. The vertical surcharge must be considered as a uniform load applied at the ground surface as follows:

600 pounds per square foot for X < 5 feet

600 – 40 (X-5) pounds per square foot for X between 5 and 20 feet

0 for X greater than 20 feet
Where:

X = Vertical distance from the top of tunnel roof to ground surface

The DOR does not need to apply the above surcharge, when:

i. The alternative traffic loading that is greater than the above is specified, or

ii. A specific, applicable building surcharge that is greater than the above is specified.

722.3.1.6 Water Loads: WA, WAf, WAt, and WAtsu

722.3.1.6.1 Water loads must follow Article 3.7 of AASHTO 2017, except as supplemented or modified in this section.

722.3.1.6.2 Water Load (WA)

722.3.1.6.2.1 The Water Load (WA) applied to the tunnel and underground structures must be the actual hydrostatic pressure on the tunnel as determined by the groundwater elevation or water surface elevation as determined in the project-specific subsurface investigation per Geotechnical Criteria. The hydrostatic pressure must vary linearly across the height of the tunnel and underground structures from crown to invert according to the depth.

722.3.1.6.2.2 Design water load for cases where the tunnel is constructed within a confined aquifer according to the groundwater pressures within the aquifer.

722.3.1.6.3 Water Load due to Flooding (Waf), Transitient Water Load (Wat), and Water Load due to Tsunami (Watsu)

722.3.1.6.3.1 The design must account for the effects of tsunami and flood water. Do not combine them with other extreme loads. The DOR must determine the tsunami and flood water surface elevation levels from historical data or modeling. The DOR must include climate change or other phenomena that may impact extreme event conditions based on project-specific guidance in effect at the time of the design that is provided in the project Request for Proposal (RFP). The design must assume a direct connection between flood or tsunami water levels and groundwater levels. The deviation is subject to the approval of Sound Transit Geotechnical Engineer or its representative.

722.3.1.7 Air Pressure (AP)

722.3.1.7.1 AP must follow Article 3.8 of AASHTO 2017, except as supplemented or modified in this section.

722.3.1.7.2 The DOR must determine the AP from the design of the tunnel ventilation system and apply to the tunnel ventilation structure, its connections, and attachments to the tunnel and underground structures.

722.3.1.7.3 The DOR must use the AP generated by passing trains in the design of the tunnel and underground structures, and supports for signs, signals, cameras, piping, and any other feature located inside the structures in accordance with air flow pressures calculated using a subway analytical simulation program. The DOR must define the design force on attachments and the tunnel structure, and apply the force in both directions, but not concurrently, and act in a load reversal manner. The minimum AP must be 50 pounds per square foot.

Commentary: Subway Environmental Simulation (SES) software is typically used by the mechanical designer to provide the predicted transitory pressure in accordance with NFPA 130 7.1.3.

722.3.1.7.4 The DOR must determine the number of cycles for use in the fatigue design of attachments based on the number of trains expected to pass through the tunnel during the anticipated service life of the attachment.

722.3.1.8 Earthquake Effects, EQ, follow section 722.3.11.

722.3.1.9 Force Effects due to Superimposed Deformations: TU, TG, RB, SH, CR, PS, and SE.

722.3.1.9.1 Force effects due to superimposed deformations must follow AASHTO LRFD Article 3.12, except as supplemented or modified in this section and Set 721 Bridges and Elevated Structures.

722.3.1.9.2 Design operational temperature range for various materials as follows:

722.3.1.9.2.1 Concrete

i. Between 10 degrees and 100 degrees Fahrenheit for tunnel within 300 feet from portal.
ii. Between 30 degrees and 80 degrees Fahrenheit for underground stations and tunnel beyond 300 feet from portal.

722.3.1.9.2.2 Structural Steel

i. Between 0 degrees and 120 degrees Fahrenheit for tunnel within 300 feet from portal.
ii. Between 30 degrees and 80 degrees Fahrenheit for underground stations and tunnel beyond 300 feet from portal.

Commentary: The range of 30 degrees to 70 degrees Fahrenheit is from State Route 99 RFP. Raise the upper limit by 10 degrees to consider the weather change.

722.3.1.9.3 The TG between the inside face (face of lining exposed to the inside of the tunnel and underground structures) and the outside face (face of lining adjacent to the ground) is a function of the average yearly variation in the outside ambient air temperature at the tunnel or underground structures site. The design must account for the temperature gradient for both the lower and higher temperature on the inside face of the lining.

722.3.1.9.4 The design must account for the frictional restraint from the structural elements and backfill material. Frictional restraint can influence longitudinal axial forces.

722.3.1.10 Fatigue

722.3.1.10.1 The design must include the effect of change of stress levels caused by passage of rail trains during the 100-year design life (approximately eight million cycles).

722.3.1.11 Braking Force (BF)

722.3.1.11.1 The DOR must apply longitudinal force from Sound Transit LRV train loads as the BF for tunnels. See Set 721 Bridges and Elevated Structures for LRV Longitudinal Force.

722.3.1.12 Construction Load Cases

722.3.1.12.1 Temporary construction loads are dependent upon the construction methodology. Construction sequence and procedures may result in conditions that are more severe than the general permanent loading conditions. The DOR must design the mined and bored structures to resist the load effects generated during construction.

722.3.1.12.2 The DOR must develop the loadings applicable to the proposed construction scheme and to clearly state assumptions in the contract documents and issued construction plans. The contract documents must require that the contractor provide a complete analysis for the actual construction loads based on the means and methods for all construction stages, including any variation from the assumed sequencing or methods. The DOR and Sound Transit structural engineer or his/her representative must review and approve the contractor’s analysis.

i. Examples of loads generated by the construction sequence and procedure include the following, but the EOR should also consider other construction loads if applicable. Crane and other equipment loading.
ii. Stripping of forms prior to concrete attaining 28-day compressive strength.
iii. Loads from temporary facilities such as ventilation, lighting, power cables, and conveyor belts.
iv. Thrusting loads from the TBM.
v. Loads imposed on segmental linings due to lifting, stacking, transporting, and erecting.
vi. Loads imposed by construction vehicles operating inside the tunnel.
vii. Loads imposed by backfill or contact grouting.

722.3.2 Structural Materials and Design Considerations

722.3.2.1 The structural design of tunnel and underground structure components and material requirements must follow AASHTO 2017, AASHTO 2010 and the following additions and exceptions.

722.3.2.2 The tunnel lining and underground structure exterior box structure must be reinforced concrete. The interior structural component must be reinforced concrete or steel. Wood structures are not allowed. The DOR may use concrete masonry unit (CMU) in the underground structure as the interior non-load bearing wall.

722.3.2.3 Concrete Structures

722.3.2.3.1 Concrete Durability

722.3.2.3.1.1 The DOR must design concrete structures to meet the project design life requirements in Set 001 General. The DOR can achieve durable concrete by specifying the use of supplementary cementitious material (SCM), such as fly ash, silica fume, or blast furnace slag, which can reduce concrete permeability and improve concrete durability. See section 722.3.2.5 for design life prediction and durability.

722.3.2.3.1.2 The design must investigate the structural behavior of components constructed from concrete for each stage, including construction, handling, transportation, and erection, and during the design life of the structure of which they are part of.
Commentary: Design life prediction using software investigates concrete material, in perfect condition, and does not take construction effect, such as concrete crack width, into consideration. Construction stage can implicitly impact structure service as a result from the following effects. They must be enforced through specifications.

i. Cracking during transportation, handling, and installation (especially for precast concrete segmental lining). This is contractor’s means and methods. The contractor shall establish a QC program to confirm any defected segment that exceeds project requirements can’t be used.
ii. Alkali-Silica Reactivity (ASR) can’t be predicted from software, but from project QA by specifying ASTM test protocol to ensure non-reactive aggregates.

iii. *Mass concrete and temperature loading during construction will be limited to ACI tolerance range and curing program to avoid premature cracks.*
iv. *Sulfate – mainly controlled by limiting C_3A content in cementitious material or through ASTM testing.*

722.3.2.3.1.3 Underground station and shaft structural components must not use plain concrete.

722.3.2.3.1.4 Design structural components to satisfy the requirements at the strength, extreme event, service, and fatigue limit states.

722.3.2.3.2 Reinforced and Prestressed Concrete

722.3.2.3.2.1 Reinforced and prestressed concrete design must follow AASHTO 2017 and AASHTO 2010. For the design of interior structural components in underground structures (similar to buildings) that are not part of the lateral force resisting system, see section 722.3.11.5.

722.3.2.3.2.2 Minimum Concrete Design Strengths at 28 days must follow the requirements below:

722.3.2.3.2.2.1 Specify a minimum f'c = 4,000 pound-force per square inch (psi) for underground reinforced concrete cast-in-place structures, including box structures and stations, abutments, retaining walls, shafts, cross-passages, portals, U-sections, spread footings, piles, drilled-in caissons, and basement walls.

722.3.2.3.2.2.2 Specify a minimum f'c = 6,000 pound-force per square inch (psi) for post-tensioned concrete.

722.3.2.3.2.2.3 Specify a minimum f'c = 5,000 pound-force per square inch (psi) for precast or pre-tensioned concrete.

722.3.2.3.2.3 Reinforcing and Prestressing Steel

722.3.2.3.2.3.1 All concrete reinforcement must be deformed and conform to ASTM A615 or ASTM A706. For elements requiring ductility and/or welding, the design must specify A706 Grade 60 reinforcing steel. In addition, the DOR may use reinforcing bars conforming to ASTM A1035 as transverse reinforcement or spiral reinforcement as allowed in ACI 318. Follow Set 720 Building Structures for the limit on ASTM A615 for underground structure interior beams and columns that are not part of the lateral force resisting system.

722.3.2.3.2.3.2 *Commentary: Welded deformed wire conforming to ASTM A1064 and ASTM A1022 may be used on precast and shotcrete lining in accordance with ACI 318.*

722.3.2.3.3 Fiber-reinforced Concrete (FRC)

722.3.2.3.3.1 The use of FRC must follow AASHTO 2017 and AASHTO 2010. Follow ACI 544.7R-16 for the design of FRC tunnel lining. For residual flexural strength test for FRC, both ASTM C1609 and BS EN 14651:2005 test methods are acceptable.

722.3.2.3.3.2 Do not use lightweight concrete in FRC. For shotcrete initial lining, macro-synthetic or steel fiber reinforcement may be used as allowed in AASHTO 2017 and AASHTO 2010. The use of steel fibers in the final shotcrete lining requires further review and approval by ST Structure Engineer or their representative. The Contractor must submit the information listed in 722.3.7 and the explanation of the effect of steel fiber to the stray-current.

722.3.2.3.3.3 Steel fiber reinforcing must conform to ASTM A820 – Standard Specifications for Steel Fibers for Fiber-Reinforced Concrete, and ASTM C1116/C1116M – 10a Standard Specification for Fiber Reinforced Concrete and Shotcrete.

722.3.2.3.3.4 Shotcrete concrete design must follow AASHTO 2017, AASHTO 2010 and ACI 506.5R.

722.3.2.3.3.5 Design precast concrete lining with either mild rebar or a hybrid combination of mild rebar and steel fiber reinforced concrete.

722.3.2.4 Steel Structure

722.3.2.4.1 Steel structures must follow AASHTO 2017 and AASHTO 2010.

722.3.2.4.2 Underground station and shaft structural steel components that are interior and not part of the lateral force resisting system must follow AISC 360, AISC 303, and AISC Steel Construction Manual in lieu of AASHTO.

722.3.2.5 Design Life, Durability, Corrosion Control, and Corrosion Protection

722.3.2.5.1 Design life Prediction and project Durability Report must be conducted in the early stage of a project in accordance with the Sound Transit Engineering Procedure EP-03 Tunnel Design Submittal Checklist because this report will provide minimum requirements for design details and concrete mixtures.

Commentary: For example, the minimum concrete cover thickness to protect the rebar corrosion, from a Chloride mode of degradation, specified by AASHTO is general valid for 75 years; however, Sound Transit requires 100-year design life for the tunnel and underground structure structural components in Set 001 GENERAL.

722.3.2.5.2 For design-build projects, the contractor must engage its concrete mix provider early enough to provide inputs to the Design life Prediction and Durability Report. In addition, some quality control compliance for concrete mix tests can last over a year. The design-builder must initiate these tests as early as possible to avoid potential schedule delay and be in conformance with EP-03 Tunnel Design Submittal Checklist. These tests must include Alkali-Silica Reaction (ASR) and sulfate resistance tests.

722.3.2.5.3 Design Life

722.3.2.5.3.1 The DOR must design the tunnel and underground structural components for a design life of 100 years. Design for design life must account for the potential effects of material deterioration, including alkali aggregate reaction, internal sulfate attack as a result of cement mix having high tri-calcium aluminate (C3A) that exceeds its permissible level, corrosion, corrosive characteristics of the soils and groundwater, leakage, stray currents, and other potentially deleterious environmental factors (including the exposure of chloride, de-icing salt, carbonation, freezing and thawing, and sulfate) on each of the material components composing the structure, and for load effects experienced as part of the construction process (including drying and shrinkage cracks, thermal damages).

722.3.2.5.3.2 The maximum permissible crack width is 0.008 inch for concrete structural components. During concrete placement, the maximum temperature differential for concrete structures and the maximum curing temperature for precast concrete structures must be in accordance with Sound Transit specifications and ACI associated requirements.

Commentary: The crack width limit of 0.008 inch is for structures subjected to service load and during fabrication and construction. Any crack greater than this limit has to be repaired. This criterion has become a standard for highway tunnels and many water/wastewater tunnels, including the Port of Miam Tunnel, the Ohio River East End Crossing Tunnel, the Parallel Thimble Shoal Tunnel, the Hampton Road Bridge, and Tunnel Expansion.

Commentary: In addition, Mass Transit Railway Corporation specification for Hong Kong and overseas tunnel projects requires that all cracks in the concrete greater than or equal to 0.2 millimeter (0.0078 inch) must be repaired.

722.3.2.5.3.3 Submit the design life prediction software, in accordance with ACI 365.1R Report on Service Life Prediction or other methods for approval from the Sound Transit Structural Engineer or its representative, prior to the commencement of the service life prediction work.

722.3.2.5.3.4 For design life prediction purpose, the service life of the coating and galvanizing is 20 years. In addition, the corrosion propagation duration is 5 years.

722.3.2.5.4 Durability

722.3.2.5.4.1 The DOR must demonstrate, through a durability report, that the durability for the tunnel and underground structures and their associated metal components of the proposed design can fulfill the durability and design life requirements. The analysis must include structural components, such as the permanent bolts, dowels, and other associated inserts, that are used in design of the joints for the segmental lining and the gaskets.

722.3.2.5.4.2 The tunnel lining design must consider the effects of fire on the lining. The lining must be able to withstand the heat of the specified fire intensity and period of time (as derived from DOR's Fire Analysis) without loss of structural integrity. Protection from fire may consider concrete cover on the reinforcing, additional tunnel finish, and special treatment of the concrete mixes. Similar requirements are applicable to other underground structures. See Set 601 Fire–Life Safety for additional information on design fires.

722.3.2.5.5 Corrosion Control

722.3.2.5.5.1 Corrosion control systems are required to prevent premature corrosion failures on transit system fixed facilities and other underground structures. Such measures and systems must minimize stray current levels and their effects on underground structures. Corrosion control systems must meet the design life requirements for the facilities by avoiding premature failure caused by corrosion. The DOR must conduct the soil and groundwater analysis to determine the type of corrosion control measures to be used. Design must utilize mitigation measures, such as coating, cathodic protection, continuous welding of reinforcing steel top layer in trackway inverts, and stray current test facilities. Install stray current monitoring facilities and track-to-earth resistance testing according to Set 222 Stray Current Corrosion Control. See Set 902 Utilities for soil corrosion and stray current corrosion control for utilities.

722.3.2.5.5.2 The DOR must design the lining elements for the elimination of stray currents from the surrounding ground area.

722.3.2.5.5.3 Make reinforcing steel in underground trackway structure inverts electrically continuous by welding splices of the top layer reinforcing bars. Coordinate with the project corrosion engineer or cathodic protection specialist for the details of welding requirements, collector members, and bridging over expansion joints.

722.3.2.5.5.4 Where steel fiber reinforced concrete is approved to be used in underground trainway structure inverts, install stray test boxes as required by the project corrosion engineer or cathodic protection specialist.

722.3.2.5.5.5 Where a segmental lining system is used, steel reinforcing within the segments does not require special provisions for electrical continuity, unless required by the project corrosion engineer or cathodic protection specialist. Isolate connecting hardware between adjacent segments from the reinforcement.

722.3.2.5.5.6 Insulate any metallic components that will be exposed to the soil/groundwater electrically. Consult the project corrosion engineer or cathodic protection specialist for details.

722.3.2.5.5.7 Make underground metallic structures bonded and electrically continuous throughout their entire length. Coat all exposed metallic components.

722.3.2.5.5.8 Make elements of the structure treated for corrosion control electrically isolated from external (new and existing) metallic structures. They must be electrically isolated from reinforcing steel at concrete penetrations, copper grounding grids, and tracer wires.

722.3.2.5.5.9 Install stray current test boxes at the collector members as required by the project corrosion engineer or cathodic protection specialist.

722.3.2.5.5.10 Coordinate corrosion control systems with other disciplines, including mechanical, utility, electrical, civil, trackwork, electrification, signaling, and communications designs. The DOR must coordinate with the corrosion control discipline throughout the design, installation, and startup of the system. See Set 222 Straw Current Corrosion Control for additional requirements.

722.3.2.5.6 Corrosion Protection

722.3.2.5.6.1 The DOR must design provisions in the lining elements for corrosion prevention. Groundwater, ground chemicals, leaks, dissimilar metals, iron eating bacteria, and stray currents are all sources of corrosion in metals.

722.3.2.5.6.2 Corrosion protection must take the form of increased cover for reinforcing and concrete and metal coatings such as epoxies, powder coatings, paint, or galvanizing. Install insulation between dissimilar metals and sources of stray currents.

722.3.2.6 Buoyancy

722.3.2.6.1 The design must account for the effects of hydrostatic uplift pressure whenever groundwater is present. Assume the maximum design flood levels based on 500-year flood elevations and assess the future sea level rise and account for it in selecting the design flood elevations.

722.3.2.6.2 For the permanent condition, calculate the buoyancy for all sections. Resistance to buoyancy calculations must rely on the dead weight of structural components and the weight of the soil/rock above the underground structures only, without accounting for any equipment or other removable items. The design must not account for the shear strength and friction of overburden. The use of tie downs, tension piles, and other elements specifically designed to resist uplift forces is not permitted.

722.3.2.6.3 For buoyancy calculation, the maximum unit weight of the concrete must be no more than 150 pounds per cubic foot, unless the DOR can demonstrate heavyweight aggregates or any proposed heavy material in the concrete mix and get the approval from the Sound Transit Structure Engineer or their representative.

722.3.2.6.4 Use Service T-1A load combination to check the resistance of the underground construction for the entire length of the structure at each cross.

722.3.2.6.5 For the short-term (temporary) construction condition (i.e. prior to completing the permanent structure), the DOR must calculate the buoyancy using Service T-1A load combination with a minimum 1.05 load factor for WA load case for all construction phases and maintain for the entire length of the structure at each cross section.

722.3.3 Watertightness

722.3.3.1 Design tunnels and underground structures to limit water ingress and prevent visible water leakage.

722.3.3.2 Material used in preventing or stemming water ingress must not compromise the fire safety or the durability of the structures in which they are used. If passive fire protection systems or architectural finishes are used inside the tunnel, the DOR must design the proper drainage system for seepage drainage behind such system.

722.3.3.3 For tunnels, design track drainage to carry away any seepage through the walls or the floor.

722.3.3.4 General

722.3.3.4.1 The DOR must design the underground structures to meet the watertightness performance criteria shown in Table 722-2. However, regardless of the type of tunnel, water leakage must not compromise the safety with regard to fire safety components, electrical components, and durability of the structure.

722.3.3.4.2 Design and construct the interface between underground structures (including bored/mined tunnels, tunnel portals, cross passages, cut-and-cover tunnel sections) such that the joint between the two structures is fully watertight over the range of movement for seismic hazards or differential settlement predicted.

722.3.3.4.3 For cut-and-cover tunnels, mined tunnels/caverns, and any underground structure, no groundwater infiltration is permitted immediately after the completion of construction.

Table 722-2: Watertightness Performance Criteria for Underground Structures

Structure	Tightness Class	Allowable Infiltration	Definition
Elevator and Escalator Pits and Floor	1	0.01 gallon per day per square feet area (Maximum overall infiltration)	No moisture patches are detectable on the inside.
Mechanical Pits and Floor			
Underground Restroom			
Back of House (Sump Pump Room, Janitor Room, Mechanical room, Fire Valve Room, Elevator Mechanical Room, UPS Room, Unassigned Room, Communication Closet, Electrical Closet, etc.)			
Internal Finished Station Wall and Floor (including staircase)			
Traction Power Substation (TPSS) Underground Structure			
Underground Garage Wall and Floor (including staircase)	2	0.1 gallon per day for 10 square feet of area (local infiltration limit)	Only slightly, isolated moisture patches are detectable on the inside (e.g., as a result of discoloration.) After touching such slightly moist patches with the dry hand, no visible traces of water should be detectable on it. If a piece of blotting paper or newspaper is placed upon a patch, it slightly discolors as a result of absorbing moisture. No dripping or visible leakage from a single location shall be permitted.
Underground Stairwell Wall and Floor			
Pedestrian Tunnel			
Cross Passage Connecting Bored Precast segmental lining Tunnel			
Tunnel Portal Zones	3	0.2 gallon per day for 10 square feet of area (local infiltration limit)	Only isolated, locally restricted patches of moisture occur. Restricted patches of moisture are such that they reveal that the wall has been penetrated by moisture, and a piece of blotting paper or newspaper discolors if placed upon it. No dripping or visible leakage from a single location shall be permitted.
Traffic and Transit Tunnel Trackway (bored tunnel with precast segmental lining)			

Commentary: The watertightness criteria were generated based on the lesson learned from previous Sound Transit projects and the following references, which were reviewed and considered to be consistent with each other:

i. *Water Leakages in Subsurface Facilities: Required Watertightness, Contractual Matters, and Methods of Redevelopment, (ITA 1991).*

ii. *UK Leakage Criteria and Classes of Tunnel.*

iii. *FHWA-NHI-10-034 / 09-010 Technical Manual for Design and Construction of Road Tunnels.*

iv. *BART Facility Standards Design Criteria Section 2.4.1.*

Other references reviewed but not considered:

v. *ST Project Specifications (N140 and N150 Underground Stations, and N125 Precast Concrete Tunnel Specs 31 74 16).*

vi. *BART Facility Standards Design Criteria Section 2.4.2.*

vii. *CBBT Parallel Thimble Shoal Tunnel Technical Requirements.*

viii. *HRBT Technical Requirements Section 23.3.1.4.*

722.3.3.4.4 Do not use bentonite water proofing system below the maximum water table, or as the waterproofing for the structures that are required to be Tightness Class 1 in Water Tightness Performance Criteria, unless allowed for Hycrete concrete as specified in ST Standard Specification Section 03 15 13 Waterstops.

722.3.3.4.5 Show waterproofing details on the contract drawings, including, but not limited to, all forms of anticipated penetrations, and the interface between wall and roof or base slab.

722.3.3.5 Stations and Crossovers

722.3.3.5.1 The DOR must provide membrane waterproofing over the entire mined and cut-and-cover station and crossover structures. The DOR must design the seepage management system to conceal and convey water from leaks. The contract drawing must show boundary condition details, such as reglets, flashing, and laps.

722.3.3.6 Equipment Rooms

722.3.3.6.1 The DOR must design train control rooms, electrical rooms, and auxiliary equipment spaces that have roofs or walls in contact with earth with an external membrane. Slope the base floor to drain and place the equipment on raised pads, regardless if the structure is subject to hydrostatic pressure. Locate the equipment so as to permit repair of leaks while the equipment is in operation.

722.3.3.6.2 Substations, switchgear, and other electrical rooms must have roof surfaces waterproofed with an external membrane as previously described.

722.3.3.6.3 The DOR must lay out conduits leading from walls or roofs of any of the above spaces to prevent water infiltration or along the conduit to the equipment.

722.3.3.7 Mined and Cut-and-Cover Tunnels and Underground Station

722.3.3.7.1 Provide waterproofing for mined tunnel, cut-and-cover tunnels, bored tunnel with cast-in-place concrete lining, and underground stations at their exterior faces against support of excavation or earth. This is to mitigate the leakage of infiltrating surface water from dripping onto Overhead Contact System and electrical components in these structures.

722.3.3.7.2 Give special consideration to design details and construction sequences for reduction of cracking.

722.3.4 Joints

722.3.4.1 The DOR must design for continuous temperature and shrinkage reinforcement, as required by applicable specifications and codes, in all walls and slabs of these underground structures.

722.3.4.2 The DOR must show the location of the joints on the structural plans to minimize the occurrence of shrinkage cracks. The DOR must detail the placement of reinforcement and concrete pouring sequence to minimize shrinkage cracks.

722.3.4.3 Each joint at the interface between the cast-in-place and the precast elements (e.g., tunnel portals and cross passages) must design a re-injectable grouting system.

722.3.4.4 The DOR must provide construction and expansion joints in accordance with provisions stipulated below:

722.3.4.5 Construction Joints

722.3.4.5.1 Design construction joints to transmit all the forces that may occur under any design condition.

722.3.4.5.2 To control shrinkage stresses in monolithically poured concrete slabs and walls, and to minimize cracking, provide construction joints at the maximum spacing of 40 feet. The spacing must be closer, if appropriate, to the framing construction or as designed in order to meet project crack criteria. Joints must have reinforcing steel continuous across the joint, keys, roughened joints, or other positive means of shear transfer.

722.3.4.5.3 The DOR must detail the transverse joints in interior walls, invert slabs, and emergency egress corridors of the tunnel structure as construction joints.

722.3.4.5.4 Reinforcement must be continuous through the construction joint. Each construction joint must contain a shear key or an intentionally roughened surface to a +/- ¼ -inch amplitude that meets ACI 318, if shear friction concept is employed.

722.3.4.5.5 Longitudinal and transverse construction joints must have a hydrophilic (water-reactive, swelling) waterstop adjacent to the exterior surface of the structure and a polyvinyl chloride (PVC) waterstop placed near the center of the concrete section of the exterior wall or slab that is in contact with the highest water table.

722.3.4.5.6 At the tunnel and station entrance, install re-injectable grout tube waterstops on both sides of the PVC waterstop.

722.3.4.6 Movement Joints

722.3.4.6.1 The DOR must provide movement joints at locations of major change in structure section (e.g., from cut-and-cover tunnel to station, from bore/mined tunnel to cut-and-cover tunnel, and from cut-and-cover structure to U-wall structure). Where the box line section meets the station section, design the connection either to absorb any differential movements or to transmit the forces that may occur under any design conditions. In all cases, the DOR must design these joints to be watertight to meet the water tightness requirements.

722.3.4.6.2 Detail the joints to accommodate differential settlements, thermal expansion and contraction, fire resistance, and seismic compatibility.

722.3.5 Analysis of Tunnel and Underground Structures

722.3.5.1 The tunnel and underground structural systems are installed after excavation to provide long--term ground support, to maintain the structure opening, to limit the inflow of groundwater, to support appurtenances, and to provide a base for the final finished surface of the structure. Tunnel precast segmental linings can be used both for initial stabilization of the excavation (initial ground support) and permanent ground support (final lining).

722.3.5.2 The design of these structures must account for the performance requirements, including the design life, the proposed use, ground conditions, groundwater conditions, maximum flood water levels, buoyancy, ground and groundwater chemistry, seismic load cases, fire resistance, and other extreme events specified in this set and codes it references.

722.3.5.3 These structures can impact other structures near them such as existing structures and other tunnels. Their designs must account for the impact on other structures and vice versa for both short-term (during construction) and permanent conditions. Their design must account for future developments and staging and sequence of construction.

722.3.5.4 Methods of Analysis

722.3.5.4.1 The DOR must apply the state-of-the-art numerical modeling techniques, simulation procedures, material properties, and material definitions. Use finite element or finite difference models to predict ground movement due to tunnel construction. Fully validate any software for its intended use. The numerical simulations must be applicable to and reflect the work and construction stages proposed. Analysis must take account of short- and long-term soil-structure interaction (SSI) characteristics of the ground and the tunnel lining. Verify results generated utilizing numerical models for reasonableness utilizing alternative analysis methods.

722.3.5.4.2 The design must limit the use of analytical methods or simplified methods using closed-form solutions included in AASHTO 2017 and AASHTO 2010 to cases that meet all three conditions: (1) the tunnel is complete circular in shape for ovaling response or rectangular in shape for racking with uniform lining, (2) surrounding ground is uniform, and (3) there is no interaction effect from adjacent tunnels, or other structures. If actual soil-structure interactions are anticipated to be more complex than these assumptions, the DOR must adopt the numerical modeling approach as presented in AASHTO 2017 and AASHTO 2010 and get the approval from the Sound Transit Geotechnical Engineer or its representative. In this approach, the DOR must use no less than full overburden for tunnels in soft ground, or no less than the weight of two diameters of rock overburden, provided that the geotechnical report considers the rock condition, fracture, and weathering.

Commentary: For bored/mined tunnels:

i. *Tunnel linings are a structural system that differs from other structural systems in that their interaction with the surrounding ground is an integral aspect of their behavior, stability, and overall load carrying capacity. The loss or lack of the support provided by the surrounding ground can lead to failure of the lining. The ability of the lining to deform under load is a function of the relative stiffness of the lining and surrounding ground. Frequently, tunnel linings are more flexible than the surrounding ground. This flexibility allows the lining to deform as the surrounding ground deforms during and after the excavation of the tunnel. Likewise, this deformation mobilizes the strength and stability of the ground. The tunnel lining deformation allows the moments in the tunnel lining to redistribute such that the main load inside the lining is thrust or axial load. The most efficient tunnel lining is one that has high flexibility and ductility.*
ii. *Tunnel linings maintain stability and load carrying capacity through contact with the surrounding ground. Applied load to one portion of the lining, the lining begins to deform, and in so doing, develops passive pressure along other portions of the lining.*
iii. *This passive pressure prevents the lining from buckling or collapsing. Ductility in the lining allows for the creation of hinges at points of high moment that relieve the moments in adjacent lining sections so that the primary load action becomes essentially axial force.*

722.3.5.5 Critical Sections

722.3.5.5.1 The DOR must evaluate all critical sections for the structural design of the tunnel and underground structures, for the assessment of surface settlements and for the assessment of potential impacts on existing and planned structures. Assess critical sections based on the tunnel geometry, alignment, geological conditions, groundwater table, depth of cover, and proximity to other structures.

722.3.5.5.2 Tunnel critical sections must include, at the minimum, the deepest underground sections, shallowest underground sections, sections with the highest groundwater table, sections with the lowest groundwater table, and other sections with variation in the geology or groundwater that warrant changes in the vertical or lateral loading conditions. Design the critical sections separately for every tunnel type along the alignment (i.e., bored, mined, cut-and-cover).

722.3.5.5.3 The DOR must design critical sections for cross passages, other special areas, tunnel interfaces with other structures, or other types of tunnels (such as between cut-and-cover tunnel and bored tunnel), tunnel adits, and any openings through the tunnel lining separately and analyze them based on the intersection geometry specific loading and geotechnical conditions at such locations.

722.3.5.5.4 Critical section design must be approved by the Sound Transit Structural and Geotechnical Engineers, or their representatives.

722.3.5.6 Additional Loads Consideration

722.3.5.6.1 The design must account for the following additional loads, in addition to the load combination from Table 722-1:

i. Additional loads due to the driving of adjacent tunnels.
ii. Effects of tunnel breakouts at cross-passages, portals, and shafts.
iii. Additional loads due to ground modifications such as ground freezing.
iv. Erection loads, including transportation, jacking, and annular grouting loads, for segmental lining.
v. Erection load during the precast concrete segmental lining production, when the segment is removed from its mold and is transported to curing kiln when the concrete of the segment is of low strength at this stage.
vi. Effects of tunnel niches and adits.

722.3.6 Cut-and-Cover Tunnel Structures

722.3.6.1 This section includes cut-and-cover tunnels and cut-and-cover stations that behave in similar manner as a rectangular structure during earthquake shaking/raking. Design must follow AASHTO 2017, AASHTO 2010, and the additions in this set.

722.3.6.2 General Requirements

722.3.6.2.1 The dead load for structures constructed by cut-and-cover methods must consist of the weight of the basic structure, 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. Design the weight of the earth cover as an EV load. Lateral earth pressure must use at-rest pressure condition.

722.3.6.2.2 The DOR must apply the dead load in stages to represent the lift history of the designed structure.

Commentary: For example, removal of the earth cover from a prestressed concrete span at some future date may create a serious upward deflection problem. As a result, the DOR must analyze it as a separate loading case.

722.3.6.3 Minimum Earth Cover for Design

722.3.6.3.1 For all underground rail transit structures in the public ROW, the DOR must design for actual cover depth or for an assumed minimum cover depth of 3 feet, whichever is greater. Use the actual cover depth for the floatation check.

722.3.6.4 Load Case

722.3.6.4.1 The DOR must analyze four basic loading cases in accordance with limit states from Table 722-1. The DOR must develop values from applicable loads listed in 722.3. The DOR must analyze additional permanent, temporary, and construction loading cases as required by circumstances.

i. Case I: Full vertical and long-term horizontal load without hydrostatic pressure.
ii. Case II: Full vertical load, long-term horizontal load on one side, and short-term horizontal load on the other.
iii. Case III: Full vertical load with short-term horizontal load neglecting hydrostatic pressure on both sides.
iv. Case IV: Full vertical load with long-term horizontal load, including hydrostatic pressure.

722.3.6.5 Additional Design Considerations

722.3.6.5.1 The DOR must not include compression forces in shear design of the slabs in box sections. In evaluating the design for temporary loadings produced by construction conditions, such as the removal of horizontal struts, the DOR must account for:

i. Allowable increase in stresses due to the temporary nature of the loading.
ii. Creep in the concrete.
iii. Effect of soil arching.
iv. Wall and slab flexibility.

722.3.6.5.2 The construction specifications that are not part of Sound Transit's standard specification must stipulate that the working drawings, supporting computations, and order of procedure submitted for approval by the contractor reflect proper consideration of such aspects as the magnitude of preload in replacement struts, crushing of packing, and thermal-induced stress and deflection of the permanent structure. The contractor's proposal must detail the proposed instrumentation and monitoring thereof so as to ensure that the permanent structure meets the design intent after construction. In all cases, the specifications for support of excavation must reflect all limitations inherent in the design of the permanent structure. The DOR must get the approval of these specifications from the Sound Transit Structural or Geotechnical Engineer, or its representative.

722.3.7 Mined and Bored Tunnel Structures

722.3.7.1 Mined tunnel refers to tunnel excavated by sequential excavation method or drill-and-blast method or the combination of both, such as station cavern and cross-passages between tunnels. Its final lining consists of cast-in-place concrete. For the use of shotcrete as the final lining, the Contractor must submit the following for approval from Sound Transit Structure Engineer or their representative:

722.3.7.1.1 The locations where it will be used;

722.3.7.1.2 Shotcrete concrete quality control plan, including, but not limited to, nozzleman qualification, how to protect the waterproofing, how to achieve good finish (for example, smooth surface, no rust on surface overtime), mock-up plan, constructability in challenging tunnel geometry; and

722.3.7.1.3 How to prevent the early loading damage or high deformation if there is any.

722.3.7.2 Bored Tunnel

722.3.7.2.1 Tunneling in soft ground: To maintain ground stability, closed faced TBM (Earth Pressure Balance Machine, or Slurry Shield TBM) is required. Its ground support and final lining consists of bolted, gasketed, precast concrete segmental lining.

722.3.7.2.2 Tunneling in hard rock: Open face main beam TBM is generally employed. During tunnel construction, initial ground supports generally consist of shotcrete, rock dowel, and steel set with wood lagging. The final tunnel lining is generally constructed by cast-in-place concrete lining method with waterproofing membrane.

722.3.7.3 One Pass Bored Tunnel with Precast Concrete Segmental Lining

722.3.7.3.1 The DOR must determine the configuration of the completed rings, individual segments and details of joints and connections to suit ground and groundwater conditions, all handling loads, erection and TBM thrust loadings, methods and sequences of construction, tail void (annular) grout pressure distribution, and all functions in the completed tunnel as described herein. For the temporary construction loads, the DOR must make sure what is assumed in the calculation will be verified by the final temporary load conditions based on the actual means and methods. The design must at least address the following aspects as applicable.

722.3.7.3.2 Fill the annulus between the lining and the ground with annular grout placed, through the tail shield of the TBM, immediately and continuously behind the TBM as it advances. Ring configurations, including tapered rings to fit the alignment vertical and horizontal curvature and to correct line and level during construction and attain the required degree of water tightness of the tunnel. Avoid cruciform joints.

722.3.7.3.3 Do not use timber or steel spacers for negotiating curves between segments or rings.

722.3.7.3.4 In tunneled sections below the water table, design the linings as precast concrete segments with bolt and gasket connection. The DOR must design the EPDM sealing gaskets for the maximum expected groundwater head with safety factor of 2.0 to account for long-term relaxation of gasket material, and design life of 100 years. The DOR must account for gasket groove construction tolerance and offset in gasket design. The gasket material must be able to withstand exposure within any aggressive environment present in the ground or groundwater. It must withstand chemical attack and biological degradation such that the gasket functions properly for the design life of 100 years.

722.3.7.3.5 The design must address connection details and other components, including circle (circumferential) joint connectors, cross (radial) joint connectors, demolding, handling, stacking, transportation and installation, holes, niches, recesses and fixtures for other system components, allowances for tolerances in segment production and in building the rings, and water tightness of gaskets.

722.3.7.3.6 Provide visual indicators on the interior lining face to mark locations free of reinforcing and suitable for post-installed anchors.

722.3.7.3.7 In addition to the load combinations from Table 722-1, the loads must include:

i. Loads due to imperfect lining erection, but not less than 0.5 percent diametrical distortion, based on median diameter. For bored tunnel diameter of 30 feet or greater, ring build tolerance less than 0.5 percent of diameter may be considered provided the tolerance is consistent with the contract specifications.
ii. Additional loads due to the driving of adjacent tunnels.
iii. Effects of tunnel breakouts at cross-passages, portals, and shafts.
iv. Additional loads due to ground modifications, such as ground freezing.
v. Erection loads, including transportation, jacking, and annular grouting loads, for segmental lining.
vi. Effects of tunnel niches and adits.

722.3.7.3.8 Design strength for governing load cases must follow ACI 533.5R.

722.3.7.3.9 Segmental Lining Stiffness

722.3.7.3.9.1 When analyzing a segmental tunnel lining, the design must use the effective moment of inertia, or otherwise use the numerical model to simulate the segmental lining joints. Calculate the effective moment of inertia per Muir Wood (1975) as shown below:

$I_e = I_j + I_g\,(4/n)^2$

where:

I_e = effective moment of inertia (in^4),

I_j = moment of inertia of the joint (in^4),

I_g = gross moment of inertia of the lining section (in^4),

n = number of joints in the lining ring.

722.3.7.3.10 Segment Joint Design

722.3.7.3.10.1 The DOR must design segment joints to resist the load effects resulting from the loads and load combinations specified. Analyze the design of segment joints for bearing and bursting load effects by utilizing the actual contact surface area available. The actual contact surface area must account for the contact area lost to chamfers, packing, and gaskets used to seal the joints.

722.3.7.3.10.2 The design drawing must specify where the erection bolts need to stay, and the torque required to re-tighten the bolts.
Commentary: Several tunnel inspection reports show that the existing bolts have loosened due to train vibration. This will help ST Operations to decide what bolts need to be retightened and what can be taken out.

722.3.7.4 Mined/Two-Pass Bored Tunnels, Crossover, and Cross Passages with Cast-in-Place Concrete Lining

722.3.7.4.1 These structures include all components of mined stations, crossovers, cross passages, and tunnel constructed by open face main beam TBM with initial ground support and final concrete lining. The final lining of these structures must be reinforced concrete, either cast-in-place or shotcrete. The DOR must design a waterproof membrane between the final lining and the initial ground support.

722.3.7.4.2 The design must provide appropriate temporary ground support with the associated calculation to prove its adequacy.

722.3.7.4.3 The DOR must design the two-pass bored tunnel lining to sustain all the permanent loads to which they will be subjected in accordance with appropriate LRFD load combinations from Table 722-1, without the beneficial effects of temporary ground support system.

722.3.8 Shafts

722.3.8.1 General Requirements

722.3.8.1.1 The permanent shaft wall must be in either precast segmental lining rings or reinforced concrete (cast-in-place or shotcrete). The DOR must determine the loading imposed on the shaft by the surrounding ground in accordance with the subsurface investigations and consistent with the shaft configuration. The tunnel that is inclined less than 45 degrees from the vertical must be considered as a shaft.

722.3.8.2 Design of Shaft Lining

722.3.8.2.1 The DOR must calculate the earth pressure using full overburden pressure multiplied by the effective at-rest lateral earth pressure coefficient (Ko). Derive Ko based on the actual horizontal in-situ stress measured for the project site from Project geotechnical exploration program.

722.3.8.2.2 Design the shaft linings to sustain all the loads that they will be subjected and in accordance with the appropriate limit states from Table 722-1. For the temporary construction loads, the DOR must make sure what are assumed in the calculation will be verified by the final temporary load conditions based on the actual means and methods. In addition to the load combinations from Table 722-1, loads and conditions must include:

i. Annular grouting loads.

ii. Effects of tunnel breakouts, niches, and adits.

iii. Provisions for the ground structure interaction and lateral support of the surrounding ground.

722.3.8.2.3 Design the shaft for watertight, with PVC waterproofing membrane between the final concrete lining and the ground.

722.3.9 Tunnel Break-ins and Break-outs

722.3.9.1 General Requirements

722.3.9.1.1 Permanent walls for tunnel break-outs in shafts, cross passages, or any other location must be steel reinforced. The DOR must determine the requirements of special segments to suit break-out configurations for tunnels lined with precast concrete segmental tunnel linings. The DOR may combine cross-passages with other structures, such as pump and ventilation structures. Refer to Set 601 Fire–Life Safety for cross passage spacing and egress requirements.

722.3.9.2 Design of Cross Passages

722.3.9.2.1 In tunnels where cross passages are provided and separate profiles are defined for the left and right tracks, the maximum slope of the cross passage is 5 percent.

722.3.9.2.2 Cross passage design must account for level landing within the tunnel, and a minimum 3-foot-6-inch level threshold to accommodate for the door swing in the cross passage. See Set 520 Vehicle Clearances and Track Spacing for door open direction.

722.3.10 Portals and U-Sections

722.3.10.1 General Requirements

722.3.10.1.1 The DOR must design tunnels and box section entrance portals in the manner to minimize the rate-of-change of pressure on the train passing through the portal.

722.3.10.1.2 In locating portals and determining the ends of U-sections and walls, the DOR must provide protection (such as the use of portal trench drains, sumps and pumps) against flooding resulting from local storm runoff.

722.3.10.1.3 The design must provide adequate resistance to hydrostatic uplift using the Factor of Safety in paragraph 722.3.2.6 Buoyancy and provide means for immediate and effective removal of water from rainfall, drainage, groundwater seepage, or any other source.

722.3.10.1.4 The DOR must use U-sections, with both walls continuous with full-width base slab, for open-cut sections where the top of rail is less than 4 feet above the maximum groundwater table.

722.3.10.1.5 The DOR may analyze U-sections as continuous structures on elastic foundations. If at any station the two walls are of unequal heights, then check the structure sliding using one of the following resistance factors. The more critical situation must control:

i. 0.8 with no passive resistance of the soil.
ii. 0.5 with passive resistance of the soil.

722.3.10.1.6 The DOR must design the wall thickness for U-sections using:

i. The geotechnical soils report recommendations for at-rest coefficient of lateral earth pressure.
ii. Hydrostatic pressure.
iii. Surcharge effects.

722.3.10.1.7 U-section grade slab design thickness must be 6 inches greater than the wall thickness. Design the grade slab for the hydrostatic uplift pressure in accordance with Table 722-1.

722.3.10.1.8 If, at the last U-section segment away from the portals, the abutting at-grade trackway does not consist of track slab, then the DOR must provide a depressed approach slab to permit the construction of tie-and-ballast track bed up to the end of the U-section base slab that avoids a sharp break in support at that point.

722.3.10.1.9 The design must provide expansion joints spaced at no more than 100 feet apart at U-section. Locate these expansion joints in both the walls and the invert of U-section in the same plane.

722.3.11 Tunnel and Underground Structures Seismic Design and Detailing

722.3.11.1 The design of underground structures for seismic loading must meet the applicable portions of the current editions of the codes, manuals, or specifications identified in Set 701 Geotechnical Engineering and Set 721 Bridges and Elevated Structures, and those given below. If there is any difference between the current code edition and what is specified in this set, the DOR must consult with Sound Transit structural engineer or its representative for further clarification.

722.3.11.1.1 Tunnels and underground structures must design for the two-level earthquake, the Operating Design Earthquake (ODE) and the Maximum Design Earthquake (MDE), and meet the seismic performance objectives as specified in Set 721 Bridge and Elevated Structures.

722.3.11.1.2 AASHTO LRFD Road Tunnel Design and Construction Guide Specifications, 1st Edition, 2017 (AASHTO 2017).

722.3.11.1.3 AASHTO Technical Manual for Design and Construction of Road Tunnels- Civil Elements (2010) (AASHTO 2010).

722.3.11.1.4 For retaining walls only: Seismic Analysis and Design of Retaining Walls, Buried Structures, Slopes, and Embankment, NCHRP Report 611, 2008 Transportation Research Board.

722.3.11.2 Bored Circular Tunnels

722.3.11.2.1 Bored circular tunnels include earth tunnel sections and rock tunnel sections, using either the precast concrete segmental lining or cast-in-place concrete lining. Design details for the seismic design of the reinforced concrete tunnel lining must be in accordance with the provisions of AASHTO 2017 and AASHTO 2010 and must comply with the requirements specified in this set.

722.3.11.2.2 Seismic Loads due to Ovaling Deformations

722.3.11.2.2.1 The DOR must combine the seismic ovaling deformation with deformations resulting from non-seismic loads defined in this set. For the ODE level design, the DOR must design the lining to respond essentially in an elastic manner with no ductility demand. The DOR must check that the material strains of the lining, including the longitudinal strain due to axial and curvature deformation, is less than 0.002 for concrete and 0.002 for steel. For the MDE level design, the DOR must keep inelastic deformations to acceptable levels. The material strains of the lining must be less than 0.0033 for concrete and 0.02 for steel.

722.3.11.2.2.2 The DOR must design the lining to satisfy the strength requirements for the ODE and MDE level designs. Modify γ_p factor in Table 722-1 to be 1.2 in ODE load combination and 1.0 in MDE load combination for the load combination Extreme Event T-1, with EQ defined as Elastic seismic force due to seismic ovaling deformation.

722.3.11.2.3 Interface Joints

722.3.11.2.3.1 The DOR must design interfaces between the bore tunnel structures and the more massive structures, such as the cut-and-cover structures, mined station sections, and ventilation/access structures as flexible joints to accommodate the differential movements. The DOR must design the differential movements in consultation with the Final Design Geotechnical Consultant.

722.3.11.3 Reinforced Concrete Box Structures

722.3.11.3.1 The reinforced concrete box (rectangular) structures include cut-and-cover structures and mined station sections that behave in similar manner to rectangular structure during earthquake shaking. Design details for the seismic design of the reinforced concrete box structures must be in accordance with the provisions of the AASHTO 2017 and AASHTO 2010 and must comply with the requirements specified in this set.

722.3.11.3.2 Seismic Loads due to Racking Deformations and Vertical Motions

722.3.11.3.2.1 Seismic design of the transverse cross section of the structure must account for two loading components:

i. The racking deformations due to the vertically propagating shear waves, which is similar to the ovaling deformations of the circular tunnel lining, and

ii. Inertia forces due to vertical seismic motions.

722.3.11.3.2.2 The DOR must apply the effects of vertical and horizontal seismic ground motion using the following combinations:

EQ = 100% EQvert ± 30% EQhoriz

EQ = 100% EQhoriz ± 30% EQvert

722.3.11.3.2.3 The DOR must combine seismic loads due to racking deformations and vertical seismic motions with non-seismic loads using the load combination for Extreme Event T-I given in Table 722-1. Modify γp factor in Table 722-1 to be 1.2 in ODE load combination and 1.0 in MDE load combination for the load combination Extreme Event T-1.

722.3.11.3.3 Capacity Evaluation

722.3.11.3.3.1 The DOR must evaluate members designed to perform beyond the yield limit state using the moment-curvature (M-Φ) analysis to determine the strain distribution in the reinforcing steel and concrete as well as the displacement capacity of the inelastic system. The DOR must assume that the analytical plastic hinge length (Lp) is equal to half of the component thickness (h/2) unless justification for a larger value can be made.

722.3.11.3.3.2 The DOR must use nonlinear static “pushover” analyses to determine displacement capacity of the structure. The DOR must estimate the displacement capacity based on the material strain limits in Table 722-3:

Table 722-3: Strain Limit for Box Structure

EQ	Material	Strain Limit
ODE	Steel (ε_s)	0.002
	Concrete (ε_c)	0.003
MDE	Steel (ε_s)	0.020
	Concrete (ε_c)	0.006 (with seismic hoop confinement)

722.3.11.3.3.3 Where the DOR expects inelastic behavior to occur in the member adjacent to the slab/beam-to-column/wall joint, the DOR must design the horizontal member to respond elastically. The plastic hinge must not be on the soil side of the structural member, which is not easily accessible for inspection and repair.

722.3.11.3.4 Longitudinal Strain due to Axial and Curvature Deformations

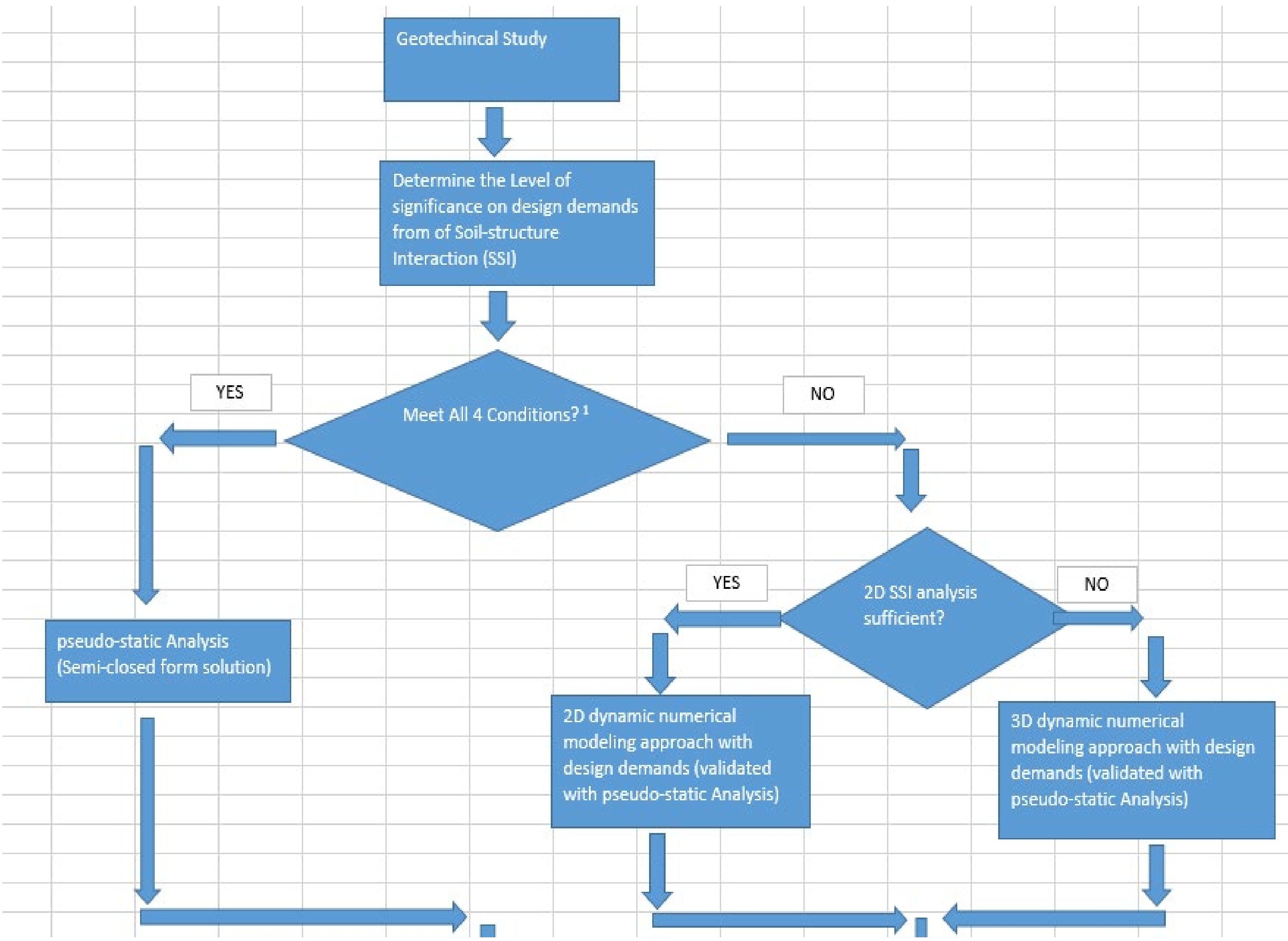
722.3.11.3.4.1 The DOR must apply the design and evaluation procedure specified in the AASHTO 2017 and AASHTO 2010 for cut-and-cover tunnel structures subject to axial and curvature deformations, except that the definition of "Y" is changed to the following:

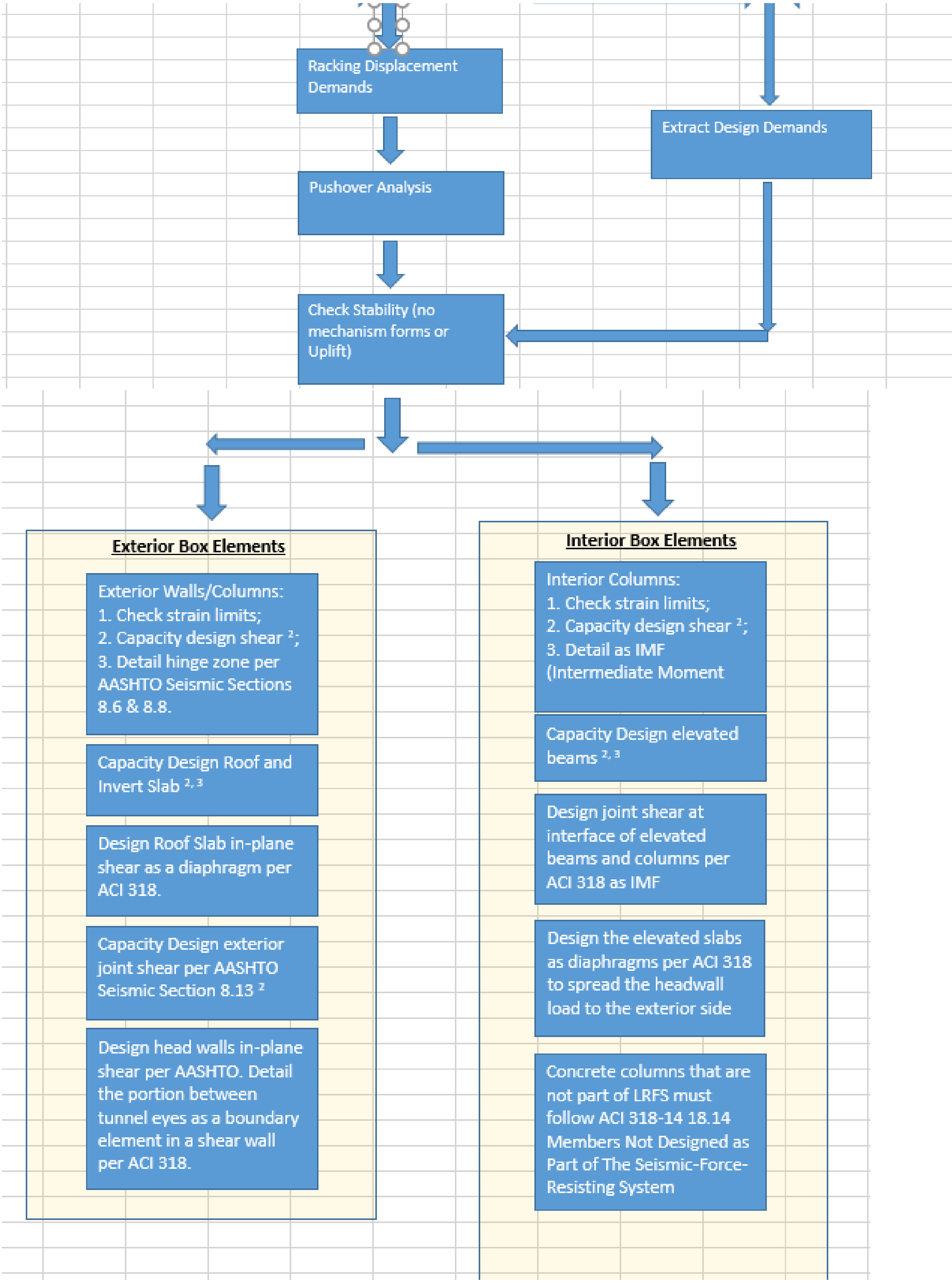
i. Distance from the neutral axis of the tunnel cross section to the extreme fiber of the cross section.

ii. Use material strain limits specified in Table 722-3.

Commentary: The seismic design of the cut-and-cover underground station structure may follow the flow chart in Figure 722-1.

Figure 722-1: Cut-and-Cover Underground Station Structure Seismic Design Flow Chart




Racking Displacement Demands
Pushover Analysis
Check Stability (no mechanism forms or Uplift)
Extract Design Demands
Exterior Box Elements
Exterior Walls/Columns: 1. Check strain limits; 2. Capacity design shear [2]; 3. Detail hinge zone per AASHTO Seismic Sections 8.6 & 8.8.
Capacity Design Roof and Invert Slab [2, 3]
Design Roof Slab in-plane shear as a diaphragm per ACI 318.
Capacity Design exterior joint shear per AASHTO Seismic Section 8.13 [2]
Design head walls in-plane shear per AASHTO. Detail the portion between tunnel eyes as a boundary element in a shear wall per ACI 318.
Interior Box Elements
Interior Columns: 1. Check strain limits; 2. Capacity design shear [2]; 3. Detail as IMF (Intermediate Moment
Capacity Design elevated beams [2, 3]
Design joint shear at interface of elevated beams and columns per ACI 318 as IMF
Design the elevated slabs as diaphragms per ACI 318 to spread the headwall load to the exterior side
Concrete columns that are not part of LRFS must follow ACI 318-14 18.14 Members Not Designed as Part of The Seismic-Force-Resisting System

1. Four conditions [MRDC 12th Rev Section 3B8.1]:
(1) The structure is of rectangular shape.
(2) The surrounding soil is reasonably uniform.
(3) There is no interaction effect from adjacent tunnels or other structures.
(4) The structure is continuous for great length with respect to the cross-section dimensions.

2. If exterior walls/columns are considered an integral part of the energy dissipating system but remain elastic at the demand displacement, the forces to use for capacity design of other components are to be a minimum of 1.2 times the elastic forces resulting from the demand displacement in lieu of the forces obtained from overstrength plastic hinging analysis, and the shear design of exterior walls/columns shall be based on 1.2 times elastic shear force resulting from the demand displacement and normal material strength shall be used for capacities. [WSDOT BDM 2020, Section 4.2.2]

3. When capacity design roof/ inverted slab/ elevated beams, ignore compression for shear capacity.

722.3.11.3.5 Interface Joints

722.3.11.3.5.1 The DOR must design interfaces between the cut-and-cover structures and the more massive structures, such as the station sections and ventilation/access structures, as flexible joints to accommodate the differential movements. The DOR must design for the differential movements in consultation with the Final Design Geotechnical Consultant.

722.3.11.4 Ventilation/Access/Entrance Shafts

Commentary: The seismic considerations for the design of vertical shaft structures are similar to those for the lined circular tunnel structure, except that ovaling and axial deformations in general do not govern the design. Racking will govern the shaft seismic design in soil.

722.3.11.4.1 The DOR must consider the curvature strains and shear forces of the lining resulting from vertically propagating shear waves. Force and deformation demands may be considerable in cases where shafts rest in deep, soft deposits. In addition, the DOR must properly assess and design for potential stress concentrations at the following critical locations along the shaft: (1) abrupt change of the stiffness between two adjoining geologic layers, (2) shaft/tunnel or shaft/station interfaces, and (3) shaft/surface building interfaces. The design must use flexible connections between any two structures with drastically different stiffness/mass in poor ground conditions.

722.3.11.4.2 Entrance Shaft Structure

722.3.11.4.2.1 The seismic design of the entrance shaft structure that supports the head house above ground must meet the following additional design requirements.

722.3.11.4.2.2 The design must consider the seismic loads in 722.3.11.3.2 under both ODE and MDE cases.

722.3.11.4.2.3 The design must meet Section 722.3.11.3.3 Capacity Evaluation with the except that, where the DOR expects inelastic behavior to occur in the member, the plastic hinge can be either on the beam or the column. The DOR must try to limit the plastic hinge to interior members where the inspection and repair can be performed post-earthquake. If the plastic hinge is expected on the column, the DOR must follow

AASHTO Seismic for column detailing and design the horizontal member to behave elastically. If the plastic hinge is expected on the beam, the beam must follow ACI 318 Chapter 18 Earthquake-Resistant Structures, Section 18.6, “Beams of Special Moment Frames,” and the column must behave elastically. Beam-to-column joint must follow ACI 318, Section 18.8, “Joints of Special Moment Frames.”

722.3.11.4.2.4 The DOR must propose the analysis approach for the review and approval from the Sound Transit Structural Engineer or its representative.

722.3.11.4.2.5 The wall that is considered as the shear wall must follow ACI 318, Section 18.10, “Special Structural Walls for Detailing."

722.3.11.4.2.6 Elevated floor slab that is designed as the diaphragm to transfer the lateral loads must follow ACI 318 Section 18.12 “Diaphragms and Trusses for detailing.”

722.3.11.5 Design the interior structural components in entrance shafts and underground stations that are not part of the Lateral-Force-Resisting-System accordance with IBC and the corresponding structural material (concrete, steel, and masonry) design codes referenced by IBC. Concrete columns that are not part of Lateral-Force-Resisting-System must follow ACI 318 Section 18.14 “Members Not Designed as Part of The Seismic-Force-Resisting System.”

722.3.11.6 Influence of Nearby Structures

722.3.11.6.1 The DOR must account for the influence of load effects from the nearby buildings or other significant structures in the design of underground structures and both ODE and MDE seismic events. The method of analysis must, at a minimum, include numerical analysis methods accounting for the potential base shear and deformations developed by the nearby building or structure. DOR must develop a detailed design approach and submit for review and approval from ST Structure Engineer or its representative.

Commentary: WSP’s Memorandum Task Order 32.00 Underground Structures Seismic Recommendations Memo (01/04/2022) suggests that the “nearby” structures that will influence the tunnel be identified during Preliminary Engineering phase. The mandate to account for these structures in the final design phase will be outlined in Engineering Procedure EP03 and defined as a technical requirement of the given project.

722.3.11.6.2 The detailed design approach must include an engineer familiar with the building design to estimate the realistic seismic effect from the nearby buildings.

722.3.11.7 Tunnel and Underground Structure Seismic Load during Construction

722.3.11.7.1 For temporary structures for cut and cover tunnels and box structures, their design must follow the section “Staged Construction and Temporary Structures” of the Set 721 Bridges and Elevated Structures criteria.

722.3.12 Nonstructural Components

722.3.12.1 The component importance factors of non-structural components in underground structures must be in accordance with Set 720 Building Structures.

722.3.12.2 Treat elements that are not considered to be part of Later-Force-Resisting-System as non-structural components. Use ASCE 7 Chapter 13 “Seismic Design Requirements for Nonstructural Components” to determine seismic loads.

722.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

722.4.1 System Breakdown Structure

722.4.2 System Sites and Locations

722.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this Requirements Set and other requirement sets.

Table 722-4: Interface Between Tunnel and Underground Structures and Other Disciplines

SET SERIES	SET NAME	SET 721 INTERFACE
000	General	X
100	Train Control and Signals	
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	
500	Track	X
600	Fire-Life Safety	X
700	Structures	X
800	Architecture	
900	Civil	X
1000	Mechanical-Electrical and Building Systems	
1100	Technology	
1200	Security	X

722.5.1 General

722.5.1.1 See Set 007 Noise and Vibration for noise level inside the LRV in a tunnel, and the vibration isolation of the tunnel and underground station.

722.5.2 Traction Electrification

722.5.2.1 Stray current requirements

722.5.3 Track

722.5.3.1 Cross passage spacing and door open requirements

722.5.4 Fire/Life Safety

722.5.4.1 Fire design requirements

722.5.5 Geotechnical Engineering

722.5.5.1 Geotechnical requirements

722.5.6 Building Structures

722.5.6.1 This Set provides the pressure load requirement for the design of components inside the tunnel and underground stations.

722.5.6.2 Non-structural component anchorage design

722.5.7 Bridge and Elevated Structures

722.5.7.1 Seismic design policy and seismic performance objectives

722.5.7.2 Seismic load during construction

722.5.8 Civil

722.5.8.1 Soil corrosion and stray current corrosion control for utilities

722.5.9 Security

722.5.9.1 Deterrence and detecting mechanism to prevent terrorist attack.

722.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

722.7 ENGINEERING MANAGEMENT REQUIREMENTS

722.7.1 Interface and Integration Management (Not Used)

722.7.2 Design Management

722.7.2.1 If any of submittal reviews are performed by the reviewers hired by the Design-Builder instead of by Sound Transit, the independent review team must meet the following requirements:

722.7.2.1.1 The independent review team members must have expertise in the relevant area, with the team lead having no less than 20 years of experience in the relevant area, and the Design-Builder must get the approval from Sound Transit Design Manager about the team;

722.7.2.1.2 The Design-Builder must get written approval from the independent review team that the method of analysis, basis of design (beyond what is prescribed in this section) and the team's comments have been satisfactorily addressed before construction can begin;

722.7.2.1.3 The independent peer review team must be completely independent of the design team consultants.

722.7.3 Manufacturing and Construction Management (Not Used)

722.7.4 Installation Management (Not Used)

722.7.5 Inspection and Testing Management (Not Used)

722.7.6 Training, Pre-Revenue Operations (Not Used)

722.7.7 Certification Management (Not Used)

722.8 APPENDICES (NOT USED)

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801 ARCHITECTURAL MATERIALS, ELEMENTS, AND FURNISHINGS

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SET - 801 ARCHITECTURAL MATERIALS, ELEMENTS, AND FURNISHINGS

801.1 INTRODUCTION

801.1.1 Document Scope

801.1.1.1 The following basic requirements and criteria have been established for finish materials used in public and non-public areas. While convenience, comfort, and attractiveness must be considered in the selection and application of finishes, safety, durability, and economy are essential attributes that must be satisfied.

801.1.1.2 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 801 owner to determine the technical source for the design criteria.

801.1.2 Regulations, Codes, Standards, and Guidelines

801.1.2.1 International Regulations, Codes, Standards, and Guidelines

801.1.2.1.1 International Code Council (ICC).

801.1.2.1.2 International Building Code (IBC).

801.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

801.1.2.2.1 American Architectural Manufacturer's Association (AAMA), Voluntary Specification, Performance Requirements and Test Procedures for Pigmented Organic Coatings on Aluminum Extrusions and Panels, AAMA 2603.

801.1.2.2.2 American Architectural Manufacturer's Association (AAMA), Voluntary Specification, Performance Requirements and Test Procedures for Pigmented Organic Coatings on Aluminum Extrusions and Panels, AAMA 2604.

801.1.2.2.3 American National Standards Institute (ANSI), Specifications for Ceramic Tile, ANSI A137.1.

801.1.2.2.4 American National Standards Institute (ANSI), American National Standard Test Method for Measuring Dynamic Coefficient of Friction of Hard Surface Flooring Materials, ANSI A326.3.

801.1.2.2.5 American National Standards Institute (ANSI), ESD Association Standard Test Method for the Protection of Electrostatic Discharge Susceptible Items – Floor Materials – Resistive Characterization of Materials, ANSI/ESD STM7.1.

801.1.2.2.6 Americans with Disabilities Act (ADA) standards and guidelines, refer to Set 001.

801.1.2.2.7 American Society for Testing and Materials (ASTM), Standard Test Method for 45-deg Specular Gloss of Ceramic Materials, ASTM C346.

801.1.2.2.8 American Society for Testing and Materials (ASTM), Standard Test Method for Specular Gloss, ASTM D523.

801.1.2.2.9 American Society for Testing and Materials (ASTM), Standard Practice for Determination of Graffiti Resistance, ASTM D6578.

801.1.2.2.10 Federal Transit Administration (FTA) Regulation, Buy America Requirements, 49 CFR Part 661.

801.1.2.2.11 Tile Council of North America (TCNA), Handbook for Ceramic, Glass, and Stone Tile Installation.

801.1.2.2.12 Underwriter's Laboratories (UL), Standard for Bullet-Resisting Equipment, UL 752.

801.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

801.1.2.3.1 Washington State Administrative Code.

801.1.2.3.2 Washington Industrial Safety and Health Act (WISHA).

801.1.2.3.3 Occupational Safety and Health Administration (OSHA)

801.1.2.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

801.1.2.5 Other Jurisdictions (Not Used)

801.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

801.1.2.7 Station Experience Design Guidelines.

801.1.3 Abbreviations and Acronyms

801.1.3.1 ADA–Americans with Disabilities Act

801.1.3.2 ANSI–American National Standards Institute

801.1.3.3 CCTV–closed-circuit television

801.1.3.4 CIP–cast-in-place

801.1.3.5 CMU–concrete masonry unit

801.1.3.6 DOR–designer of record

801.1.3.7 ETEL–emergency telephone system

801.1.3.8 FPZ–fare paid zone

801.1.3.9 HDPE–high-density polyethylene

801.1.3.10 L&I–Washington State Department of Labor & Industries

801.1.3.11 MSE–mechanically stabilized earth

801.1.3.12 OSHA–Occupational Safety and Health Administration

801.1.3.13 PA–public audio

801.1.3.14 PET–passenger emergency telephone

801.1.3.15 SCR–smart card reader

801.1.3.16 SOC–Security Operations Center

801.1.3.17 STPe– silyl-terminated polyether

801.1.3.18 TCNA–Tile Council of North America

801.1.3.19 TSS–Transportation, Safety, & Security

801.1.3.20 TVM–ticket vending machine

801.1.3.21 WAC–Washington Administrative Code

801.1.3.22 WISHA–Washington Industrial Safety and Health Act

801.1.4 Definitions and Classifications (Not Used)

801.1.5 References (Not Used)

801.2 STAKEHOLDER NEEDS

801.2.1 Passenger Experience

801.2.1.1 Accommodate the needs of persons with disabilities and comply with the requirements of ADA standards.

801.2.1.2 Consider the use of ceiling materials designed for the attenuation of sound. Ceiling finishes/systems and noise walls offer an effective means of controlling noise levels within tunnel and elevated stations.

801.2.1.3 The quality of the materials and the workmanship of their application must be at, or above, current industry standards. Refer to the qualifications and technical specifications of each section for further details.

801.2.1.4 Refer to the Station Experience Design Guidelines for passenger experience expectations.

801.2.2 Operational Needs

801.2.2.1 Materials, elements, and furnishings in public areas must withstand spray pressure washing.

801.2.2.2 Material, elements, and furnishings must be cleanable in a single operation with commonly used equipment and biodegradable cleaning agents.

801.2.2.3 Seating material must withstand inclement weather and repeat cleanings.

801.2.2.4 Provide maintenance and replacement access to roof and equipment areas.

801.2.2.4.1 Wall and ceiling finishes must accommodate maintenance access to equipment located behind the finish. Coordinate and identify equipment access requirements with other sub-systems.

801.2.2.5 Provide lockable access panels to access concealed systems for inspection, repair, and/or replacement.

801.2.3 Maintenance Needs

801.2.3.1 Initial materials costs must be weighed against long-term maintenance and replacement costs.

801.2.3.2 Floors in heavy wear areas must have a wear surface separate from the structural slab to facilitate replacement.

801.2.3.3 Materials, elements, and furnishings must not soil and stain easily.

801.2.3.4 The touch zone is subject to abuse and willful damage; therefore, materials, elements, and furnishings in this area must be especially resistant to damage and vandalism and capable of being quickly repaired in a cost-effective manner.

801.2.3.5 Materials, elements, and furnishings must be selected that are highly resistant to vandalism and retain their original appearance with a minimum amount of maintenance and repair.

801.2.3.6 Surfaces exposed to the public must be finished in such a manner that the results of casual vandalism can be readily removed with common maintenance techniques.

801.2.3.7 Minimize shelves, ledges, gaps, and elements that accumulate dirt and trash.

801.2.4 Safety Needs

801.2.4.1 Finish materials must not pose safety hazards to passengers. Safety hazards include but are not limited to:

i. Slips, trips, and falls
ii. Falling overhead objects
iii. Protruding objects

iv. Sharps edges
v. Pinch points

Commentary: An example of a safety hazard is a perforated material adjacent to escalators that would be capable of catching fingers as passengers ride the escalators.

801.2.4.2 Proper fasteners and adequate bond strength must be used to minimize hazards from dislodgment due to temperature change, vibration, water, wind, and vehicle movement through stations, seismic forces, aging, or other causes.

801.2.4.3 Floor materials with slip resistant qualities, as defined by relevant ANSI and/or ADA standards, must be used to increase pedestrian safety and accommodate the needs of individuals with disabilities. Stairways, platform edge strips, and areas around equipment must have high slip resistant properties.

801.2.4.4 Prevent vehicle intrusion into stations and station areas.

801.2.5 Security Needs

801.2.5.1 Fasten materials, elements, and furnishings to prevent removal or vandalism.

801.2.5.2 Provide deterrents to vehicle intrusion into stations and station areas.

801.2.6 Reliability, Availability and Maintainability Needs

801.2.6.1 Provide 2 percent of total material in attic stock of flooring, wall panels, ceiling tile, and soffit panels. Deliver to Sound Transit in factory packaging cross-referenced to the as-built specifications.

801.2.6.2 Structure, walls, ceilings, and canopy finishes and systems must allow access for future retrofitting of sub-systems.

Commentary: An example is the addition of data and power conduits for new CCTV and PA systems.

801.2.6.3 Material units must be large enough to reduce the number of joints yet small enough to facilitate replacement if damaged. Units must be able to be removed by no more than two people. Monolithic materials may be used if they can be easily repaired without the repair being noticeable.

801.2.6.4 Materials must be detailed and specified to be installed in accordance with industry standards and manufacturer's printed directions for long life, low maintenance, and compliance with manufacturer’s warranty requirements.

801.2.6.4.1 Provide continuous, evenly distributed 25-percent spare capacity by volume within voids of structure, walls, ceilings, and canopy systems for future installation of new systems.

Commentary: An example need for spare capacity would be post-installation of data and power conduits for additional CCTV and PA devices.

801.2.7 Environmental and Sustainability Needs

801.2.7.1 Sound Transit seeks to:
i. Minimize or eliminate the use of hazardous chemicals in the products used.
ii. Maximize the use of recycled products and sustainable materials.
iii. Meet third-party design levels indicated in Set 803 Sustainability.

801.3 SYSTEM REQUIREMENTS

801.3.1 General Requirements

801.3.1.1 Assist in the creation of a durable, well-ordered, safe, and visually pleasing transit system.

801.3.1.2 Facilitate passenger guidance, information, safety, and security in an aesthetically pleasing manner.

801.3.1.3 Architectural materials, elements, and furnishings must comply with the service life requirements in Set 001 General.

801.3.1.4 Exterior wall and roof systems must be designed for the Pacific Northwest climate best practices, including proper ventilation and rain shedding.

Commentary: To prevent long-term issues associated with water penetration, humidity control, and associated maintenance activities, wall and roof assemblies must be designed using industry best practice for weather resistant and rainscreen design principles.

801.3.2 Buy America

801.3.2.1 Materials, elements, and furnishings must comply with Buy America requirements.

801.3.2.2 Comply with the requirements of Section 165(a) of the Surface Transportation Assistance Act of 1982, as amended, and the applicable regulations in 49 CFR, Part 661.

801.3.3 Americans with Disabilities Act (ADA)

801.3.3.1 Comply with ADA standards. Refer to Set 001.

801.3.4 Safety

801.3.4.1 Fire Safety

801.3.4.1.1 Interior wall and ceiling finishes must comply with IBC Chapter 8 fire performance and smoke development criteria.

801.3.4.1.2 Comply with Set 601 Fire/Life Safety for furniture combustibility requirements.

801.3.4.2 Slip Resistance

801.3.4.2.1 Flooring must meet or exceed the wet dynamic coefficient of friction in accordance with ANSI A137.1 or the Exterior, Wet category as defined by ANSI A326.3.

Commentary: ANSI A137.1 is a standard for measuring the slip-resistance of ceramic tile commonly applied to other flooring materials. ANSI A326.3 is a newly adopted standard that communicates areas of use based on the slip resistance characteristics of products.

801.3.4.2.2 Expansion joint cover plates must be serrated, have grooved edges, or be of slip-resistant material to prevent slip hazard when wet.

801.3.4.3 Injury Prevention

801.3.4.3.1 Texture, voids, edges, composition, and application of finish materials must not pose safety hazards to passengers.

Commentary: Distracting floor patterns may disorient passengers or interfere with wayfinding.

801.3.4.3.2 Materials, elements, and furnishings must be securely anchored to prevent dislodgment hazards due to temperature change, vibration, water, wind, vehicle movement through stations, seismic forces, aging, and passenger impact.

801.3.5 Quality

801.3.5.1 Floor finish patterns must be simple and uniform.

801.3.5.2 Materials, elements, and furnishings must be installed in accordance with industry standards and manufacturer's printed materials.

801.3.5.3 Materials, elements, and furnishings must be recommended by the manufacturer for the specific conditions and use.

801.3.5.4 Use non-proprietary materials and products unless system-wide standard exists.

801.3.5.5 Select materials that retain their original appearance with a minimum amount of maintenance and repair, 20 years minimum to first repair or maintenance per manufacturer's printed data.

801.3.6 Sustainability

801.3.6.1 Comply with Set 803 Sustainability for sustainability requirements and considerations in the selection of materials, including:

i. Maximizing use of products containing recycled materials.
ii. Maximizing use of sustainable materials.
iii. Minimizing use of hazardous chemicals.

801.3.7 Light Reflectance

801.3.7.1 Wall finish in public areas must have a light reflectance value greater than 0.8.

801.3.7.2 Ceiling finish in public areas must have a light reflectance value greater than 0.8 measured in accordance with ASTM E1477.

801.3.8 Gloss

801.3.8.1 Materials, elements, and furnishings in public areas must have a minimum 10 gloss units and a maximum 70 gloss units measured in accordance with ASTM C346 and ASTM D523.

801.3.9 Acoustic Performance

801.3.9.1 Wall and ceiling materials must comply with Set 007 Noise and Vibration when used as acoustical treatment to meet noise level and reverberation criteria.

801.3.10 Resistance to Vandalism

801.3.10.1 Materials, elements, and furnishings within the reach of passengers must be robust and vandal-resistant to 15-foot-pound force without damage or deformation. See 801.8.2 Required Materials and Finishes.

801.3.10.2 Detailing of materials, elements, coatings, fasteners, and furnishings must discourage vandalism and be resistant to malicious defacement, damage, and removal.

801.3.10.3 Detailing of materials, elements, and furnishings must discourage skateboard rail riding. Provide physical breaks or physical blocks along edges at maximum 30-inch centers.

801.3.10.4 Materials and finishes must be designed to minimize the ability to climb them.

801.3.11 Graffiti Resistance

801.3.11.1 Comply with Sound Transit Standard Specifications for anti-graffiti coating requirements.

801.3.11.2 Materials, elements, and furnishings must be graffiti-resistant to minimum level 6 per ASTM D6578.

801.3.11.3 Exposed concrete and CMUs in the touch zone must be sealed with graffiti resistant coatings that do not affect appearance and allow easy removal of graffiti. Stop sealer at a logical breakpoint above the touch zone such as head of wall, control joint, and change of material.

801.3.11.4 Guideway concrete walls, piers, columns, abutments, MSE walls, superstructure at station areas, and other concrete elements must have WSDOT-approved pigmented sealer in WSDOT gray. Pigmented sealer must start and stop at joints, corners, and other physical demarcations.

Commentary: This allows easy coverage of graffiti.

801.3.12 Ballistic Resistance

801.3.12.1 Security office transaction window, wall, door, and door glazing must be bullet-resistant to minimum level 3 per UL 752.

801.3.12.2 Fall Protection

801.3.12.3 Comply with Set 804 Fall Protection for fall protection requirements.

801.3.12.4 Design team must enlist a fall protection design expert to design a fully functional fall protection and window washing system that complies with all requirements of WAC and WISHA.

801.3.13 Concrete

801.3.13.1 Staining of concrete floors is prohibited.

801.3.13.2 CIP topping slabs must include an improved finish that addresses the aesthetic quality of the station, including concrete color, scoring, and finish. Excessive cracking and defective finishes are prohibited.

801.3.14 Metals

801.3.14.1 Comply with Set 1005 Electrical Power for acceptable locations of exposed conductive surfaces at Link platforms.

801.3.14.2 Non-structural carbon steel and alloy steel assemblies, fixtures, and conduits for use in tunnels, stations, crawlspaces, vaults, and above grade which do not receive a corrosion control coating or architectural finish must be hot-dip galvanized. Refer to Set 222 Stray Current Corrosion Control and Sound Transit Standard Specifications for additional requirements.

801.3.14.3 Exposed steel, windscreens, railings, and mock-ups must be designed, detailed, and specified according to their level of visibility to the public. Use of Architecturally Exposed Structural Steel categories is prohibited. Exposed steel must comply with the following:

i. Exposed steel within 16 feet vertical and horizontal of the floor level in public areas must have welds ground smooth, exposed edges ground to a minimum radius, piece marks hidden, and erection aides removed.
ii. Exposed steel beyond 16 feet vertical and horizontal of floor level in public areas, areas visible only from the train, and in non-public spaces do not require welds ground smooth, exposed edges ground to a minimum radius, and piece marks hidden. Remove erection aids.

801.3.14.4 Provide weep holes at low spots of all tube and pipe sections to drain condensation.

801.3.14.5 Tolerances used for structural steel must be accommodated in the design of interfacing elements. This includes maintaining required clearances and providing accurate installation details for adjacent materials with differing tolerances. The interface details between structural steel and other materials must account for these dimensional variations. Plumb and level finishes with consistent unit dimensions and joints must be provided.

801.3.14.6 Selected steel members must be available within current average lead times as reported by national steel sector publications.

801.3.14.7 Exposed steel must be finished per Section 09 96 00 High Performance Coating in the Sound Transit Standard Specifications.

801.3.14.8 Steel must be shop-fabricated in sections, shop primed, shop finished, and assembled on site. Mechanical attachment and anchoring preferred. Minimize on-site welding and touch up painting.

801.3.14.9 Metals must be isolated from concrete and dissimilar metals. Type of isolation must be based on best practice standards for the specific conditions.

801.3.14.10 Corrosion control engineering must be provided and coordinated with other elements including mechanical, utility, plumbing, fire protection, electrical, civil, structural, trackwork, electrification, signaling, and communications systems.

Commentary: Atmospheric corrosion control helps prevent premature corrosion and defects in facilities.

801.3.15 Stainless Steel

801.3.15.1 Stainless steel must be Type 316 or Type 316L for welding conditions. Stainless steel must have chemical passivation treatment. Use Type 304 stainless steel with prior Sound Transit approval only.

Commentary: When parts of specified products or assemblies are only available in Type 304, Sound Transit may approve the use of Type 304 pending compliance with other requirements noted in this set. An example of this exception are components of overhead coiling grilles.

801.3.15.2 Stainless steel must be Type 316 for installations between finished floor and 18 inches above finished floor.

Commentary: Metals near walking surfaces are routinely exposed to de-icing materials, water, or other corrosives. Type 316 stainless steel, with its additional corrosion resistance over Type 304, is the more durable material at these locations.

801.3.15.3 Stainless steel finish must have a random orbital finish unless noted otherwise.

801.3.15.4 Stainless steel must be isolated from ferrous metal. Do not weld stainless steel to ferrous metal.

801.3.15.5 All gutters and downspouts at stations must be Type 316 stainless steel. Refer to Set 901 Storm Drainage.

801.3.16 Aluminum

801.3.16.1 Use at least 70 percent fluoropolymer coatings for aluminum framing systems with color. Refer to Section 801.3.29.1 Colors for additional requirements.

801.3.17 All Stairs

801.3.17.1 Slope treads and landings to drain towards the tread nosing to avoid water ponding and freezing. Conduct water to drains with flashings, gutters, leaders, and downspouts to prevent water ingress to weather-protected spaces and voids.

Commentary: Sloping treads and landings toward the tread or landing below avoids water ponding, freezing, and dripping to onto stairs directly below.

801.3.17.2 Comply with Set 1002 MEP – Plumbing for drainage requirements at stairs.

801.3.17.3 Landing and tread nosings must have two-part replaceable inset aluminum tread nosing with contrasting grit insets.

801.3.17.4 Intermediate infill of railings must deter climbing.

801.3.17.5 Refer to Sound Transit Customer Signage Design Manual for directional braille signage requirements on handrails.

Commentary: Directional braille signage on handrails qualifies as a LEED Transit credit.

801.3.18 Metal Stairs

801.3.18.1 Comply with Table 801-5.

801.3.19 Concrete Stairs

801.3.19.1 Precast concrete tread and riser units must be mechanically attached to structure. Epoxy connections are prohibited.

Commentary: Mechanically attached tread and riser units can be removed and replaced for future repairs.

801.3.20 Public Stairs

801.3.20.1 Use precast concrete treads and landings with medium sandblast or acid etch finish on treads for non-slip surface.

801.3.20.2 Handrails and guardrail top and bottom rails must be Type 316 stainless steel with number 4 satin finish.

801.3.20.3 Intermediate infill of railings:

i. At weather-protected stairs: stainless steel (preferred) or painted steel with high performance coatings.
ii. At non-weather-protected stairs: stainless steel.

801.3.20.4 Weld all joints prior to coating.

801.3.21 Non-Public Stairs

Commentary: Non-public stairs include stairs that are not intended for daily public use such as dedicated emergency egress stairs as well as maintenance stairs accessible only by Sound Transit or authorized personnel.

801.3.21.1 Use cast-in-place or precast tread and riser units with precast landings.

Commentary: Concrete-filled metal pan stairs may be allowed if they are fully enclosed to prevent corrosion. Sound Transit approval to use concrete-filled metal pan stairs is required.

801.3.21.2 Coat handrails and guardrails with high-performance coating in accordance with Sound Transit Standard Specifications.

801.3.21.3 Refer to Set 721 Bridge and Elevated Structures for guideway stair and railing requirements.

801.3.22 Openings

801.3.22.1 Maneuvering Clearances

801.3.22.1.1 Door and gate maneuvering clearances must not overlap with the dynamic envelope at station platforms.

801.3.22.2 Doors and Frames

801.3.22.2.1 Comply with Table 801-5 for material requirements.

801.3.22.2.2 Doors, overhead coiling grilles, and vertical lift gates must be designed to prevent intrusion from the exterior.

Commentary: Openings with perforations, such as steel-grated doors, are subject to being opened from the exterior with a strap or other device that can be inserted through the perforation.

801.3.22.3 Emergency Access

801.3.22.3.1 Emergency access key boxes (Knox Box or equal) must be provided to allow for rapid entry by emergency responders. Quantities, types, and locations per local fire department. Refer to Set 601 Fire–Life Safety for emergency access requirements.

801.3.22.3.2 Elevator key boxes must be provided to allow elevator and elevator machine room access by Washington State Department of L&I as required by WAC section 296-96.

801.3.22.3.3 Elevator key box must be manufactured by Quality Elevator Products, Inc. The key box model must be High Security Fire Key Box model SKB-H-39504, black powder-coated, engraved “ELEVATOR” label.

801.3.22.3.4 Elevator machine room doors must be keyed to allow L&I access. Intervening doors must be keyed to match the elevator machine room doors or access card readers must be provided.

Commentary: Locate elevator machine rooms with direct exterior access or through one main door to avoid unintended access to other areas of the facility.

801.3.22.4 Door Hardware

801.3.22.4.1 Doors accessible to the public must have stainless-steel kick plates on both sides.

801.3.22.4.2 Door closers must have parallel closer arms.

801.3.22.4.3 Door hardware in exterior locations must be marine hardware with brass interior parts.

801.3.22.4.4 Hardware must be compatible with Sound Transit’s proprietary keying systems:

i. BiLock for Link facilities.
ii. Kaba Peaks for Sound Transit-maintained parking garages, Sounder stations, and Sound Transit Express facilities.
iii. Keying systems at other facilities must be confirmed with ST Facilities & Systems Maintenance.

801.3.22.4.5 Overhead coiling grilles and vertical lift gates must be activated by access card readers. Refer to Set 1203 Access Control Systems.

801.3.22.5 Access Control

801.3.22.5.1 Access card readers are required. Location of access card readers must be determined in conjunction with Sound Transit and requirements identified in Set 1203 Access Control Systems.

801.3.22.5.2 Access card readers on interior exit stair doors must be fail-safe. Electric latches and hinges must be used in these conditions in lieu of electric strikes.

801.3.22.5.3 Access card readers located on exterior entrance doors must be fail-secure.

801.3.22.5.4 Intrusion detection systems are required. Refer to Set 1203 Access Control Systems.

801.3.22.5.5 Comply with security parameters listed in Table 801-4 in the Appendices.

801.3.23 Glass and Glazing

801.3.23.1 Glass sizes in headhouses and shelters owned and maintained by Sound Transit must not exceed 4 by 8 feet. Comply with Table 801-1 for size requirements specific to canopies, windscreens, and elevator shafts.

801.3.23.1.1 Larger glazing sizes must be limited to areas away from platforms and tracks and areas that are easily accessible. Where there are additional entrances into the station through a Joint Development agreement, larger glass sizes are acceptable at storefront and in canopies.

Commentary: This language aligns with the SEDG.

801.3.23.2 Where the total glazed surface area is greater than 40 percent relative to the entire façade, provide bird collision deterrent on the glazing.

Commentary: The quantity is based on a study performed by the City of Toronto on the amount of glazing that can reduce fatal bird collisions, documented in a development guideline (Bird-Friendly Best Practices – Glass). Examples of bird collision deterrent are frit or decals.

801.3.23.3 Clear glazing directly adjacent to the track or within 10 feet of the OCS is prohibited.

Commentary: Glazing adjacency to the track limits cleaning and repairs to non-revenue hours. Additionally, the OCS must be deactivated for every maintenance or repair if glazing is within 10 ft of the OCS.

801.3.24 Elevator Shaft Glazing

801.3.24.1 Elevator glass must be laminated. Hoistway glass must be replaceable from the exterior.

801.3.24.2 Elevator shaft glass size must comply with Table 801-1.

801.3.24.3 Glazing must comply with Table 801-1 when structural steel members are in the same plane.

Table 801-1: Glass Sizes

Application	Glass Size (Actual)	Grid Size
Windscreen / Elevator Shaft	2'-9" x 3'-11"	2'-10" x 4'-0"
	2'-9" x 2'-9"	2'-10" x 2'-10"
	3'-11" x 3'-11"	4'-0" x 4'-0"
Canopy / Elevator Shaft	1’-11 ½” x 3’-11 ½”	2’-0” x 4’-0”
	2’-5 ½” x 3’-11 ½”	2’-6” x 4’-0”
	3’-11 ½” x 3’-11 ½”	4’-0” x 4’-0”
	3’-11 ½” x 5’-11 ½”	4’-0” x 6’-0”

801.3.24.4 For all other glazing locations, coordinate glass sizes with Sound Transit Station Experience Design Guidelines.

801.3.24.5 Elevator shaft glass in the touch zone must have anti-graffiti film that is accessible by maintenance personnel.

801.3.25 Windscreen Glass

801.3.25.1 Windscreen glass must be minimum 1/4-inch fully tempered clear glass.

801.3.25.2 Windscreen glass in the touch zone must have anti-graffiti film on all sides and be accessible by maintenance personnel.

801.3.25.3 Where windscreen glazing is located above traffic lanes or trackway, tempered-laminated glass may be used with Sound Transit approval.

801.3.26 Vertical Glazing

801.3.26.1 Vertical glazing up to 12 feet from floor or grade must use minimum 1/4-inch thick fully tempered clear glass.

801.3.26.2 Vertical glazing above 12 feet from floor or grade must use tempered-laminated with two layers of minimum 1/8-inch clear glass.

801.3.27 Canopy and Sloped Glazing

801.3.27.1 Canopy and sloped glazing must use laminated glass with a 65 percent light transmittance translucent white interlayer between two layers of minimum 1/8-inch clear glass or as otherwise required to meet code.

801.3.27.2 Canopy and sloped glazing may consist of laminated clear glass at locations where art is integrated into the glass. See Set 808 STart Program for artwork requirements.

801.3.28 Frames and Framing Systems

801.3.28.1 Framing must be detailed to maintain conformance with required glass sizes and to accommodate structural movement without breakage or dislodgement. Refer to Set 720 Building Structures for structural requirements.

801.3.28.2 Frames must accommodate up to 1-inch total glass thickness where art is integrated into the glass. Refer to Set 808 STart Program for artwork requirements.

801.3.28.3 Refer to Sections 801.3.14 Metals and 801.3.29.1 Colors for additional requirements.

801.3.29 Finishes

801.3.29.1 Colors

801.3.29.1.1 Colors must be consistent with system-wide identity colors, compatible with the surrounding area, and of sufficient contrast and accent to provide visual interest, warmth, and concealment of minor soiling.

801.3.29.1.2 Refer to the Sound Transit Station Experience Design Guidelines for station accent colors and the process for selection.

801.3.29.1.3 Materials, elements, and furnishings with integral colors or factory finishes, such as tile, metal wall panels, and metal roofing panels, may use colors other than the standard steel colors identified in Table 801-2. Factory finishes must be of the most durable type available for the product, 70percent fluoropolymer or similar.

801.3.29.1.4 Metallic colors are prohibited.

Commentary: Metallic colors are difficult to replicate. Non-metallic or "solid" paints will allow future touch-ups to blend more easily with adjacent surfaces.

801.3.29.1.5 Kynar aluminum framing systems are preferred in the touch zones for glazing or metal panels.

801.3.29.1.6 Comply with colors listed in Table 801-2 for painted metal finishes.

Table 802-2: Metal Paint Colors

Color Name	Color Code[a]	Application
Sound Transit Dark Blue - FED 25042	Sherwin Williams 8156-39371	
Charcoal Gray – FED 27038	Sherwin Williams 8156-38953	
Custom Mix Old Monterey	Sherwin Williams 8156-53607	
Light Gray	Sherwin Williams 8156-39372	Interior walls in non-public spaces
Ferrari Red	Sherwin Williams (Pompeii Red) 8156-53606	Accent color
Pencil Yellow	Sherwin Williams 8156-39373	Accent color
a. Color code is provided for matching purposes only. Specification or use of proprietary product is not required.		

801.3.29.2 Materials

801.3.29.2.1 The use of a standardized family of materials for stations provide consistency for the system. Comply with 801-5 in Appendices.

801.3.29.3 Public Areas

801.3.29.3.1 Materials in public spaces refer to materials used to finish surfaces of a facility that are exposed to the public and to the environment including sun, wind, and rain.

801.3.29.3.2 Open wall elements refer to vertical wall surfaces that provide enclosure while permitting ventilation and views into and out of space.

801.3.29.3.3 Align panel joints and mullions in stairs and escalators vertically.

Commentary: Diagonal joints perpendicular to sloped elements can create a sense of vertigo for passengers.

801.3.29.4 Non-Public Areas

801.3.29.4.1 Materials in non-public spaces refer to materials used to finish surfaces of a station or facility that are not directly exposed to the exterior environment, nor to public view or use.

801.3.29.4.2 Finishes and wall substrates in non-public areas must be moisture and impact resistant.

801.3.30 Flooring

801.3.30.1 Flooring must comply with Sound Transit Standard Specifications.

801.3.30.2 Movement joints must comply with TCNA Handbook directions. Align movement joints with structural joints in substrate.

Commentary: Tile and pavers expand and contract differently than the structural substrate. Movement joints eliminate these stresses and prevent defects. Refer to TCNA EJ171 for guidance on spacing. Generally, joints should be aligned with the structural grid and platform structure joints. For exterior installations, the maximum is 8 to 12 feet.

801.3.30.3 Platform flooring must comply with Sound Transit Standard Drawings for assembly and drainage requirements.

801.3.31 Coatings

801.3.31.1 Coatings must have performance records for the intended service.

801.3.31.2 Coatings must have a minimum service lifetime-to-major-maintenance or reapplication of 20 years.

801.3.31.3 Coatings must have a minimum 20-year gloss retention, color retention, and resistance to chalking.

801.3.31.4 Coatings must be compatible with the base metal.

801.3.31.5 Coatings applied on the same member or assembly must be compatible.

Commentary: Shop-applied primers for steel are typically specified in Division 05, while high-performance coatings are specified in Division 09. The intent of this requirement is to indicate that the entire coating system, regardless of application location, needs to be reviewed for compatibility.

801.3.31.6 Organic coating systems must consist of a wash primer (for galvanized and aluminum substrates only), a primer, intermediate coat(s), and a finish coat. Acceptable organic coatings for exterior applications are:

i. Aliphatic polyurethanes.
ii. Vinyl copolymers.
iii. Fusion-bonded epoxy polyesters, polyethylenes, and nylons.
iv. Acrylics, where not exposed to direct sunlight.
v. Alkyds, where not exposed to direct sunlight.
vi. Epoxy as a primer where exposed to the atmosphere or as the complete system where sheltered from sunlight.

801.3.31.7 Conversion coatings, such as phosphate and chromate coatings, may only be used as pretreatments for organic coatings.

801.3.31.8 Ceramic-metallic coatings are acceptable for metal panels and fastening hardware.

801.3.31.9 Use one of the following barrier coating systems where corrosion protection is needed but appearance is not a primary concern. Apply coatings according to manufacturer's specifications.

i. Three-coat epoxy.
ii. Three-coat epoxy zinc.
iii. High-build epoxy.

801.3.31.10 Use one of the following barrier coating systems where corrosion protection and good appearance are needed. Apply coatings according to manufacturer's specifications.

i. Three-coat inorganic zinc.
ii. High-build epoxy.
iii. Polyester urethane.
iv. Three-coat vinyl.

801.3.32 Sealants

801.3.32.1 Seal all joints with a compatible, non-staining polysulfide, polyurethane, silyl-terminated polyether (STPe), acrylic latex, synthetic rubber, or silicone sealant.

801.3.33 Restrooms

801.3.33.1 Restrooms must comply with ADA standards and local accessibility requirements.

801.3.33.2 Restrooms must have electric hand dryers. Self-reporting features are not required.

801.3.33.3 All restroom hygiene products (e.g., lavatory faucets, urinals, toilets, hand dryers) must have "hands-free" operation.

801.3.33.4 Diaper changing stations or syringe disposal chutes are not required.

801.3.33.5 Refer to Sound Transit Standard Drawings for restroom layouts.

801.3.33.6 Restroom finishes must comply with Table 801-5.

801.3.33.7 Refer to Set series 1000 for MEP requirements.

801.3.34 Public Restrooms

801.3.34.1 Public restroom doors must not be accessible to the public during non-revenue hours.

801.3.34.2 Public restrooms must be unisex and ADA compliant.

801.3.34.3 Security camera coverage must be provided at the restroom entry area.

801.3.34.4 Provide an intercom adjacent to the exterior side of the door at each restroom. Refer to Set 1203 Access Control for concept of operations.

801.3.34.5 Provide restroom door with electronic latch linked to SOC for remote access. Door must be self-closing. Provide door with privacy lock indicating "Vacant/Occupied" at exterior that can be overridden with a physical key.

801.3.34.6 Public address speaker inside each restroom.

801.3.34.7 Intercom system inside each restroom.

801.3.34.8 Public restrooms must use the following stainless-steel, vandal-resistant fixtures and accessories by Duraclenz:

i. Sensor-operated toilet.
ii. Sensor-operated soap dispenser. Self-reporting features are not required.
iii. Electronic paper dispenser. Self-reporting features are not required.
iv. Mirror.
v. Recessed sanitary disposal unit.

801.3.35 Staff Restrooms

801.3.35.1 Staff restrooms must be located out of public view.

801.3.35.2 Provide a visual "Occupied" lock separate from the keyed lock.

801.3.35.3 Staff restrooms must have feminine hygiene dispensers that do not require coins to operate.

801.3.35.4 Staff restrooms must be unisex and equipped with a urinal

801.3.35.5 Cubicle mounting system must be floor-to-ceiling type.

801.3.36 Seating

801.3.36.1 Each "seat" must be defined as a seat width of 21 to 24 inches.

801.3.36.2 Seating design must prevent individuals from lying down or sleeping.

801.3.36.3 Seating must conform to ADA standards.

801.3.36.4 Seating must not be provided adjacent to railings, stairways, or other openings which may present a fall hazard where the grade difference is more than 4 feet at the location of the seating.

801.3.36.5 Comply with Sound Transit Standard Specifications for approved seating products.

801.3.36.6 Bench supports must be isolated from the concrete structure and flooring materials with minimum 1/4- inch thickness HDPE or mylar shims.

Commentary: Isolation prevents degradation due to deicers and stray current corrosion.

801.3.37 Lean Rails

801.3.37.1 Comply with Sound Transit Standard Specifications for approved lean rail products.

801.3.37.2 Lean rail supports must be isolated from the concrete structure and flooring materials with minimum 1/4- inch thickness HDPE or mylar shims.

801.3.38 Vehicle Barriers

801.3.38.1 Provide barriers to deter vehicular intrusion where pedestrians congregate and at elements that are essential to the continued operation of the facility, including plazas, station entrances, elevators lobbies, exit stairs, and critical equipment. Refer to Set 720 Building Structures for structural requirements and other sets that identify critical equipment.

801.3.38.2 Barriers in an array must not leave a gap larger than 5 feet.

Commentary: This spacing deters vehicles while still allowing frequently utilized maintenance equipment access and flow of pedestrians.

801.3.38.3 Acceptable vehicle barrier solutions include bollards, planters, boulders, grade changes, or other elements.

801.3.38.4 Bollards must achieve the following crash ratings. Coordinate ratings with Sound Transit Transportation Safety and Security.

i. M# rating when tested in accordance with ASTM F3016.
ii. K# rating when tested in accordance with the US Department of State and Department of Defense standard.

801.3.38.5 Allowable bollard materials include:

i. At highly visible, public locations: Grade 316 stainless steel.
ii. At public locations: Concrete-filled steel tube with high performance coating. Comply with the Sound Transit Standard Specifications for high performance coatings.
iii. At non-public locations: Galvanized, concrete-filled steel tube.

Commentary: See Set 1007 Electrical Lighting for bollard lighting requirements.

801.3.38.6 Bollards must be a removable type with a keyed lock when located along maintenance circulation paths.

Commentary: Maintenance vehicles and equipment, including lifts, must be able to navigate within and around facilities. Circulation path for future replacements of larger equipment must also be maintained.

801.3.38.7 Provide vehicle barriers between parking stalls and accessible aisles in parking garages. Curbs or wheel stops as a form of vehicle barrier is prohibited.

Commentary: Vehicle barriers facilitate safe movement of passengers with disabilities from their vehicle to the garage exits/entries. Low walls or bollards are more effective than wheel stops at preventing vehicles from intruding into the clear width of the accessible aisle. Additionally, wheel stops hinder use of maintenance equipment in the surrounding area.

801.3.38.8 Provide recessed flanged surface-mount bollards in parking garages. Through bolt connections through the slab is prohibited.

801.3.39 Trash and Recycling Receptacles

801.3.39.1 Comply with Set 820 Facility Area Planning, Set 821 Station Layout – Commuter Rail, Set 822 Station Layout – Light Rail, and Set 830 Parking Facilities Layout for locations at each facility type.

801.3.39.2 Comply with Sound Transit Standard Specifications for receptacle requirements.

801.3.39.3 Receptacles must be isolated from the concrete structure and flooring materials with HDPE or Mylar shims.

Commentary: This prevents degradation due to deicers and stray current corrosion.

801.3.39.4 Receptacles must be secured to the floor or ground to avoid removal by unauthorized persons and must be vandal-resistant.

801.3.39.5 Trash and recycling receptacles must be placed together as a pair wherever receptacles are located.

801.3.39.6 Ash urns are prohibited except at OMF smoking sheds.

801.3.40 Bicycle Facilities

801.3.40.1 Accommodate bicycle parking where required in Set 807 Bike Program.

801.3.41 Bird Control

801.3.41.1 The following lists the hierarchy of acceptable bird control, in descending order of preference:

i. Access prevention, such as fully enclosed ceilings and blocked openings to cavities and spaces.
ii. Elimination of exposed horizontal surfaces, such as open ledges, exposed or suspended light fixtures, light fixtures with flat tops and no protection, and exposed structural members.
iii. Shaping of members or sloping of exposed horizontal surfaces at a 45-degree angle.
iv. Application of physical deterrents.

Commentary: Sloping exposed horizontal surfaces deters birds from roosting on those surfaces.

Commentary: Fully enclosing the ceiling serves a dual purpose of concealing conduits and pipes that run under the guideway and optimizing station aesthetics and passenger experience. An example of a fully enclosed ceiling surface is a suspended metal panel system.

801.3.41.2 Structures and parts of structures must be designed and located to prevent bird roosting.

Commentary: An example would be tightlining exposed structures to the underside of roofs or ceiling, or avoiding the use of horizontal W-sections that provide a ledge for birds to roost on

801.3.41.3 Fully closed ceiling surfaces are required at stations and plaza areas. Bird netting as a station ceiling finish is prohibited.

801.3.41.4 Bird control devices must not rely on equipment that need power, batteries, or ongoing maintenance.

801.3.41.5 Provide bird deterrent solutions that are visually unobtrusive.

801.3.41.6 Bird deterrent materials must comply with fire resistance requirements outlined in NFPA 130, IBC, and Set 601Fire–Life Safety.

801.3.41.7 Provide bird deterrent systems to horizontal structures and parts of structures open to bird roosting.

Commentary: Spikes are a method of bird deterrent on exposed horizontal surfaces such as lower girder flanges.

801.3.41.8 Use netting on larger openings in non-public spaces, or flexible joint material in smaller openings where feasible to minimize use of bird deterrent devices.

801.3.41.9 Provide netting or other bird deterrent to prevent birds from entering the interstitial spaces through open expansion joints, drain holes, or other points of entry. Refer to Set 721 Bridges & Elevated Structures for bird control requirements at non-station areas.

801.3.41.10 Adhere to, the following requirements where netting is provided:

i. Specify a high-quality netting that is intended for bird control purposes. Openings must be maximum ¾-inch wide in both directions. Netting color must be dark to recede visually.
ii. Use clamped connections to structural members.
iii. Provide zippers at locations requiring future access, such as junction boxes, speakers, or other ceiling-mounted devices. Locate zippers within 12 inches of elements requiring maintenance.
iv. Suspend light fixtures below the bird netting surface to provide easier access for relamping, maintain lighting levels prescribed by Set 1007 Electrical Lighting, and support passenger experience via improved aesthetics. Comply with Set 1007 Electrical Lighting for bird deterrent strategies at light fixtures.

v. Ensure that the bird netting product's melting temperature is higher than the heat load anticipated by the light fixtures.
vi. Netting must be inspected at least monthly to ensure that it has not been damaged. Enlarged netting holes that permit bird access exacerbate the bird control problem. Birds that become caught in the netting may die, creating an inhumane condition in addition to health and aesthetic problems. Trapped birds must be removed promptly along with repairs to the damaged netting.
vii. Netting may be used not only at ceiling surfaces, but also to enclose vertical openings anticipated to be attractive to birds.
viii. Netting has an approximate 10-year life. Total cost of ownership calculations must take the replacement cost into account when calculating alternatives.
ix. Where netting is unable to be used due to small areas or geometric constraints, use semi-rigid wire mesh that is formed to the required shape. Bird spikes may also be used but can sometimes have the unintended effect of providing birds a structure around which to build a nest. Finally, bird wire is an effective strategy on linear applications such as suspended cable trays, signage, or piping.

801.3.41.11 Where elements cannot be designed or blocked accordingly, install stainless-steel bird deterrent devices appropriate for the condition such as piano wire, movable spiders, spikes, or other deterrents.

801.3.41.12 Refer to Section 801.7 Engineering Management Requirements for bird control submittal requirements.

801.3.42 Advertising

801.3.42.1 Advertising must be in conformance with all applicable codes.

801.3.42.2 Sound Transit determines whether advertising will be accommodated in facilities depending on location and patronage. Refer to the procedure outlined in the Sound Transit Customer Signage Design Manual.

801.3.42.3 When advertising is to be accommodated, identify appropriate locations for advertising.

801.3.43 Design

801.3.43.1 The format and size of advertising must be compatible with the volumes of the interior or exterior spaces in which they are located and must in all cases be compatible with the architectural expression of the facility.

801.3.43.2 Advertising must work with the existing ambient lighting of the facility. Special lighting for advertisements is prohibited.

801.3.44 Location

801.3.44.1 Advertising must not compromise the function, wayfinding, architectural, and artistic expression of the facility.

801.3.44.2 Advertising must not conflict, by placement or treatment with, or take priority over, operations, wayfinding, system signing, information, or art.

801.3.44.3 Advertising must be carefully located so as not to obstruct, cause distraction, or impede passenger movement. The materials used and the location of advertising must not create a safety hazard.

801.3.44.4 Do not locate advertising where points of decisions are being made, customer information is provided, or where confusion may result due to its presence. Refer to Sound Transit Customer Signage Design Manual for requirements.

801.3.44.5 Advertising must not to conflict with visual legibility of emergency exits or equipment, particularly at platforms.

801.3.44.6 Entry, ticket concourse, and mezzanine areas are not suitable for advertising due to the amount of customer information and passenger movement occurring at these locations.

801.3.44.7 Advertising must not be in areas that block or interfere with FPZ signs.

801.3.44.8 A minimum two-foot clear buffer zone without advertising must be maintained around all TVMs, SCRs, ETELS, PETs, customer information, and signage. FPZ signs require a 5-foot minimum buffer.

801.3.44.9 Advertising may be appropriate in across-track locations on the platform level. It must not conflict with regulatory signs, system signing, and information.

801.3.44.10 The placement of advertising in vertical transportation spaces are a distraction for the passenger. Advertising must not be located at the top and bottom landings or along walls of escalators and stairs. Advertising must not be placed near elevator control buttons, on elevator doors, or inside the elevator car.

801.3.45 Digital Advertising

801.3.45.1 Advertising must be carefully controlled on all electronic message units that are used for system signing and information.

801.3.45.2 Provide infrastructure, including power and data, as described in the Sound Transit Customer Signage Design Manual.

801.3.46 Material

801.3.46.1 Advertising material must meet code requirements regarding flame spread and level of combustibility for the type of structure where it is installed.

801.3.46.2 Materials used in the fabrication of advertising material must be durable and vandal-resistant.

801.3.46.3 Installation of advertising material must not damage permanent surfaces.

801.3.46.4 Advertising material must not be placed on painted surfaces.

Commentary: This prevents damage to painted surfaces.

801.3.46.5 Advertising material must be low maintenance and withstand pressure washing.

801.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

801.4.1 System Breakdown Structure

801.4.1.1 Architectural materials, elements, and furnishings include the following elements:

i. Materials and finishes
   a. Aesthetic
   b. Color
   c. Pattern
   d. Glazing
   e. Wood
   f. Concrete
   g. Metals
   h. Masonry
   i. Paint
   j. Coatings
   k. Roofing
   l. Flooring
ii. Access control
   a. Keying
   b. Hardware
   c. Card readers
   d. Jurisdiction access
iii. Furnishing
iv. Bird and pest control
v. Trash and recycling receptacles
vi. Stair
   a. Detailing
   b. Guardrail
   c. Handrail
   d. Infill
vii. Weather protection
viii. Detailing
ix. Restroom
   a. Fixtures
   b. Accessories
x. Skateboard deterrent
xi. Advertisement

801.4.2 System Sites and Locations

801.4.2.1 Architectural materials, elements, and furnishings is applied to all modes in the following facility types:

i. Facility area
ii. Station
iii. Parking facility
iv. Operations and maintenance base / facility

801.4.2.2 Locations include:

i. Facility area, including plazas
ii. Walls, floors, ceilings, roofs
iii. Stairs

a. Public
b. Exit
c. Maintenance

iv. Elevator
a. Hoistway

v. Platform

801.5 SYSTEM INTERFACE REQUIREMENTS

Table 801-3 lists requirement sets that are typically coordinated, and may have dependencies, with this set.

Table 801-3: Interface Between Architecture and Other Disciplines

SET SERIES	SERIES NAME	SET 801 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	
300	Operational Communications	
400	Vehicle	
500	Track	
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	
1000	Mechanical / Electrical and Building Systems	X
1100	Technology	
1200	Security	X

801.5.1 General

801.5.1.1 Coordinate Buy America requirements.

801.5.2 Noise & Vibration

801.5.2.1 Coordinate interior acoustic performance requirements.

801.5.3 Fire/Life Safety

801.5.3.1 Coordinate material flame and smoke index requirements.

801.5.3.2 Coordinate emergency access requirements.

801.5.4 Structures

801.5.4.1 Coordinate exposed structural members requirements.

801.5.4.2 Coordinate tolerances for structural movement.

801.5.4.3 Coordinate corrosion control requirements for exposed structures.

801.5.4.4 Coordinate interface of guideway and station railings.

801.5.5 MEP

801.5.5.1 Coordinate lighting requirements.

801.5.5.2 Coordinate restroom requirements.

801.5.5.3 Coordinate grounding requirements for metallic objects near platform edges.

801.5.6 Communications/Technology

801.5.6.1 Coordinate access control requirements.

801.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

801.7 ENGINEERING MANAGEMENT REQUIREMENTS

801.7.1 Interface and Integration Management

801.7.1.1 Account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructable documentation and functional designs.

801.7.2 Design Management

801.7.2.1 Location of rooms must be reviewed with Sound Transit TSS during preliminary engineering to ensure key system will allow appropriate level of access into areas.

801.7.2.2 Bollard locations, types, and finish colors must be reviewed and approved by Sound Transit TSS at milestones defined in EP-03.

801.7.2.3 Provide drawings and specifications that identify all bird control devices to be installed. Include key plans, details, and specification of each product type.

801.7.3 Manufacturing and Construction Management (Not Used)

801.7.4 Installation Management (Not Used)

801.7.5 Inspection and Testing Management

801.7.5.1 Adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

801.7.6 Training, Pre-Revenue Operations (Not Used)

801.7.7 Certification Management (Not Used)

801.8 APPENDICES

801.8.1 Security Parameters for Openings

Table 801-4: Security Parameters for Openings

Security Group	Security Element	Opening Type	Room Type	Functional Concept of Operations
A	ACR DPS EL REX	• High security areas • Exterior doors • Interior doors facing public spaces	Fire Command Center Room, Traction Power Substation, Electrical Switchgear Substation Room, Utility Meter Room, Signals Room, Main Electrical Room, UPS Room, Main Communication Room, Exterior side of egress stairwell discharge to surface (top of tunnel stair, bottom of elevated stair), Security Office	1. ACR on non-secure side releases EL and shunts DPS 2. REX on secure side of room shunts DPS
B	ACR AUD DPS REX	Public to secure area, not able to secure by lockset	Platform door to egress stairwell	1. REX on secure side shunts DPS and AUD. 2. ACR shunts DPS and AUD on Platform side.
C	ACR DPS	Tunnel/Retained Platform End Gates to Emergency Walkway or trackway, and Site perimeter pedestrian access gates.		1. ACR shunts DPS. 2. ACR must be located such that it can be accessed from either side of the gate.
D	DPS	Doors of station ancillary rooms, not defined in group A and elevated platform gates. OMF/MOW's hatches and doors, TPSS doors.	• Elevator Machine Rooms, Mechanical, electrical and communications distribution closest, Ventilation shafts, horizontal plenum access doors, Emergency Responders Room, Fire Valve Room. • Station – Ancillary Roof, Janitor Room, and Platform • End of Line Facilities - Stair # Track Level and Track Level Janitor Room • OMF/MOW includes: Roof hatches and access doors • TPSS - Entry doors and equipment doors	1. DPS reports to head end ACS.
E	DPS VIS	Tunnel cross-passage doors must have intrusion detection with visual indication		1. DPS reports to head end ACS and a 90fpm strobe is activated.

Security Group	Security Element	Opening Type	Room Type	Functional Concept of Operations
F	ACR DPS	Station Entrance security grilles/vertical lift gates and maintenance access doors, connected to LCC for off-site operation		1. ACR initiates operation of open and close functionality with door controller. 2. Provide an emergency exit button with cover if a man-door is not provided.
G	None	• Ancillary rooms not falling into any groups identified in groups A-L • End of line employee rooms and offices	At-grade platform end gates. End of Line Facility- Ancillary Roof (hatch), Base Chief Office Break Room, Chief Office, Crew/Print Room, Dispatcher Dry Room, Facility Shared Office, Facility Storage, Men's Restroom, N Entry Clerestory, Operator Ready Room, Quiet Room, Roof (hatch), S Entry Clerestory, Shared Office, Shared Workspace, Track Level Storage Room, Training/Conference Room, Trash Enclosure, Women's Restroom, Work Room, Workshop	
H	ACR LL	Janitor Closets within secure area		
J	ACR	Elevator cab or lobby that serves as separation between public space and maintenance space	Elevators serving intermediate floors that have maintenance purposes only; Surface elevator lobbies exposed to public during non-revenue hours	1. ACR must be inside the elevator cab for access to intermediate floors. 2. ACR must be on the elevator exterior when lobby exposed to public during non-revenue hours.
K	DB-OCC	Employee Restroom within secure area		
L	ACR DB-OCC DPS EL ES-OCC[a]	• Public restrooms with customer entry request • Staff restrooms in public areas		Staff restrooms: 1. ACR on non-secure side releases EL and shunts DPS. Public restrooms: 1. Refer to SET 1203 ACCESS CONTROL for concept of operations for public restrooms.
M	ACR DPS	• MEP and systems equipment closets and rooms, concourse, platforms, restrooms, employees	• Station - Ancillary Lobby, Bus Driver Rooms and Restrooms, Comm Closet, Room and UPS, Corridor, Electrical Closet, Room, UPS, Elev-# Mach/Esc Cntrl Rm, Elevator Machine Room and Closet, Elevator w/	

Security Group	Security Element	Opening Type	Room Type	Functional Concept of Operations
		rooms and offices. Site Entry Gates (integrated with motor operated gates and vehicle loops; see set 836), Access road vehicle gates.	non-public access, Emergency Equipment Room, Emergency Stairs, Employee Restroom, Fire Control Room, Fire Protection Valve Room, Fire Valve Room, Lobby, Mechanical Room and Closet, NB Concourse (VL Gate), North Entry, North Entry (VL Gate), Parking Area level #, Public Restroom, Rail Supervisors, SB Concourse (OH Door), SB Platform, Security Room, South Entry / (VL Gate), Sprinkler Valve Room, Stairs (VL Gate), Storage Room, TPSS Enclosure, Transformer Enclosure, Trash, Utility Closet, Vehicle Entrance # (VL Gate), Vestible (VL Gate), • Garage - Ancillary Lobby, Bus Driver Rooms and Restrooms, Comm Closet, Room, Electrical Room, Elevator Machine Room, Elevator w/ non-public access, Fire Protection Valve Room, Level # Exit, Vehicle Entry, and Vent Well, Lobby, Mechanical Room, Parking Area level #, Sprinkler Valve Room, Stair # (VL Gate), Stair # Exit, Storage Room, Toilet, Transformer Enclosure, Trash, Vehicle Entrance # (VL Gate) • End of Line Facilities - Comm Room, Corridor, Electrical Room, Elevator Mach Room (closet), Elevator Machine Room, Lobby, Security Office, Site - Emerg Exit Ped Gate, Site - Ped Gate, Site - Vehicular Gate, Stair Ground Level, TPSS Enclosure, Workshop (OH door) • On Guideway - Traction Power Substation	

Security Group	Security Element	Opening Type	Room Type	Functional Concept of Operations
			Building and Signal Bungalow	
N	PL		• On Guideway - Man Door, Man Gate, Vehicle Gate, Vehicle Door • Off Guideway - Man Door w/ public access, Man Gate w/ public access, Vehicle Gate /w public access, Vehicle Door /w public access	
O	DPS PL		• Off Guideway - Man Door, Man Gate, Vehicle Gate, Vehicle Door • On Guideway - Traction Power Substation Wall/Fence Enclosure Access and Signal Bungalow Wall/Fence Enclosure Access	
P	ACR DPS PL		• On Guideway - Communications Building	

a. Not required for staff restrooms.

Security Element Types:
ACR – Access Card Reader
CL - Closer
LL – Lever Lockset
REX – Request to Exit
DPS – Door Position Switch
AUD – Local Audible Alarm
VIS – Local Visual Alarm (Strobe)
EL – Electronic Lockset (ACR activated)
BL-S – Bilock keyed switch (open/close)
ES-OCC – Electronic Strike/Deadbolt for providing occupancy contact to access control system
DB-OCC – Manual lever with Occupied/Vacant indication on exterior of door
PL - Padlock

Notes:
1. Contact ST Transportation Safety & Security for openings not indicated in this table.
2. Bi-lock hardware sets and other specifics to architectural hardware requirements must conform to Requirements Manual.
3. Building Department, Fire Department, and L&I requirements must be coordinated and documented with both Civil and Systems DOR.

The use of items listed as "Y" is subject to location and environmental considerations.

801.8.2 Required Materials and Finishes

Table 801-5: Required Materials and Finished

Material	Public Space				Non-Public Space, Interior[a]			
	L	S	TL	ST	L	S	TL	ST
	L = Link, S = Sounder, TL = Tacoma Link, ST = Stride							
Flooring - At-Grade Platform								
PC-1 24-inch x 24-inch nominal concrete pavers - Wausau Tile “Terra-Pavers” Type 3 Cotillion FDX, Mutual Materials Architectural Pavers (Link mode) or Abbotsford Concrete Products Ltd. “HydraPressed Paving Slabs” (Sounder mode). Maximum of three colors to be used and selected from the following colors: • FDX 2008 Wausau Light Gray (UniFace UF-30) • FDX 3008 Wausau Dark Gray (UniFace UF-60) • FDX 4008 Wausau Dark Red (UniFace UF-50) • FDX 5008 Wausau Dark Tan (UniFace UF-40)	Y	Y			N/A	N/A		
Cast-in-place (CIP) concrete, sealed. Finish/color to be selected from the following: • Integral color • Textured/sandblasted	Y	Y			N/A	N/A		
Flooring - Tunnel Platform (Fully Covered Above)								
PT-4: 12-inch x 12-inch nominal unglazed porcelain ceramic tiles - Cross-Colors Mingles by Crossville Inc. Finish: Cross-Slate. One color to be used and selected from the following colors: • A850 Graphite (Dark Gray) • A900 Mica (Light Gray) • A790 Burgundy Smoke (Dark Red) with cross sheen finish • A876 Truffle (Tan)	Y	N/A			N/A	N/A		
Flooring - Elevated Platform								
CIP topping slab over structural slab. Scoring: 2 feet on center, each way, aligned with platform edge panel joints	Y	N/A			N/A	N/A		
Flooring - Detectable Warning Surface								
PC-4: 12-inch x 12-inch nominal concrete polymer tile - Tekway ADA Domes Architectural Series by StrongGo Industries. Dome pattern: orthogonal. Color: Natural yellow. Edges must be butt jointed with no grout between tiles. See Architectural Standard Drawings	Y	Y			N/A	N/A		

Material	Public Space				Non-Public Space, Interior[a]			
	L	S	TL	ST	L	S	TL	ST
	L = Link, S = Sounder, TL = Tacoma Link, ST = Stride							
Flooring - Tactile Wayfinding Surface								
PB-1: 8-inch x 24-inch nominal granite paver - Mount Airy white or equal. Pattern: directional bar. Texture: sandblasted. Finish: coarse. Sealer: alcohol-based, Evonik Protectosil Chem-Trete 40 VOC or equal. Mock-ups are required before approving use of any sealer products. See Architectural Standard Drawings	Y	Y			N/A	N/A		
Flooring - Tactile Waiting/Boarding Surface								
PC-2: 12-inch x 12-inch nominal precast concrete paver - Wausau Tile. Texture: ribbed. Color: FDX 3008 Wausau Dark Gray. See Architectural Standard Drawings	Y	Y			N/A	N/A		
Flooring - Fare Paid Zone								
PC-5: New Construction[b] – 12-inch x 12-inch replaceable CIP molded glass- and carbon-fiber-reinforced polyester. Finish: slip-resistant treatment on domes and field of tile. Pattern: 4 directional bars. Color: Federal yellow	Y	N/A			N/A	N/A		
Retrofits - 12-inch x 12-inch surface-applied molded glass- and carbon-fiber-reinforced polyester w/integral color. Finish: slip-resistant treatment on domes, field of tile, and beveled outside edges. Pattern: 4 directional bars. Color: Federal yellow.	Y	N/A			N/A	N/A		
Flooring - Plaza								
Concrete pavers[b] – see Flooring – At-Grade Platform section	Y	Y			N/A	N/A		
Granite, thermal finish (minimum)	Y	Y			N/A	N/A		
CIP concrete, sealed. Finish/color to be selected from the following: • Integral color • Textured/sandblasted	Y	Y			N/A	N/A		
Brick pavers	N	N			N/A	N/A		
Permeable pavement or paver system	Note c	Note c			N/A	N/A		
Bituminous toppings	N	N			N/A	N/A		
Synthetic resin toppings	N	N			N/A	N/A		
Terrazzo	N	N			N/A	N/A		
Marble	N	N			N/A	N/A		
Flooring – Concourses, Mezzanines & Pedestrian Bridges								
Porcelain tile[b] – see Flooring – Tunnel Platform section	Y	N			N/A	N/A		
Terrazzo	Y	N			N/A	N/A		
CIP concrete, sealed. Finish/color to be selected from the following: • Integral color	Y	Y			N/A	N/A		

Material	Public Space L	Public Space S	Public Space TL	Public Space ST	Non-Public Space, Interior[a] L	Non-Public Space, Interior[a] S	Non-Public Space, Interior[a] TL	Non-Public Space, Interior[a] ST
	L = Link, S = Sounder, TL = Tacoma Link, ST = Stride							
• Textured/sandblasted								
Granite, thermal finish (minimum)	Y	N			N/A	N/A		
Flooring - Elevators								
Resin epoxy flooring, seamless, flexible, resilient flooring system with high solids with colored rubber chips in a troweled mortar system,1/4-inch thickness. “SofTop” Decorative Flooring by General Polymers or approved equal, with “Shark-Grip” Slip Resistant additive to meet coefficient of friction	Y	Y			Y	Y		
Flooring - Restrooms								
Porcelain tile	N	N			Y	Y		
Concrete, sealed with slip-resistant grit sealer	Y	Y			N	N		
Flooring - Showers								
Porcelain tile	N	N			Y	Y		
Flooring - Systems Rooms								
Electrostatic dissipative epoxy coating system with dissipative resistance values between 10^6 and 10^9 ohms when measured using the test method of ANSI/ESD STM7.1-2001 or later	N/A	N/A			Y	Y		
Flooring - Offices & Crew Rooms								
Synthetic resin or epoxy toppings	N/A	N/A			Y	Y		
Carpet (offices only)	N/A	N/A			Y	Y		
Vinyl composition tile	N/A	N/A			Y	Y		
Vinyl, other	N/A	N/A			Y	Y		
Resilient flooring with heat treated seams	N/A	N/A			Y	Y		
Flooring – Garage Ancillary Spaces								
CIP concrete, sealed. Finish: polished	N/A	N/A			Y	Y		
Flooring - All Other Areas[d]								
CIP concrete, sealed. Finish: textured/sandblasted	Y	Y			Y	Y		
Tile, mosaic, and small format	N	N			N	N		
Polished concrete	N	N			N	N		
Polished stone	N	N			N	N		
Wood	N	N			N	N		
Marble	N	N			N	N		
Glazed tile	N	N			N	N		
Bituminous toppings	N	N			N	N		
Rubber flooring	N	N			N	N		
Sand set pavers	N	N			N	N		
Cellular grassed paving (e.g., Grasscrete)	N	N			N	N		
Walls								
Architectural precast concrete	Y	Y			Y	Y		
Aluminum framed glazing system	Y	Y			Y	Y		

Material	Public Space				Non-Public Space, Interior[a]			
	L	S	TL	ST	L	S	TL	ST
	L = Link, S = Sounder, TL = Tacoma Link, ST = Stride							
CIP concrete, sealed. Finish/color to be selected from the following: • Integral color • Textured/sandblasted	Y	Y			Y	Y		
Porcelain enamel metal wall panels, with or without acoustical treatment	Y	Y			Y	Y		
Metal wall panels, with or without acoustical treatment	Y	Y			Y	Y		
Stone tile	Y	Y			Y	Y		
Stone veneer system	Y	Y			Y	Y		
Brick, sealed	Y	Y			Y	Y		
CMU, sealed. Finish to be selected from the following: • Textured • Ground face • Glazed	Y	Y			Y	Y		
Glass block	N	N			N	N		
Porcelain tile	Y	Y			Y	Y		
WT-1(A): Glazed ceramic tile on cement backer board (outside touch zone preferred)	Y	Y			Y	Y		
Baked/coated steel panels	Y	Y			Y	Y		
Portland cement plaster	N	N			Y	Y		
Gypsum wall board, moisture resistant core, anti-mold and anti-fungal with fiberglass mat facing (conditioned spaces only). DensArmor Plus for interior rooms above grade; DensGlass Sheathing or DensShield Tile Backer for below grade rooms, or approved	N	N			Y	Y		
Gypsum backed plaster synthetic stucco system	N	N			N	N		
Reinforced glass fiber panels	N	N			N	N		
Wood	N	N			N	N		
Plastic	N	N			N	N		
Single wythe masonry walls for conditioned spaces or as primary barrier for water intrusion	N	N			N	N		
Galvanized painted steel	N	N			N	N		
Painted faux finish	N	N			N	N		
Exposed acoustic or thermal insulation	N	N			N	N		
Walls – Open Elements								
Expanded metal, aluminum, or stainless steel, 16 ga. or heavier	Y	Y			Y	Y		
Expanded metal, painted	N	N			Y	Y		
Perforated metal, aluminum, or stainless steel, 16 ga. Or heavier	Y	Y						
Perforated metal, painted	N	N			Y	Y		

Material	Public Space L	Public Space S	Public Space TL	Public Space ST	Non-Public Space, Interior[a] L	Non-Public Space, Interior[a] S	Non-Public Space, Interior[a] TL	Non-Public Space, Interior[a] ST
	L = Link, S = Sounder, TL = Tacoma Link, ST = Stride							
Crimp metal, stainless steel or steel welded at each connection and painted	Y	Y			Y	Y		
Metal louver	Y	Y			Y	Y		
Aluminum grating	Y	Y			Y	Y		
CMU, sealed. Finish to be selected from the following: • Textured • Ground face • Glazed	Y	Y			Y	Y		
Brick	Y	Y			Y	Y		
Vegetated green screens	Note c	Note c			Note c	Note c		
Welded wire mesh	N	N			Y	Y		
Laser-cut sheeting	N	N			N	N		
Painted faux finish	N	N			N	N		
Walls – Restrooms								
Stainless steel wall panels	Y	Y			N	N		
FRP or fiberglass wall panels	N	N			N	N		
Mosaic tile	N	N			Y	Y		
Gypsum board	N	N			N	N		
Walls – Showers								
Mosaic tile	N	N			Y	Y		
Doors & Frames								
Hollow metal doors and frames, 14 ga., with zinc rich primer and high-performance coating	Y	Y			Y	Y		
Hollow metal doors with lites and frames, 14 ga., with zinc rich primer and high-performance coating. See note h.	N	N			Y	Y		
Stainless steel doors	Y	Y			Y	Y		
Overhead coiling doors with stainless steel or aluminum grilles or slats	Y	Y[b]			Y	Y[b]		
Vertical lift gates with welded structural aluminum construction with standard or specialty overlay aluminum locking panels. Operation must include a balanced counterweight system and chain and sprocket lift drive for greater reliability	Y[b]	Y			Y	Y		
Grout filled hollow metal frames	N	N			Y	Y		
Wood doors and frames	N	N			N	N		
Overhead coiling doors with painted grilles or slats	N	N			Y	Y		
Perforated or grated doors	Note c	Note c			Note c	Note c		
Ceiling								
Stainless steel	Y	Y			Y	Y		
Porcelain enamel steel panels with or without	Y	Y			Y	Y		

Material	Public Space				Non-Public Space, Interior[a]			
	L	S	TL	ST	L	S	TL	ST
	L = Link, S = Sounder, TL = Tacoma Link, ST = Stride							
acoustical treatment								
Factory finished baked enamel metal panels, with or without acoustical treatment	Y	Y			Y	Y		
Expanded metal: painted or stainless steel, with or without acoustical treatment	Y	Y			Y	Y		
Perforated metal: painted or stainless steel, with or without acoustical treatment	Y	Y			Y	Y		
Gypsum cement plaster, smooth finish (not on GWB backer)	Y	Y			Y	Y		
Portland cement plaster	N	N			Y	Y		
Metal ceiling system with rigid attachment, with or without acoustical treatment	Y	Y			Y	Y		
Wood above touch zone	Y	Y			Y	Y		
Acoustical ceiling tiles (conditioned spaces only)	N	N			Y	Y		
Paper-faced gypsum wall board	N	N			Y	Y		
Plastics	N	N			N	N		
Wood within touch zone	N	N			N	N		
EIFS	N	N			N	N		
Painted faux finish	N	N			N	N		
Exposed acoustic or thermal insulation	N	N			N	N		
Exposed spray fireproofing	N	N			N	N		
Ceiling – Restrooms								
Stainless steel panels	Y	Y			N	N		
Gypsum board	N	N			Y	Y		
Canopy – Structure								
Structural steel – see Metals section	Y	Y			N/A	N/A		
Tube or round steel (round preferred for horizontal members)	Y	Y			N/A	N/A		
Concrete	Y	Y			N/A	N/A		
CMU	Y	Y			N/A	N/A		
Wood above touch zone[f]	Y	Y			N/A	N/A		
Architecturally Exposed Structural Steel requirements	N	N			N/A	N/A		
Wood within touch zone	N	N			N/A	N/A		
Galvanized steel, painted or unpainted	N	N			N/A	N/A		
Canopy – Materials								
Laminated translucent or clear glass (art locations only) – see Glazing section	Y	Y			N/A	N/A		
Factory finished baked enamel metal deck, Kynar or better[i]	Y	Y			N/A	N/A		
Baked/coated steel roofing	Y	Y			Y	Y		
Aluminum roofing	N	N			Y	Y		
Single ply roofing	Y	Y			N/A	N/A		

Material	Public Space				Non-Public Space, Interior[a]			
	L	S	TL	ST	L	S	TL	ST
	L = Link, S = Sounder, TL = Tacoma Link, ST = Stride							
Ballasted roof in limited areas	Note c	Note c			N/A	N/A		
Resin or polycarbonate panels, UV resistant, outside touch zone	Note c	Note c			N/A	N/A		
Photovoltaic panels (Note: slope and details must be designed for positive drainage)	Y	Y			N/A	N/A		
Wood	N	N			N/A	N/A		
Tile roofing	N	N			N/A	N/A		
Built-up roofing	N	N			N/A	N/A		
Composition roofing	N	N			N/A	N/A		
Painting over galvanized steel	N	N			N/A	N/A		
Fabric roof	N	N			N/A	N/A		
Translucent sandwich panel systems (e.g., Kalwall)	N	N			N/A	N/A		
Plastics	N	N			N/A	N/A		
Painted faux finish	N	N			N	N		
Roofing								
Translucent sandwich panel systems (e.g., Kalwall)	N	N			N	Y		
Miscellaneous Metal Surfaces & Fixtures								
Stainless steel[b]	Y	Y			Y	Y		
Porcelain enamel over steel	Y	Y			Y	Y		
Factory applied baked on enamel	Y	Y			Y	Y		
Fluoropolymer coatings	Y	Y			Y	Y		
Factory applied powder coating	Y	Y			Y	Y		
High performance coating	Y	Y			Y	Y		
Polyurethane (three coat system)	Y	Y			Y	Y		
Painted galvanized materials	N	Y			Y	Y		
PVC downspouts	N	N			N	N		
Rain chains	N	N			N	N		
Site-painted metal panels	N	N			N	N		
Site-painted metal, excluding touch-ups	N	N			N	N		
Stainless steel railing system	Y	Y			Y	Y		
Galvanized railing - see BRIDGES AND ELEVATED STRUCTURES for guideway requirements	N	N			Y	Y		
Galvanized railing, exit stairs, protected from rainwater and runoff	N	N			Y	Y		
Galvanized steel, other	N	N			Y	Y		
Glass guardrails or railings	N	N			N	N		
Painted faux finish	N	N			N	N		
Restrooms – Partitions, Fixtures, & Accessories[e]								
Toilet partitions - stainless steel	Y	Y			Y	Y		
Toilet partitions - solid polymer	Y	Y			Y	Y		

Material	Public Space L	Public Space S	Public Space TL	Public Space ST	Non-Public Space, Interior[a] L	Non-Public Space, Interior[a] S	Non-Public Space, Interior[a] TL	Non-Public Space, Interior[a] ST
	L = Link, S = Sounder, TL = Tacoma Link, ST = Stride							
Toilet partitions - plastic laminate, phenolic core or baked enamel	N	N			Y	Y		
Plumbing fixtures - stainless steel	Y	Y			Y	Y		
Plumbing fixtures - vitreous china or porcelain	N	N			Y	Y		
Toilet accessories - stainless steel, vandal-resistant	Y	Y			Y	Y		
Toilet accessories - plastic or fiberglass	N	N			Y	Y		

a. Use acceptable material or finish in corresponding public space columns when non-public space is exposed to the exterior environment.
b. Preferred by Sound Transit.
c. Requires Sound Transit pre-approval.
d. Flooring at all other locations not specified elsewhere within table, e.g., ancillary spaces.
e. See additional information provided in Restrooms section
f. Total cost of ownership analysis is required for Sound Transit pre-approval
g. For artwork materials and finishes, refer to Set 808 STart Program.
h. Applicable to occupiable back of house spaces, such as crew rooms or offices.
i. Fasteners visible from the underside of the metal deck must be concealed with a soffit material.

END SET - 801

802 LANDSCAPING

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SET - 802 TABLE OF CONTENTS

TABLES

FIGURES

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SET - 802 LANDSCAPING

802.1 INTRODUCTION

802.1.1 Document Scope

802.1.1.1 The purpose of this set is to establish the Sound Transit standard for all landscape requirements and to provide guidance for all phases of design.

802.1.1.2 The scope includes landscaping requirements for station sites, track and guideway, park and ride areas, maintenance facilities, site preparation, slope stabilization, topsoil preparation, stormwater management, irrigation requirements, plant materials, trees, shrubs and ground covers, Integrated Management Plan, landscaping sensitive areas and the standard plant list.

802.1.1.3 Related requirement sets include the following:

i. 200 Track Electrification
ii. 300 Operational Communications
iii. 500 Track
iv. 800 Architecture
v. 1000 Mechanical/Electrical and Building Systems
vi. 1200 Security

802.1.1.4 Applicable modes include all Sound Transit modes where landscaping is provided as well as park and ride locations (surface lots and garages), and maintenance facilities.

802.1.1.5 Where the landscape designer encounters cases of special designs not specifically covered by these criteria, the landscape designer must bring them to the attention of the Requirements Set 802 owner to determine the technical source for the design criteria.

802.1.2 Regulations, Codes, Standards, and Guidelines

802.1.2.1 International Regulations, Codes, Standards, and Guidelines (Not Used)

802.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

802.1.2.2.1 American Joint Committee on Horticulture Nomenclature (AJCHN) Standard Plant Names.

802.1.2.2.2 American Standard for Nursery Stock (ANSI Z60.1). American Association of Nurserymen, Inc.

802.1.2.2.3 Federal Aviation Administration (FAA) Wildlife Hazard Mitigation, if in jurisdiction.

802.1.2.2.4 National Park Service (NPS). US Department of the Interior. Standards for Rehabilitation, for landscaping near historic buildings.

802.1.2.2.5 United States Department of Agriculture (USDA) Zone 7.

802.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

802.1.2.3.1 Use the most current available appraisal method for trees and plants in the Northwest.

802.1.2.3.2 Washington State Department of Ecology (WSDOE). Publication #06-06-011b Wetland Mitigation in Washington State – Part 2: Developing Mitigation Plans.

802.1.2.3.3 WSDOT Roadside Design Manual for areas to be maintained by WSDOT.

802.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

802.1.2.4.1 Bailey's Standard Encyclopedia of Horticulture.

802.1.2.4.2 CPTED.

802.1.2.5 Other Jurisdictions (Not Used)

802.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

802.1.2.6.1 Sound Transit Customer Signage Design Manual and Production Drawings.

802.1.2.6.2 Sound Transit Integrated Pest Management Plan (IPM) Washington State Department of Ecology, U.S. Army Corps of Engineers Seattle District, and U.S. Environmental Protection Agency Region 10. March 2006.

802.1.2.6.3 Sound Transit Low Impact Development Stormwater Management (LID).

802.1.2.6.4 Sound Transit Right of Way Manual.

802.1.2.6.5 Sound Transit Standard Specifications.

802.1.2.6.6 Sound Transit's Interpretive Signage Design Criteria.

802.1.3 Abbreviations and Acronyms

802.1.3.1 BMS–building management system

802.1.3.2 CPTED–Crime Prevention Through Environment Design

802.1.3.3 DBH–diameter at breast height

802.1.3.4 HGM–hydrogeomorphic

802.1.3.5 IPM–integrated pest management plan

802.1.3.6 LID–low impact development

802.1.3.7 LRV–light rail vehicle

802.1.3.8 OMF–operations and maintenance facility

802.1.3.9 OCS–overhead contact system

802.1.3.10 ROW–right-of-way

802.1.4 Definitions and Classifications

802.1.4.1 See Set 001 for definitions.

802.1.5 References (Not Used)

802.2 STAKEHOLDER NEEDS

802.2.1 Passenger Experience

802.2.1.1 Landscaping design must allow for clear sightlines and not interrupt passenger flow or create bottlenecks. Landscape design must preserve the inherent natural and cultural characteristics while balancing transportation, community, and environmental considerations. It must provide for the comfort and safety of the sound transit system user.

802.2.2 Operational Needs

802.2.2.1 Landscaping at Sound Transit facilities encompasses and contains embankments and earthworks for the purpose of shape and drainage, view corridor and site line preservation, plantings for boundary treatment, the enhancement or screening for stations, traction power substations, communications/signal facilities, yards, shops and ROW alignment, conservation of indigenous flora, fauna, and wetlands, sensitive area mitigation, ballast work, and footpaths.

802.2.3 Maintenance Needs

802.2.3.1 Determine ownership and maintenance responsibility of landscape and irrigation during the preliminary design to confirm responsible decision-making authority for planting, soil requirement, irrigation, and other requirements. Document all responsibilities with agreements and/or letters of concurrence. In cases where other parties will own and maintain the landscape, the requirements of this set may be superseded by local codes and standards.

802.2.4 Safety Needs

802.2.4.1 Landscaping must allow for clear visibility and accessible mobility for all users of the station area as well as clear sightlines of the track area and any bus or auto routes within the station area. Landscaping must not obstruct the visibility of the physical address sign, fire hydrants, and fire department connections for emergency responders. Design must account for pedestrian, cyclist, and micro-mobility access and visibility of and by those user groups. Plant choices must not include plants toxic to humans or animals per WSDOT publication, *Poisonous Plants of Washington State.*

802.2.5 Security Needs

802.2.5.1 Landscaping designs must be coordinated with security and communications designers to allow for clear site lines for cameras and the general public and follow key CPTED policies. Design must consider mature growth, impact on visibility, and other CPTED principles.

802.2.6 Reliability, Availability and Maintainability Needs

802.2.6.1 Landscaping must be designed and installed to maximize resiliency and minimize maintenance. The effects of maintenance on the surrounding environment and facilities must be considered when designing the landscape plan and selecting plants.

802.2.7 Environmental and Sustainability Needs

802.2.7.1 Environmental protection must be a key benchmark in the design of the landscape plan and selection of plants, soil, and infrastructure. Resiliency, climate appropriateness, and resource impact must be considered in the landscape design and selection of plantings and infrastructure. Existing soil must be protected and retained to the maximum extent possible. Limit soil disturbance to the minimum necessary to complete the project. Develop and coordinate a soil protection plan with Sound Transit and provide documentation of implementation of the plan.

802.3 SYSTEM REQUIREMENTS

802.3.1 General Requirements

802.3.1.1 The attainment of the following objectives must not adversely affect the site distance of train operators and the public with respect to Link light rail or other vehicular traffic.

802.3.1.1.1 Provide landscape design responsiveness to and compatible with transit vehicle and station operations, station architecture, graphics, furniture, art, and lighting design, as well as the neighborhood and nearby environs.

802.3.1.1.2 Provide a safe, secure, comfortable, and attractive environment throughout the transit system, particularly at and along approaches to station entrances.

802.3.1.1.3 Control access to the system by reinforcing designated pedestrian and vehicular circulation system movement and creating both physical and/or visual barriers elsewhere along the ROW as required.

802.3.1.1.4 Provide a landscape design that is compatible with local climatic conditions and conserving of water resources. Local climatic conditions may vary throughout a site and certain microclimates, and unique conditions must be accounted for within the project site.

802.3.1.1.5 Provide a landscape design that minimizes the heat island effect by:

i. Reducing low albido materials such as dark pavements

ii. Providing shading

iii. Utilizing plantings and pavers with an aged solar reflectance of at least 0.28 or, where this information is not available, utilizing an initial solar reflectance of at least 0.33.

Commentary: Solar reflectance must be balanced with passenger experience considerations to reduce glare.

802.3.1.1.6 Provide a landscape design compatible with the regional aesthetic character and with the character, or envisioned character, of existing neighborhoods adjacent to the alignment, and station and maintenance facilities. Do not use turf, formal hedges, and espaliers, except where restoration of an existing landscape requires continuity or consistency.

802.3.1.1.7 Design a landscape that must require low maintenance in the short- and long-terms, plant selection must consider mature plant size and correct spacing of plants to minimize pruning requirements. Illustrate growth patterns at installation, at five years post installation, and at 20 years post installation.

802.3.1.1.8 Provide visual screening to buffer incompatible adjacent uses where required by AHJ.

802.3.1.1.9 Protect existing plant material as a priority to preserve a sense of scale and history. Emphasize preservation of existing vegetation (trees and shrubs) as a sustainability issue and to preserve neighborhood landscape/green space.

802.3.1.1.10 Create a site grading plan that complements the use patterns of the site and coordinates with site elements such as natural features, drainage, sun, and wind.

802.3.1.1.11 Incorporate existing site features that complement the overall site design concept.

802.3.1.1.12 All landscaping in the vicinity of historic buildings must conform to the requirements of the Standards for Rehabilitation of the U.S. Department of the Interior, latest edition.

802.3.1.1.13 Develop planting plan and materials suitable to the location, create landscapes with low maintenance requirements, and install efficient irrigation systems.

802.3.1.1.14 Do not use any small stones or other materials that can easily be used as projectiles or tracked into facilities.

802.3.1.1.15 Landscape design must account for effect on site lines and visibility. LRV operator site lines must be analyzed to provide visibility. See Set series 100 Train Control & Signals for specific requirements on visibility. Pedestrian and cyclist site lines must be analyzed for safe visibility. Provide emergency responder visibility of fire hydrants and appurtenances. See Set 601 for additional requirements.

802.3.2 Station and Facility Sites

802.3.2.1 Provide safe waiting areas that have a comfortable human scale.

802.3.2.2 Highlight and clarify pedestrian circulation routes. Minimize winding and obscure paths for ease of use by pedestrians with mobility difficulties.

802.3.2.3 Establish a consistent visual identity for station and facility areas and their immediate environs.

802.3.2.4 Enhance pedestrian safety and security by providing adequate sight line distances from adjacent areas.

802.3.2.5 Provide visual screening where requested by Sound Transit, while adhering to CPTED principles.

802.3.2.6 Focus fragrant and all-season interest plantings near station entries and other pedestrian areas. Do not design high fragrant plants in pedestrian areas that will attract bees.

802.3.2.7 Provide continuity and pleasing transitions between stations and facilities and adjacent areas while also maintaining clear identification and visibility of the station areas.

802.3.2.8 Trees and other plantings must be selected such that mature size will not interfere with performance of site lighting particularly light poles. Trees must be spaced adequately to ensure pole mounted light fixtures are effective and not screened by trees creating dark and dangerous zones in the parking area. Coordinate with Set 1007 Electrical Lighting.

802.3.3 Trackway

802.3.3.1 Provide an attractive and unifying design concept within the project, corridor, and/or segments.

802.3.3.2 The vegetation within a minimum of 300' of an at-grade crossing must not be taller than 24 inches. See Set series 900 Civil, Set 100 Train Control & Signals, and Set series 500 Track as well as EP-13. Coordinate with Sound Transit. Locate plantings to prevent the accumulation of grass, leaves, or other plant materials on the track and guideway and on drainage infrastructure including gutters and drains.

802.3.3.3 Plantings between trackway are not permitted due to access limitations for maintenance.

802.3.3.4 At tree maturity, branches and dripline must be at least 15 feet clear of the OCS. Trees planted by Sound Transit must not pose a future threat of falling on tracks, guideway, or OCS and must account for mature height and distance from facilities. Design and selection must take into consideration future access to OCS and guideway for maintenance and must not impede this access.

802.3.3.5 At elevated guideway and transition structures, trees and plantings are permitted outside the vegetation clear zones identified in figures 802-1 and 802-2. Refer to Set series 900 Civil and the Sound Transit Right of Way Manual for definition of easement limits. Please note that the vegetation clear zone is contained within the easement limits but does not match the easement. This is to facilitate simpler easement descriptions yet allow for more planting area to help support tree replacement project needs.

802.3.3.6 Plantings around columns must ensure access for maintenance and inspection of the structure.

802.3.3.7 At grade and retained cut alignments must have a vegetation clear zone that matches the vegetation clear zone from elevated guideway above the top of rail as shown in Figure 802-1 and Figure 802-2.

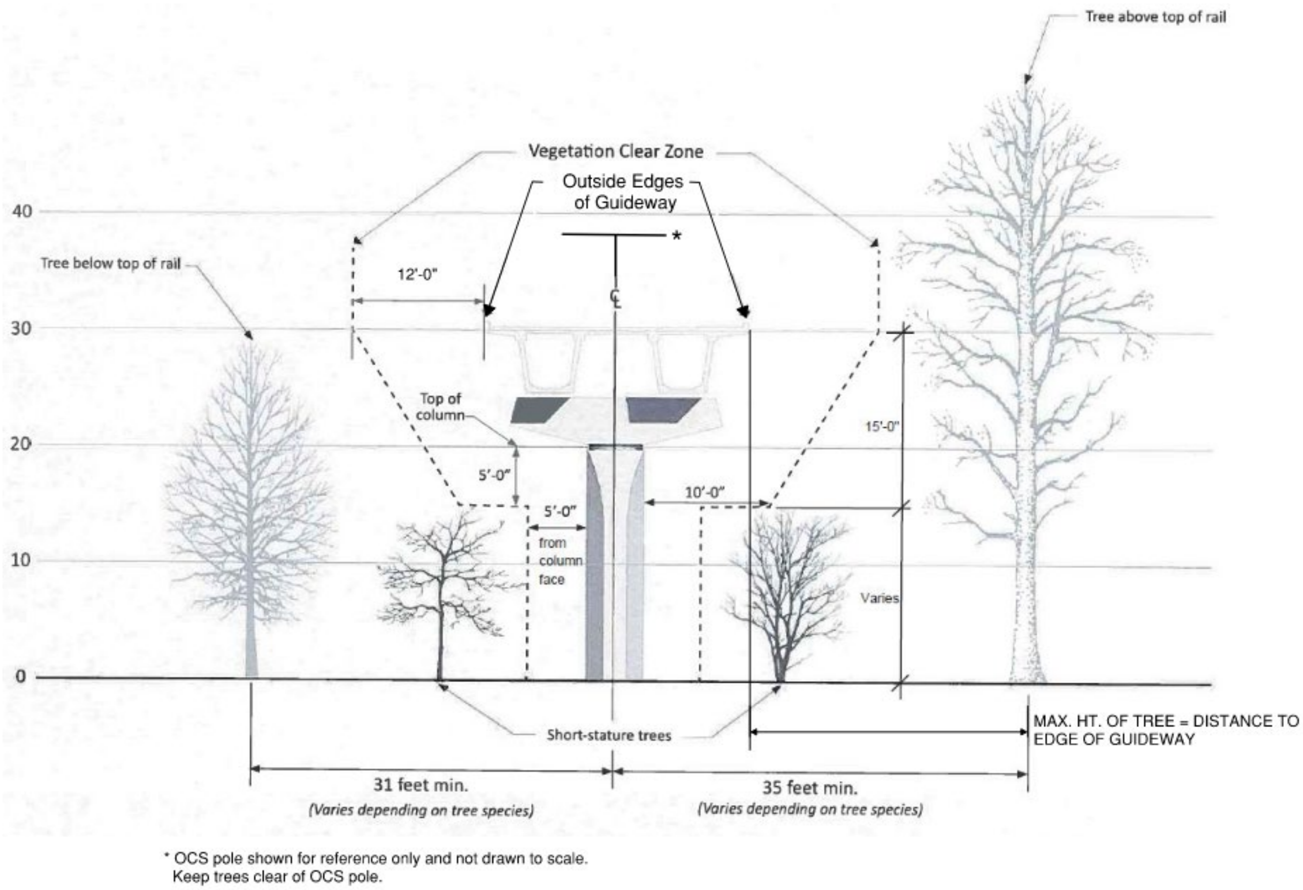
802.3.3.8 Vegetation clear zone requirements for new landscaping shown in figures 802-1 and 802-2 must be used to determine extent of removal of existing vegetation.

802.3.3.8.1 GC is required to conduct a post-grading hazard tree analysis of the remaining existing trees in and adjacent to the guideway, track and OCS corridor and provide a report as a submittal for Sound Transit to review. The assessment must be performed by an ISA (international society of arboriculture) certified arborist for trees greater than 4 inches DBH that have indicators it could fail and damage a valued target (i.e., guideways, structures, roadways). Coordinate with Sound Transit for format and additional requirements of the analysis.

802.3.3.8.2 Tree branch clear zone must be a minimum of 15 feet from OCS clear zone. If an existing tree has not yet reached maturity, evaluate if mature size will have branches within the vegetation clear zone or 15 feet of OCS clear zone, whichever is greater. If so, remove the existing tree and replace with more suitable landscaping. Do not retain trees that will require on-going pruning maintenance to meet the vegetation clear zone and OCS clearances. Qualified arborists from design team must work with Sound Transit facilities staff to address the current approach and future maintenance issues.

802.3.3.8.3 Select trees that will not fall across tracks, guideway, or OCS at mature height. Work with AHJ to identify and mitigate any existing problem trees which have potential to impact Sound Transit infrastructure.

Figure 802-1: Elevated Guideway Section

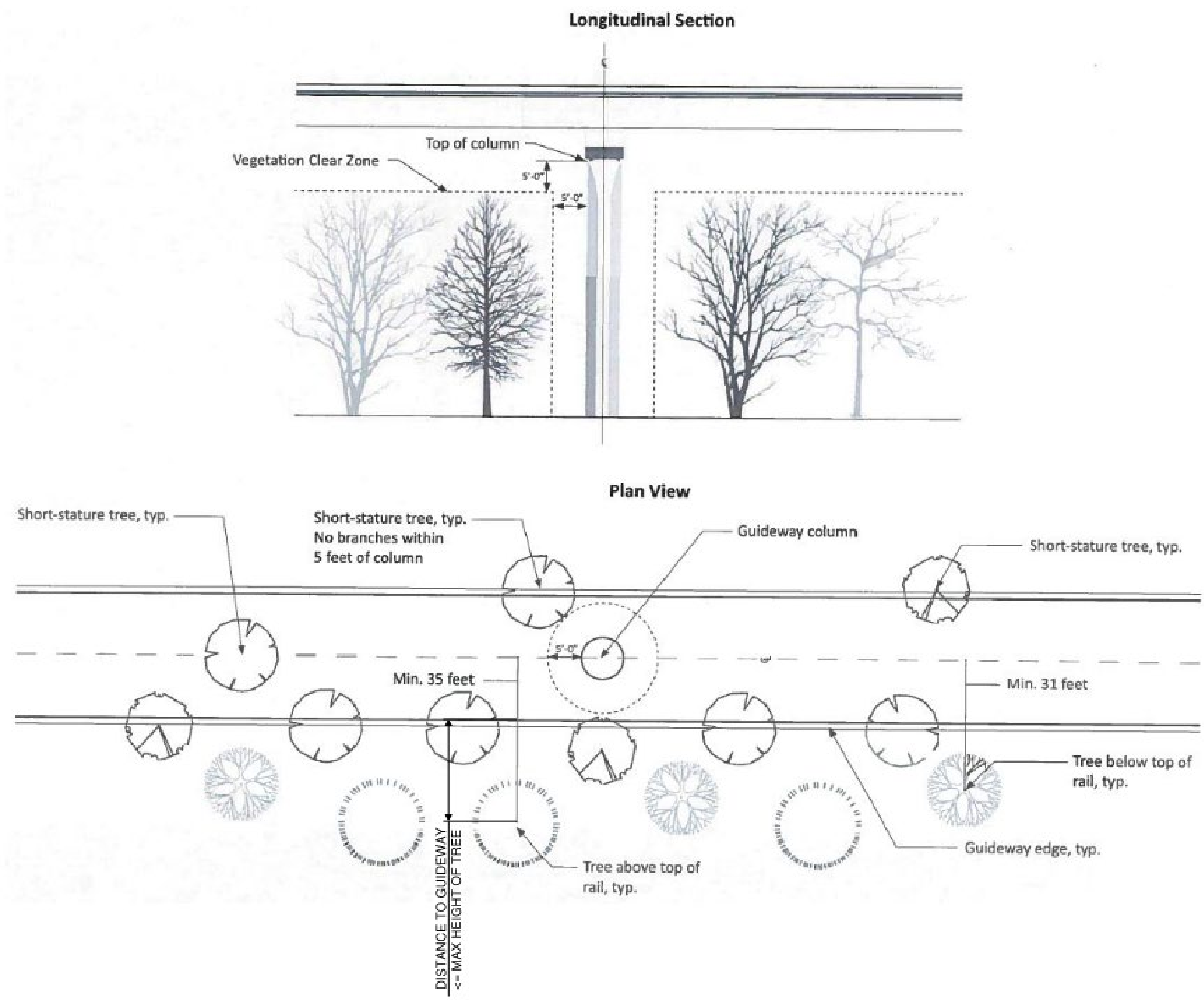


802.3.3.9 Planting areas under elevated guideways must be located under elevated guideways at least 25 feet high to receive sufficient water and light year-round. Exceptions for sensitive areas, such as wetlands, must be approved by Sound Transit. Other hardscape or features must be provided beneath the guideway structure.

802.3.3.10 Planting areas near the edges of the guideway may be permitted to extend under the edge of the guideway depending on water and light availability and site specifics. Sound Transit must review and approve all proposed planting areas that extend beneath the guideway structure. See irrigation requirements below.

802.3.3.11 Planting may be permitted under the guideway structure outside the vegetation clear zone where other jurisdictions have agreed to all responsibilities of planting maintenance, including removal of volunteer plants that may reach into the vegetation clear zone.

Figure 802-2: Elevated Guideway - Elevation and Plan View



Planting areas using a rainwater guideway dispersal system, if used at elevated guideways, must be designed to reduce erosion and promote infiltration, consistent with the local stormwater manuals and Sound Transit LID Stormwater Manual. Plants in these locations must be planted a maximum of three feet on center.

802.3.3.12 Evergreen plants must make up between 60 and 80 percent of the species mix. Chose plant mixes that tolerate Pacific Northwest conditions of wet winters and dry summers.

802.3.3.13 Rain angle and sun access must be considered for plantings under the guideway.

802.3.3.14 Soil conditions must be designed to permit appropriate water absorption in these areas. Minimize plantings under guideways to required mitigation and AHJ requirements due to less-than-optimal growing environment there.

802.3.4 Park-and-Ride Areas

802.3.4.1 Provide planting islands in parking areas to create visual interest and shade in large, paved areas. Finish grade of landscape areas between parking aisles must not slope up within 3 feet of the curb or wheel stop to avoid damage to plantings and irrigation from car overhang.

802.3.4.2 Enhance pedestrian safety and security by providing adequate sight line distances for both vehicles and pedestrians. Select trees and plantings such that mature size will not interfere with performance of site lighting, particularly light poles. Trees must be spaced adequately to ensure pole mounted light fixtures are effective and not screened by trees creating dark and dangerous zones in the parking area.

802.3.4.3 Provide attractive approaches to stations.

802.3.4.4 Establish visual screening of parking areas while allowing for surveillance.

802.3.4.5 Integrate design elements with adjacent areas.

802.3.4.6 Reinforce vehicular and pedestrian movement paths.

802.3.4.7 Landscaping in parking areas must meet AHJ codes.

802.3.4.8 Choose plant materials tolerant of site conditions and microclimates during establishment period and as plantings mature.

802.3.4.9 Maintain access to temporary generator taps, disconnects, meters, transformers, ground hydrants, roof access points, and access to other equipment and infrastructure.

802.3.5 Site Preparation

802.3.5.1 Finish grading must meet existing grades of adjacent areas where possible. Minimum depth of soil must be consistent with best practices for the type of plants selected.
802.3.5.1.1 Maintain drought-resistant soil through the following steps:

i. Do not use peat.
ii. Refrain from tilling/digging and minimize disruption to soil structure and biota.
iii. Enhance organic matter by annually topdressing all soil areas with organic compost in the fall.
iv. Use locally sourced soils for new plantings.
v. Safeguard soil surfaces by keeping them covered with mulch or vegetation throughout the year.
vi. During construction, adhere to TESC measures and cover bare soil with straw to reduce damage.
vii. Utilize cover crops and companion plantings with nitrogen-fixing properties.

802.3.5.2 Topsoil depth must be18 inches minimum in planting areas. For planting areas with trees, provide 24 inches minimum topsoil depth with additional depth as needed based on size of trees and root balls. Refer to Sound Transit Guide Specifications. Topsoil should be placed in a uniform depth to prevent uneven settlement. Coordinate topsoil requirements with the plant material to be installed.

Table 802-1: Minimum Topsoil Depths for Planting Types

Planting Type	Topsoil Depth (inches)*
Lawn / Sod **	12
Groundcover	18
Shrubs	24
Notes: *Soil depths will vary depending upon the plant material requirement. **Approval by Sound Transit required prior to selecting lawn / sod	

802.3.5.3 In table 802-2 below, soil volume standards are based on the mature size of the tree, defined as expected growth ten years after installation. The total soil volume requirement may be reduced up to 30 percent for the trees that share soil in continuous planting beds.

Table 802-2: Tree Soil Volumes

Mature Tree Size (at 10 years after installation)	Minimum Soil Volume
Small (under 25 ft crown spread, ~8" DBH)	500 ft^3
Medium (25-35 ft crown spread, ~16" DBH)	1000 ft^3
Large (35+ ft crown spread, ~24" DBH)	1500 ft^3

802.3.5.4 Definitions and Rules for Calculating Soil Volume

802.3.5.4.1 The following definitions apply to soil media for trees:

i. Open soil refers to either uncompacted native soils (no greater than 80 percent Proctor) or amended soils meeting the standards for approved topsoil.
ii. Available open soil is the length by width of a planting bed, multiplied by depth of preparation up to 36 inches deep. Most unprepared urban subgrade is highly compacted and does not qualify as available.
iii. Covered soil refers to soil volume provided below hardscape or paved surfaces in the form of soil cells or structural soil. Only 25 percent of the volume of structural soils may be counted.
iv. Shared soil refers to more than one tree in a planting bed sharing open soil, or an individual tree in a planting bed that is connected to other open soils via soil cells or structural soil. Areas of shared soil must have continuous root path that allows space of at least 4 feet wide or 2 feet deep.
v. Isolated soil refers to a tree well or small enclosed planting bed that is not connected to other prepared soil volumes and is totally isolated by hardscape such as driveways, sidewalks, or vaults.
vi. Connected soil refers to two areas of open soil that are connected below hardscape with either soil cells or structural soil. These connected beds can now qualify as shared soil.

802.3.5.4.2 The following standards and exceptions apply to calculating soil volumes:

i. The total soil volume provided for a tree must be calculated in cubic feet by adding the available open soil volume to the available covered soil volume within a 50-foot radius of the tree.
ii. When total soil volume consists of more than one planter bed or open soil area, those areas must be able to be connected by continuous root paths at least 4 feet wide and 2 feet deep.
iii. Soil volumes for covered soil must be calculated by using only the space available to soil and may not include the components providing structure. For example, the space occupied by modular decking in a soil cell system and the large aggregate in structural soil are not accessible to tree roots. Only 25 percent of the total volume of structural soil may be used for covered soil volume calculations.
iv. Required soil volumes may be reduced up to 30 percent for trees sharing a continuous planter strip of at least 4 feet in width, or when soil cells form a direct path between planter pits. For example, the required soil volume for large trees planted to this standard would be 1050 cubic feet.

802.3.5.5 In cut areas that are to be seeded or sodded, rock, including shale, must be covered with topsoil to a depth appropriate for the plant material chosen for this site. Finished settled grade of topsoil in lawn areas must be 1 to 1.5 inches below adjacent hardscape. Topsoil must not be stripped, placed, or worked while frozen or wet. Topsoil must not be placed on untilled or un-scarified surfaces. Walks or paving must provide positive drainage.

802.3.5.6 Mulch must be provided on all planting areas. Mulch must not be applied below ordinary high water of water bodies.

802.3.5.7 Medium wood chip mulch must be used at stations, commercial and residential restoration areas, and third-party properties. The mulch must be a minimum of 3 inches deep at groundcover area and 4 inches deep at shrub and tree areas.

802.3.5.8 Coarse wood chip mulch must be used at WSDOT, SDOT ROW (and any other AHJ ROW that requires it), and restoration of natural areas, such as parks and wetlands. The mulch must be a maximum of 4 inches deep in wetlands and minimum of 4 inches deep elsewhere.

802.3.5.8.1 Other mulches may be used upon approval by Sound Transit.

802.3.5.8.2 Pea gravel is not permitted in tree wells as it gets tracked into the facility and jams in escalators.

802.3.5.9 All planting areas must be graded to provide positive drainage. Water from planting areas must not drain across walkways.

802.3.5.10 Swales for surface drainage in lawn or planted areas must have a shallow dished cross-section with a uniform longitudinal fall of two percent minimum to six percent maximum.

802.3.5.11 Seeded or sodded areas must have a minimum slope of two percent (2 feet fall per 100 feet) and maximum slope of 1:2 (1-foot vertical change of grade per 2 feet of horizontal distance). See Section below for additional information.

802.3.5.12 Sand set pavers are prohibited. See Set 801 and Sets 820-836 for paving materials and locations.

802.3.6 Slope Stabilization

802.3.6.1 Grading and the incorporation of mounds and depressed areas must be used where appropriate to control pedestrian movements, obscure objectionable views, and reduce objectionable noise.

802.3.6.2 All slopes must be stabilized to prevent physical failure, erosion, and maintenance problems. See set 900 Civil.

802.3.6.3 Sound Transit maintained slopes that receive mowed turf or aggregate mulches must not exceed 1 foot (vertical) to 3 feet (horizontal), (while meeting local AHJ requirements, whichever is greater).

802.3.6.4 Sound Transit maintained slopes that receive non-mowed grass, ground covers, and landscape areas must not exceed 1 foot (vertical) to 2 feet (horizontal).

802.3.6.5 Open anchored matting must be used to stabilize sodded or seeded slopes and swales (surface flow lines) exceeding six percent gradient.

802.3.6.6 Sterile straw must be used to stabilize seeded slope areas and all newly seeded grass areas except where prohibited by local AHJ. Use other means approved by Sound Transit where prohibited. Straw cannot be used on Seattle Parks' property.

802.3.6.7 Wildflower seed mixes must not be used because they typically contain noxious and invasive weed seeds.

802.3.6.8 Stable rock cut faces must be left exposed.

802.3.6.9 Vertical transition curves, 6 feet to 20 feet as appropriate to scale of slope, must be provided at top and bottom of slopes or mounds.

802.3.6.10 The following plants or materials listed in Table 802-3 are suitable for slope stabilization and erosion control in areas other than critical area buffers.

Table 802-3: Slope Stabilization and Erosion Control

Material	Slope (Maximum) (Vert. On Horiz.)
Turf, Mowed (with prior Sound Transit approval only)	1 on 3
Grass (with prior Sound Transit approval only)	1 on 2
Ground Cover Plants	1 on 2

Material	Slope (Maximum) (Vert. On Horiz.)
Stone rip-rap	1 on 2
Concrete, stone, or brick paving	1 on 2

802.3.6.11 If new grading is properly blended with the existing grades, the need for retaining walls should be minimal. Where they are used, retaining walls must be treated as an architectural element with consideration being given to scale, color, texture, contrast, and appropriate materials in relationship to both the transit facilities and adjacent neighborhoods.

802.3.7 Topsoil Preparation

802.3.7.1 Soil amendments must supplement existing soils or topsoil must be brought to the site as new planting mix. Depth of amendments must be clearly defined in contract documents for tree and shrub or groundcover areas (see Table 802-1). If existing soil is to be amended, the soil must be tested before determining how much soil amendment should be added; however, amendments must include a minimum of 35 to 40 percent dry weight organics to support plant life and retain water. Make-up of topsoil must be designed for the type of plantings. Maintain current Sound Transit soil amendment requirements and WSDOT requirements, where applicable, and submit samples.

802.3.7.2 Where planting areas are designed as drainage collection areas, such as rain gardens, soil amendments must be deep enough to meet expected water retention.

802.3.7.3 Soil polymers will not be accepted without prior approval of Sound Transit.

802.3.7.4 Where trees are surrounded by pavement for vehicle traffic, sidewalk, or pedestrian plaza, Silva Cell type products or structural soil in the root zone under the pavement are preferred where feasible to assist the tree in fully developing. Determine use of these additional methods in conjunction with Sound Transit and any other entity which would be maintaining the installation.

802.3.7.5 Paving systems in non-vehicle areas that allow water to penetrate to tree roots must be considered in areas where larger tree pits cannot be accommodated. Coordinate with civil engineering and subsurface drainage requirements.

802.3.7.6 In planter areas, or where native or compacted soil exists under planting areas that may prevent water from draining, consider adding a drainage layer of material or piped drains to prevent water saturation and root rot of plantings. Coordinate with Civil and Geotechnical disciplines.

802.3.7.7 All soils brought into the site must be clean and weed free. Specifications must include language that will require contractor to remove soils at their own cost if within the plant establishment period.

802.3.8 Low Impact Development Stormwater Management/ Rain Gardens

802.3.8.1 Comply with the Sound Transit Low Impact Development Stormwater Management Guidelines. See Set series 900 Civil for additional information.

802.3.8.2 Topsoil and depth must meet requirements needed for designed infiltration rates.

802.3.8.3 Appropriate plantings must be selected for these areas that are adapted to intermittent flooding from stormwater runoff and temporary standing water.

802.3.9 Irrigation Requirements

802.3.9.1 Provisions for irrigation at Sound Transit facilities must be carefully considered. Station areas, pedestrian plazas, and park and ride facilities directly associated with stations must include automatic irrigation systems for ease of maintenance of the landscape areas.

802.3.9.2 Areas beyond stations must limit the use of landscape and irrigation wherever possible.

802.3.9.3 Consider use of water from roofs or guideway to supply water to planting areas. The infrastructure required to bring water and power to remote planting areas (outside stations) is a limiting factor where landscaping is to be provided.

802.3.9.4 When landscaping outside station areas is required, consider the ability for third parties to maintain the planting areas and possibly tie to third party irrigation systems.

802.3.9.5 All irrigation systems for Sound Transit owned and maintained facilities must be provided with an irrigation deduct meter in accordance with local water district standards. Deduct meters must be site specific per station or plaza facility to avoid crossing Sound Transit water lines under public ROW.

802.3.9.6 Coordinate the installation of the irrigation deduct meter, backflow preventers, flow meter and piping connections.

802.3.9.7 Use Rain Bird system for central control.

Commentary: Operations uses Rain Bird IQ cloud for central control, but it is over the Internet. Install cellular modules on the controllers to enable communication with IQ cloud and avoid any Sound Transit network. The controllers are best located on an exterior wall or outdoors given the cell signal strength needed to send information up to the cloud.

802.3.9.8 Irrigation controllers must be compatible with Sound Transit system-wide requirements, using Rain Bird, allowing for system-wide connectivity. Irrigation controllers must be located to facilitate access by the entity maintaining the landscape. Separate irrigation controls and systems per facility, place controls outside in lockboxes to be accessible by vendors and Operations staff.

802.3.9.9 Irrigation backflow preventers or double check valves must be provided in underground vaults with appropriate drainage space/allowance, or within the building envelope. Above ground systems are prohibited.

802.3.9.10 Use the most current irrigation methods, such as drip irrigation or watering tubes at the street, to minimize water usage. Plantings with different water requirements must be zoned separately to ensure adequate water supply to each plant type. The controller must:

i. Allow timed watering schedules.
ii. Alter the watering schedule seasonally.
iii. Allow manual interruption of the schedule in times of unpredictable weather inconsistencies.
iv. Receive input from rain sensors to bypass irrigation during periods of sufficient rainfall for plantings.
v. Automatically zone shut off leak if a leak is detected.

802.3.9.11 Planting under the guideway is prohibited except as designated in this set. Where planting is permitted under edges of guideway with Sound Transit approval, plantings must be Pacific Northwest adapted to wet winters and dry summers. Rainwater from guideway, canopy roofs, or pedestrian hardscape must be considered for this use without reliance on an irrigation system.

802.3.9.12 When irrigation systems are provided under guideways for temporary establishment periods only, the system must be freeze proof and zoned separately from other areas. Irrigation design must provide a manner to do this without jeopardizing the winterization for the balance of the system. Consider separation from main irrigation system, deeper pipes, and ease of draining the system for these zones.

802.3.9.13 The irrigation system must be designed to address slope conditions and prevent run-off of irrigation water.

802.3.9.14 Provide year-round hose bibbs, separate from the irrigation system, at station sites, plazas, and in park-and-ride areas for general maintenance and for emergency and back-up irrigation. The locations must be coordinated to permit site coverage with a 75-foot hose, except as approved in writing by Sound Transit. See Set 1002 Mechanical – Plumbing for additional information.

802.3.9.15 Wherever possible, temporary irrigation must be used that is designed to accommodate a three-to-five-year service life for specified areas where supplemental water is not needed after initial establishment.

802.3.9.15.1 Where irrigation is used, follow the directions below to enhance water efficiency and reduce demand:

i. Apply water until the soil is wet to the depth of the plant's root system.
ii. For trees, wet the soil to a 3-foot depth, ensuring that irrigation reaches 24 to 36 inches into the ground.
iii. Shrubs and vines should have the soil wet to a 2-foot depth, with water infiltration reaching roots at 18 to 24 inches.
iv. For smaller plants, water to a 1-foot depth, probing the soil easily to about 12 inches after irrigation.
v. Utilize a soil probe or rod to measure water infiltration, avoiding direct measurement at the plant crown to prevent root damage.
vi. Optimal watering time is early in the morning or pre-dawn to avoid rapidly warming soil surfaces that can dry and wick moisture from the root zone.
vii. Watering early ensures deeper penetration into the root zone, promoting longer accessibility for plant roots.
viii. For established trees and shrubs, begin irrigating any time after midnight, applying water at a slow and steady rate for multiple hours to ensure infiltration to roots at a depth of 2 to 3 feet.
ix. Check the irrigation system weekly to inspect functionality and all emitters.
x. Maintain the irrigation system seasonally and winterize it as needed.

802.3.9.16 Determine each facility project's water resources and demands. A water resource spreadsheet and a water use budget must be completed during design for use in monitoring the future operation of the facility.

802.3.9.17 Each new facility must have a final water budget established by the completion of 100 percent design. The water budget must be reconfirmed by the consultant during the project close-out after construction based upon as-built conditions.

802.3.9.18 The provided water budget must be used as the project's baseline for Sound Transit Operations. All projects must have the appropriate metering and controls included to allow Sound Transit to verify and monitor achievement of facility budget.

802.3.9.19 Sound Transit must not practice rainwater harvesting due to maintenance requirements and incompatibility with supply and demand potential of local rain patterns.

802.3.10 Irrigation for ROW, Private Properties, and Sound Transit Remnant Properties

802.3.10.1 Provide separate water meters for each property ownership.

802.3.10.2 Sound Transit remnant properties on separate blocks must have separate meters to reduce the number of street crossings.

802.3.10.3 Pipes belonging to one owner must not cross a second owner without an easement.

802.3.10.4 If portions of Sound Transit property are to be separated from Sound Transit ownership later (for future development or transfer to another agency), then those "future" parcels must have their own water meters and stand-alone irrigation systems.

802.3.10.5 Provide a written irrigation plan which identifies:

802.3.10.5.1 Which irrigation areas are temporary and for establishment only.

802.3.10.5.2 How long each area will receive irrigation- during establishment period which is typically two years.

802.3.10.5.3 Who is responsible to maintain each planting area.

802.3.10.5.4 Who is responsible for paying each water meter bill during establishment.

802.3.10.5.5 Who is responsible for paying each water meter bill after completion of establishment.

802.3.10.5.6 Disposition of each meter at the end of the establishment period. Include whether meter is transferred to another entity or if water service must be stopped and disconnected (e.g., service stopped and meter remains, service stopped and meter pulled, meter pulled and pipe capped at the main). Use the terminology of the local utility.

802.3.10.6 Irrigation must ensure each street ROW, private property, and Sound Transit remnant property planting areas have a manual valve so that the area can be disconnected and reconnected (without excavation) as required for long term maintenance.

802.3.11 Plant Materials

802.3.11.1 Plantings must be used to enhance the visual quality of the station areas and to integrate them with their surrounding environment.

802.3.11.2 Plant selection must be limited to native and adaptive plants that are suitable for the Pacific Northwest climate and that will thrive in the environment in which they are planted. See Appendix 1 for the standard plant list.

802.3.11.3 Planting design should emphasize use of native, adaptive, hardy, drought tolerant, low maintenance material that can exist without supplemental water in the local climate after the establishment period.

802.3.11.4 The following must be done during the construction and establishment period:

I. Monitor plants for signs of heat stress during periods of excessive heat and drought or low rainfall.
II. Look for indicators such as wilting leaves, drying and browning leaves, leaf drop, branch dieback, sunscald on branches and trunks, reduced or no new growth, and potential plant death.
III. Provide additional watering as needed to maintain plant health during establishment or excessive heat and dry periods.

Commentary: Certain symptoms may become evident during or shortly after extended periods of drought or extreme heat. In trees, reduced growth or mortality might also manifest in subsequent years. Factors affecting recovery after prolonged drought and heat include the extent of damage, remaining carbohydrate reserves, water availability, and temperatures. Regular vigilance and timely response are key to supporting plant health and recovery.

802.3.11.5 Plant material used in the Link light rail program must be rated hardy for use in USDA Zone 7.

802.3.11.6 Landscaping considerations for the selection of plant material include the following:

i. Sustainability
ii. Initial cost
iii. Mature height and spread
iv. Growth rate
v. Seasonal form and color
vi. Hardiness
vii. Sun/shade preferences
viii. Deciduous/Evergreen
ix. Leaf size
x. Seed/fruit/bloom toxicity

xi. Disease and pest resistance
xii. Soil and drainage conditions
xiii. Tolerance to water/lack of water
xiv. Adaption to areas prone to flooding, similar to raingarden-suitable plantings
xv. Tolerance to wind, pollutants, and salt
xvi. Transplant tolerance
xvii. Availability
xviii. Maintenance requirements
xix. Security requirements
xx. Compatibility with urban context and architecture
xxi. Characteristics of root growth

802.3.12 Trees, Shrubs, and Ground Covers

802.3.12.1 Mature, healthy existing trees of appropriate species and other existing plantings must be preserved where possible and must be indicated in all the relevant contract documents with appropriate protection specified, including demolition and grading drawings, and noted as "existing trees to remain."

802.3.12.2 Complete tree surveys of existing trees for areas affected by the project as directed by Sound Transit, including temporary construction limits. Indicate tree health, which trees to be saved, and the necessary protection methods. Tree protection must be clearly identified on all relevant contract documents such as demolition, civil, and utility work. Evaluate all trees located adjacent to or on the boundary of the clearing limits to determine if the tree can be retained or if it will become a hazard and must be removed.

802.3.12.3 Submit updated tree inventory after construction activities to Sound Transit Operations and Maintenance. Operations needs an updated and accurate inventory to manage the maintenance of the large number of trees that will have the potential to affect the system in the future.

802.3.12.4 Trees must enhance an existing street tree pattern, if any, or must be a part of a street tree pattern established by AHJ for adjoining areas. Where no pattern exists, a pattern must be established.

802.3.12.5 Minimum caliper of trees must be two inches. Trees must be spaced an appropriate distance apart depending on the species and design intent.

802.3.12.6 Tree location must be adjusted to accommodate subsurface conditions such as utilities and vaults, as well as special conditions such as existing or proposed sidewalk canopies, awnings, shelters, and vehicle traffic signage.

802.3.12.7 Excavation for tree root balls must be minimally two times wider and six inches deeper than the size of the ball and based on current best practices. Coordinate with Civil Engineering to address any subsurface drainage issues that may create problems for the root zones of trees and shrubs. This may require modifying fill materials, installing underdrains, or other methods to provide drainage of planting areas.

802.3.12.8 Where applicable, the use of Silva Cells must be explored, particularly at plazas to support a healthy root growing zone for trees and controlling water. This system allows for healthier root structure, better water management, and less conflict between roots and plaza structure.

802.3.12.9 In high pedestrian areas, tree grates may be used with a minimum area of 24 square feet provided to prevent compaction of the soil surface (5 feet by 5 feet or 4 feet by 6 feet, typical). Coordination with the AHJ is required to determine local requirements. Tree grates must be designed to support the weight of one wheel of a service vehicle. Tree grates used on Link station plazas must be the Sound Transit standard. Other tree grate types must be approved by Sound Transit based on site specifics and AHJ.

802.3.12.10 Steel tree guards must be considered only where necessary at locations where tree trunks are likely to receive abuse from service vehicles, snow removal equipment, or pedestrians.

802.3.12.11 Trees in pedestrian areas must be staked, using a standard staking detail, or as approved by the design consultant and Sound Transit. For non-pedestrian areas, trees must be staked or guyed. Trees must be guyed only where necessary. Underground staking is not allowed without prior approval from Sound Transit.

802.3.12.12 In stations and other pedestrian areas, all plants must be below 24 inches in height and trees must branch above eight feet at ten-year growth to allow for easy surveillance of the site. Mature landscape retained on site must also meet these requirements.

802.3.12.13 In pedestrian areas, plants with large leaves, messy flowers / fruit are discouraged to minimize maintenance required of adjacent areas.

802.3.12.14 Where shrubs and groundcovers are used, they must be selected and grouped in a manner to minimize maintenance and promote coverage of the planting bed.

802.3.12.15 Shrubs or other dense plantings, as allowed by the standard plant list in Appendix 1, must be used in landscaped areas and slopes to discourage pedestrian activity.

802.3.12.16 Tall shrubs and evergreen trees must only be used where pedestrian activity is unlikely. Use of tall plants as screen elements in station and pedestrian zones is not allowed to minimize the ability for people to hide behind these plants.

802.3.12.17 Plants with thorns, such as native roses, is prohibited close to pedestrian areas.

802.3.12.18 Vines must be used selectively to landscape and soften vertical surfaces. Provide support for climbing plants to reach the intended climbing structure.

802.3.12.19 Do not rely on green to provide visual screening. Do not use green walls as a permanent design feature. Due to the longevity required of Sound Transit facilities, plant materials must not be relied upon as an architectural element to visually screen areas. If plants are used as an accent to grow up wall surfaces, provide the structure and planting area needed to support the plants. If any of the plant support structure is wood, then the wood must only be above grade.

802.3.12.20 Lawn must not be used without prior Sound Transit approval.

802.3.13 Landscaping Sensitive Areas

802.3.13.1 This section provides objectives and design parameters for developing final landscape plans for sensitive area mitigation sites. Sensitive areas include wetlands, buffers, stream buffers, or other designated sensitive or critical area. Final construction design efforts must be based upon the approved conceptual or final mitigation plan approved by AHJ. Designers must include the author of the mitigation plan in the review process to ensure the intent of the approved mitigation plan is met.

802.3.13.2 Ensure that the minimum mitigation area requirements meet the intent of the approved mitigation plan.

802.3.13.3 Grading plan must use a maximum of 1-foot contours and in some areas down to 6 inches where required to create micro topographic variation to mimic the reference wetland or stream system. Consult with a hydrologist to ensure site conditions will support the appropriate wetland or stream hydrology

802.3.13.4 Obtain detailed site survey, including spot elevations, prior to construction in sensitive areas that will be temporarily disturbed during construction. Specifications must state that engineers are to verify pre-existing topography has been matched using professional survey techniques.

802.3.13.5 Avoid mitigation site designs that require complex and extensive engineering. In general, mitigation plans should restore hydrologic processes that previously occurred on the site and are appropriate for the landscape, rather than modifying water flow through the construction of weirs, deep basins, and berms that will result in atypical HGM classifications and require long-term maintenance. Slopes and shoreline edges should be constructed to mimic natural systems. Slopes should generally be gradual and shoreline edges should reflect the local conditions (e.g., sinuous in wide floodplains or circular in kettle holes).

802.3.13.6 Include specification language that requires contractor to survey the wetland area after excavation so it meets the intent of the mitigation plan in elevation and amount of mitigation area created. Require contractor to provide a submittal of the pre-construction wetland elevations prior to any temporary impacts occurring.

802.3.13.7 The proposed elevations in the grading plan may be modified in the field, however, the intent of the mitigation plan must be documented and met. Specifications must require detailed as-built plans from the contractor.

802.3.13.8 Stream protection and mitigation must be followed. When adding coir fabric over compost and mulch in floodplains, designers must evaluate for movement of materials such as mulch and compost.

802.3.13.9 Large woody debris must be retained to add to stream projects. Provide evaluation of where it will be staged or procured from.

802.3.13.10 Stream banks must be stabilized for one year before opening creeks. Designers must schedule work to ensure that stream banks are stabilized prior to releasing the creek.

802.3.13.11 Hydroperiod at a site must be monitored before and after construction. For example, observing the duration and extent of ponding and saturation for one year (or at minimum one wet season) after construction and before planting vegetation can identify problems that need to be corrected to assure the survival of the plants.

802.3.13.12 Ensure specifications include language to eliminate compacted soils.

Commentary: Use of heavy machinery during construction activities or previous land uses can compact soils. Saturated or moist soils are more easily compacted than dry soils. Compaction of soil can diminish soil permeability and pore space and severely limit root growth and the establishment of desirable plants. To loosen and aerate the soil a chisel or ripper shank should be pulled to the depth of compaction, usually about 18 inches. The depth of compaction may be shallow and should be checked in the field and ripped to that level and a little below. Care should be taken to not rip too deep to needlessly disturb subsoil or penetrate an aquitard. The most effective time to rip is when the soil is dry. Ripping through moist soil does little to relieve compaction and may cause further compaction.

802.3.13.13 Specifications must require contractor to protect all wetland soils as much as practicable. Limit grubbing if possible and place woven geotextile fabric over soils to be protected. Clearly indicate which areas are to be protected. Coordinate with Soil Protection Plan.

802.3.13.14 Specifications must include criteria regarding contractor experience. For example, the contractor selected for the job must have documented successful experience constructing and supervising similar mitigation projects.

802.3.13.15 Salvage topsoil if appropriate to site conditions and construction timing otherwise provide soil amendment.

Commentary: The type of organic amendment will depend on the characteristics of the site and proposed functions. Soil samples from a nearby reference wetland (i.e., of the same Cowardian and HGM classifications as the proposed compensatory mitigation wetland) may serve as a model to establish the type of soil needed.

802.3.13.16 Soil amendments incorporated into the subsoil must duplicate the texture, bulk density, and organic matter content of the reference wetland to minimize the introduction of plant pathogens and invasive species, sterile and weed-free organic soil amendments (i.e., have been properly composted to kill weed seeds) must be specified.

802.3.13.17 If non-native invasive plant species are present on the site consider how long-term maintenance of this species will be accomplished through site design. Mitigation sites must add an additional 5 feet to20 feet buffer around all restoration plantings for invasive species control

802.3.13.18 Upland areas must mimic natural Pacific Northwest forested conditions and achieve predominantly coniferous forested cover to mimic historic regional conditions. Riparian areas may have predominantly deciduous forested cover, however the goal must be to restore the site to meet a naturally occurring “reference site.”

Commentary: Implement plant guilds or polycultures to replicate native landscapes and harness the benefits of a drought-resistant upper canopy. The upper canopy not only provides shade but also establishes a microclimate that supports nutrient uptake for shrubs and smaller plants growing in proximity. This approach mimics natural ecosystems, enhancing resilience and water efficiency in landscaping.

802.3.13.19 Plant materials must only be species native to the Pacific Northwest and adapted to the site conditions such as shady, sunny, wet, or dry. Plant materials must be generally of small size such as one- or two-gallon, live stake, or bare root and installed with the intent of not being irrigated where possible.

802.3.13.20 Bare root plantings must be collected during dormant season and installed January through February. All woody plantings must be installed between September 30 and March 31. Wetland emergent plugs or other plants may need to be planted in early spring depending upon the depth of inundation. Maximum container size must be five gallons, with minimum set at 1 gallon

802.3.13.21 Salvage plant material, if economical and feasible, from the site if a portion of the site will be disturbed. Consider conducting general plant salvage from other areas in the project corridor that may be disturbed.

Commentary: Local volunteer organizations often conduct routine salvage operations; coordinate with these organizations to save plant material from both upland and wetland sites that will be disturbed or regraded.

802.3.13.22 Planting zones must be based on actual water levels rather than the approximation of where water should be, which can result in plants that establish faster and are healthier. It is recommended that a native, non-invasive, annual seed mix be applied to the bare soil during the construction period to prevent erosion and limit infestation of invasive species. Wildflower seed mixes is prohibited due to the presence of non-native invasive plant species.

802.3.13.23 Delay planting shade tolerant conifers and/or other plants after other faster growing sun-tolerate plant species have become established (e.g., cottonwood, willow, alder). This may require staggering the planting by one or two years.

802.3.13.24 Evaluate whether the site conditions (e.g., grassy fields, stream/pond with beaver activity, or other type of area) warrant specifying plant material collars to deter mammal or other type of herbivory and provide plant protection if required.

802.3.13.25 Mulch must be provided at all planting areas. A minimum depth of 3 inches of mulch must be provided above the water line at plant root zones and non-hydroseeded areas. Acceptable mulch types are bark or wood chip mulch. Other mulches may be proposed for review and approval by Sound Transit.

802.3.13.26 Irrigation must not be used unless recommended by the mitigation plan designers or permitting agencies. Temporary irrigation may be used as needed for up to three years to ensure appropriate amount of water is available to the site or that water can be brought to the site as needed. Temporary irrigation, if used, must be removed after it is no longer used.

802.3.13.27 Establishment period must be a minimum of 365 calendar days or as defined by code and/or agreement with AHJ.

802.3.13.28 All sensitive area mitigation sites must have signs installed at 50 feet or 100 feet intervals surrounding the area identifying it as wetland, stream, or buffer. Use signs available from AHJ if available or use Sound Transit's Interpretive Signage Design Criteria as guidance.

802.3.13.29 The goals, objectives, and performance standards of the approved mitigation plan should be reflected in the construction documents and final design.

Commentary: Using a reference site, or reference wetland, can provide a source of information and a model for the design and performance of a wetland mitigation site. Reference sites may be existing wetlands where the topographic and hydrologic conditions are similar to those proposed for the compensatory mitigation site. Alternatively, the selection of a reference wetland may be based on information about the historic condition of environmental processes at the mitigation site. However, a reference site based on historic conditions may not be appropriate in areas where the movement of water and sediment has been altered.

802.3.14 Standard Plan List

802.3.14.1 See the standard plant list in Appendix 1 for plants that have been approved for use on Sound Transit projects. Designers must ensure the chosen plant is appropriate for the location, type of soil present and available, growth habits, and site conditions. Where landscape areas are to be owned and maintained by other agencies, obtain agreements with those agencies, and defer to their plant material requirements.

802.3.14.2 Mature Tree Height Key:

i. Less than 15 feet tall
ii. 15 to 20 feet tall
iii. 20 to 30 feet tall (previously small)
iv. 30 to 70 feet tall (previously medium)
v. Greater than 70 feet tall (previously large)

802.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

802.5 SYSTEM INTERFACE REQUIREMENTS

Table 802-4 lists requirement sets that are typically coordinated, and may have dependencies, with this set.

Table 802-4: Interface Between Architecture and Other Disciplines

SET SERIES	SERIES NAME	SET 805 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	
300	Operational Communications	
400	Vehicle	
500	Track	
600	Fire / Life Safety	
700	Structures	
800	Architecture	X
900	Civil	X
1000	Mechanical / Electrical and Building Systems	X
1100	Technology	
1200	Security	X

802.5.1 Train Control and Signals

802.5.1.1 Coordinate with Set series 100 Train Control and Signal for safety and security review as well as cameras and sight lines (Set 120). Also coordinate with Set series 100 for CPTED principles.

802.5.2 Mechanical/Electrical and Building Systems

802.5.2.1 Coordinate with Set series 1000 Mechanical / Electrical and Building Systems for irrigation infrastructure, controllers, and other equipment.

802.5.3 Architecture

802.5.3.1 Coordinate with stations and other facilities on placement requirements.

802.5.3.2 Coordinate sustainability requirements, including water management, native plants, and drought tolerance.

802.5.4 Civil

802.5.4.1 Coordinate with Set series 900 Civil for slopes, walkways, fence requirements, drainage, bioswale, and raingardens.

802.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

802.7 ENGINEERING MANAGEMENT REQUIREMENTS

802.7.1 Integrated Pest Management Plan (IPM)

802.7.1.1 Provide design documents that meet Sound Transit's IPM. This plan includes strategies for controlling weeds and reducing the amount of toxic chemicals used in landscaping and operational procedures.

802.7.1.2 See additional information in Sound Transit Standard Specifications including Planting, Wetlands, and Streams.

802.7.2 Interface and Integration Management (Not Used)

802.7.2.1 Codes that require both Tree Mitigation Planting and Landscape Buffering in the same area must be reviewed and coordinated during early planning phases. Overlapping, conflicting, and/or ambiguous requirements must be brought to the attention of Sound Transit.

802.7.3 Design Management

802.7.3.1 Landscape designer must review signage infrastructure in surrounding facility area, such as plazas, with wayfinding and signage at milestones identified in EP-03. See Set 806 Signage for additional requirements.

802.7.4 Manufacturing and Construction Management (Not Used)

802.7.5 Installation Management (Not Used)

802.7.6 Inspection and Testing Management (Not Used)

802.7.7 Training, Pre-Revenue Operations (Not Used)

802.7.8 Certification Management (Not Used)

802.8 APPENDICES

Table 802-5: Standard Plant List

Scientific/Botanical Name	Common Name	Northwest Native (Y/N)	Drought Tolerant (Y/N)	Height (key above), Size or Condition
CONIFERS				
Abies grandis	Grand Fir	Y	Y	E
Abies procera	Noble Fir	Y		E
Araucaria araucana	Monkey puzzle tree	N	Y	E
Calocedrus decurrens	Incense cedar	N	Y	E
Chamaecyparis nootketensis	Weeping yellow cedar	N	Y	D
Pinus contorta var. contorta	Shore pine	Y	Y	E
Pinus nigra	Austrian pine	N	Y	E
Pinus thunbergii	Japanese black pine	N	Y	E
Pseudotsuga menzeisii	Douglas fir	Y	Y	E
Thuja plicata	Western red cedar	Y	Y	E
Tseudostuga heterophylla	Western hemlock	Y	Y	E
Tsuga mertensiana	Mountain hemlock	Y	Y	E
TALL SHRUBS / TREES				
Acer circinatum	Vine Maple	Y	Y	C / deciduous
Acer glabrum	Douglas Maple	Y	Y	C / deciduous
Acer griseum	Paperbark maple	N	N	C / deciduous
Acer palmatum 'Sango- kaku'	Coral bark maple	N	Y	C / deciduous
Amelanchier alnifolia	Serviceberry (shrublike)	Y	Y	C / deciduous
Amelanchier grandiflora ‘Princess Diana’	Serviceberry (tree form)	Y	Y	C / deciduous
Carpinus japonica	Japanese hornbeam	N	N	Deciduous
Cercidiphyllum japonicum	Katsura tree	N	N	Deciduous
Cercis occidentalis	Western redbud	N	Y	C / deciduous
Cercocarpus montanus or ledifolius	Mountain mahogany	N	Y	C/ evergreen
Cornus ‘Eddie’s White Wonder’	Eddie’s white wonder dogwood - cross with native resistant to anthracnose	Semi (cross)	N	Flowering / deciduous
Cornus kousa	Japanese dogwood	N	N	C / deciduous
Cornus kousa x nuttallii ‘Venus’	Venus dogwood – cross with native resistant to anthracnose	Semi (cross)	N	Flowering / deciduous
Cornus sericea	Red twig dogwood	Y	Y	C / deciduous

Scientific/Botanical Name	Common Name	Northwest Native (Y/N)	Drought Tolerant (Y/N)	Height (key above), Size or Condition
Garrya elliptica	Coast silk tassel	N	Y	C / evergreen
Ginkgo biloba	Ginkgo	N	N	E / deciduous
Gingko biloba ‘Jade butterfly’	Jade Butterfly gingko	N	Y	C / deciduous
Lagerstroemia indica	Crape myrtle	N	Y	C to D / deciduous
Maackia amurensis	Amur maackia	N	Y	C / deciduous
Malus fusca	Pacific crabapple	Y	Y	C / deciduous
Oemleria cerasiformis	Indian plum	Y	Y	C / deciduous
Philadelphus lewisii	Mock orange	Y	Y	C / deciduous
Physocarpus opulifolius	Ninebark (‘Dart’s Gold’ acceptable)	Y	Y	Small shrub / deciduous
Quercus garryana	Oregon white oak, Garry oak	Y	Y	E / deciduous
Rosa nutkana	Nootka rose	Y	Y	Small shrub / deciduous
Rosa pisocarpa	Clustered rose	Y	Y	C/ deciduous
Rosa woodsii	Woods rose	N	Y	Small shrub / deciduous
Stewartia pseudocamillia	Japanese stewartia	N	Y	C / deciduous
Styrax japonica	Japanese Snowbell	N	Y	C / deciduous
Tillia cordata ‘DeGroot’	DeGroot little leaf linden	N	N	deciduous
Viburnum edule and V. opulus war. americanum-	High bush cranberry	Y	Y	C / deciduous
Zanthoxylum piperitum* or simulans*	Japanese prickly ash	N	N	C / deciduous
Ziziphus jujuba	Chinese date	N	Y	D / deciduous
SHRUBS				
Aronia melanocarpa	Black chokecherry	N	N	deciduous
Cornus sanguinea ‘Cato’ **	Arctic sun red twig dogwood	N	N	deciduous
Cornus stolonifera **	Red osier dogwood	Y	N	deciduous
Cornus stolonifera ‘Kelseyi’ **	Kelsey dogwood	Y	N	deciduous
Corylus cornuta	Western Hazelnut	Y	N	deciduous
Euonymus alatus ‘Little Moses’	Little Moses burning bush	N	N	deciduous
Euonymus japanicus ‘Microphyllus’	Box-Leaf Euonymous	N	Y	evergreen

Scientific/Botanical Name	Common Name	Northwest Native (Y/N)	Drought Tolerant (Y/N)	Height (key above), Size or Condition
Gaultheria shallon	Salal	Y	Y	evergreen
Fuchsia magellanica	Magellan Fuchsia or Hardy Fuchsia	N	Y	deciduous
Hebes spp.	Hebes			evergreen
Holodiscus discolor	Ocean spray	Y	Y	deciduous
Kalmiopsis leachiana ‘LePiniec’ form		Y	Y	
Lonicera involucrata	Black twinberry	Y	Y	deciduous
Lonicera pileata	Privet honeysuckle	N	Y	Semi-evergreen
Mahonia aquifolium	Tall Oregongrape	Y	Y	evergreen
Mahonia nervosa	Low Oregongrape	Y	Y	evergreen
Mahonia repens	Creeping Mahonia	Y	Y	evergreen
Myrica californica	California wax myrtle	Y	Y	evergreen
Myrica pensylvanica	Northern bayberry	N	Y	evergreen
Paxistima myrsinites	Falsebox	N	Y	evergreen
Philadelphus coronarius	Mock orange	N	Y	deciduous
Pinus mugo	Mugo pine	N	Y	evergreen
Potentilla spp.	Buttercup shrub	N	Y	deciduous
Prunus besseyi	Sand cherry	N	Y	deciduous
Prunus laurocerasus ‘Mount Vernon’	Mount Vernon laurel	N	Y - once established	evergreen
Rhododendron occidentale	Western Azalea	Y	N	deciduous
Rhus aromatica ‘Gro-Low’	Fragrant Sumac	N	Y	deciduous
Ribes sanguinim	Red flowering current	Y	Y	deciduous
Rosemary	Rosemary	N	Y	evergreen
Rubus parviflorus	Thimbleberry	Y	Y	deciduous
Rubus spectabilis	Salmonberry	Y	Y	deciduous
Sarcococca hookeriana var. humilis	Dwarf sweetbox	N	N	evergreen
Spiraea betulifolia ‘Tor’ **	White spirea	N	N	deciduous
Symphoricarpos albus	Common snowberry	Y	Y	deciduous
Vaccinium ovatum	Evergreen huckleberry	Y	N	evergreen

Scientific/Botanical Name	Common Name	Northwest Native (Y/N)	Drought Tolerant (Y/N)	Height (key above), Size or Condition
FORBS				
Hemerocallis citrina and middendorffii	Daylilies	N	N	perennial flower
Iris douglasii	Douglas iris	Y	N	perennial flower-moist
Linum perenne	Blue flax	N	N	perennial flower
Rudbeckia fulgida	Black-eyed Susan	N	Y	perennial flower
Silphium integrifolium	Rosinweed	N	Y	perennial flower
Maianthemum racemosum	False Solomon's seal	Y	N	perennial flower
PERENNIALS				
Aquilegia formosa	Red columbine	Y	Y	perennial flower
Armeria maritima	Sea Thrift	Y	Y	perennial flower
Aruncus dioicus	Goat’s beard	Y	Y	perennial flower
Aster spp.	Aster	Y/N	Y/N	perennial flower
Camasia spp.	Camas	Y	Y	perennial flower
Columbine	Columbine	Y/N	Y/N	perennial flower
Coreopsis verticillata ‘Moonbeam’	Moonbeam coreopsis	N	Y	perennial flower
Dicentra formosa	Bleeding heart dicentra (locate away from foot traffic)	Y	N	perennial flower
Dodecatheon hendersonii	Henderson’s shooting star	Y	N	perennial flower
Echinacea purperea	Purple coneflower	N	Y	perennial flower
Hellebore purpurascens	Helebore	N	Y	perennial flower
Hemorocallis'stella de oro'	Lily	N	Y	perennial flower
Iris tenax **	Oregon iris	Y	Y	perennial flower

Scientific/Botanical Name	Common Name	Northwest Native (Y/N)	Drought Tolerant (Y/N)	Height (key above), Size or Condition
Leucanthemum superbum	Shasta daisy	N	Y	perennial flower
Liriope gigantea	Giant lily turf	N	Y - once establish ed	perennial flower
Liriope muscari ‘Big Blue’	Big blue lily turf	N	Y - once establish ed	perennial flower
Lupinus latifolius	Broadleaf lupine	Y	N	perennial flower
Maianthemum dilatum	False Lily of the Valley	Y	N	perennial flower
Oxalis oregana	redwood sorrel or Oregon oxalis	Y	N	perennial flower
Sedum divergens	Spreading stonecrop	Y	N	perennial flower
Sedum oreganum	Broadleaf stonecrop	Y	N	perennial flower
Maianthemum stellata	Start-flowered Solomon’s seal,	Y	Y	perennial flower
Maianthemum racemosa	False Solomon’s seal	Y	N	perennial flower
Solidago canadensis	Goldenrod	Y	Y	perennial flower
Tellima grandiflora	Fringe cups	Y	Y - once establish ed in shade	perennial flower
Vancouveria hexandra	Inside-out flower	Y	N	perennial flower
Zantedeschia elliottiana	Calla lily	N	N	perennial flower
GRASSES				
Briza media	Rattlesnake grass	N	Y	
Calamagrostis X Acutiflora 'Karl Foerster'	Feather Reed Grass	N	N	
Carex morrowii	Japanese Sedge	N	N	
Chasmanthium latifolium	Sea oat grass	N	Y	
Camassia Quamash	Native Camas	Y	N	
Festuca glauca	Blue Fescue	N	Y	
Helictotrichon sempervirens	Blue Oat Grass	N	Y	

Scientific/Botanical Name	Common Name	Northwest Native (Y/N)	Drought Tolerant (Y/N)	Height (key above), Size or Condition
Hakonechloa macra	Japanese Forest Grass	N	N	
Liriope muscari/spicata	Lily-turf	N	N	
Miscanthus sinensis	Maiden Grass	N	Y	
Ophiopogon japonicus	Mondo Grass	N	N	
Ophiopogon planiscapus 'Nigrescens'	Black Mondo Grass	N	N	
Panicum virgatum	Switch Grass	N	Y	
Pennisetum alopecuroides	Dwarf Fountain Grass	N	Y	
Pennisetum setaceum	Fountain Grass	N	Y	
Sisyrinchium idahoense	Blue eyed grass	Y	N	moist
GROUNDCOVERS				
Arctostaphylos uva-ursi	Kinnikinnick	Y	Y	evergreen
Asarum caudatum	Western wild ginger	Y	N	
Cornus unalashkensis	Bunchberry	Y	N	deciduous
Epimedium perralchicum	Hybrid epimedium	N	N	evergreen
Euphorbia amygdaloides var robbiae	Mrs. Robb's bonnet euphorbia	N	Y	evergreen
Fragaria chiloensis	Beach strawberry	Y	Y	evergreen
Pachysandra terminalis	Japanese Spurge	N	N	evergreen
Penstemon rupicola	Rock Penstemon	Y	Y	perennial flower
Rubus calycinoides	Crinkle-leaf Creeper	N	Y	evergreen
Sedum oreganum	Oregon stonecrop	Y	Y	evergreen
Thymus citriodorus-	Lemon thyme	N	N	evergreen
Vinca minor 'Atropurpurea'	Atropurpurea periwinkle	N	Y	evergreen
FERNS				
Athyrium filix-femina	Lady Fern	Y	N	moist
Blechnum spicant	Deer fern	Y	N	moist
Dryopteris expansa	Spiny wood fern	Y	N	moist
Dryopteris filix-mas	Male Fern	Y	N	moist
Gymnocarpium disjunctum	Common Oak Fern	Y	Y	
Polystichum munitum	Sword Fern	Y	Y	evergreen
Polystichum polyblepharum	Japanese tassel fern	N	Y	
VINES				
Akebia pentaphylla	Pentaphylla Akebia	N	N	vine
Akebia quinata	Chocolate Vine Akebia	N	N	vine

Scientific/Botanical Name	Common Name	Northwest Native (Y/N)	Drought Tolerant (Y/N)	Height (key above), Size or Condition
Clematis spp.	Clematis	N	N	vine
Codonopsis pilosula	Poor man's ginseng	N	N	vine
Dioscorea villosa Humulus	Wild yam	N	N	vine
Humulus spp.	Hops	N	N	vine
Lonicera ciliosa	Western Trumpet Honeysuckle	Y	Y	vine
Parthenocissus henryana	Silvervein creeper	N	N	vine
Parthenocissus quinquefolia	Virginia creeper	N	N	vine
Parthenocissus tricuspidata (and 'Vetchii')	Boston Ivy	N	Y	vine
Passiflora incarnata	Passion flowers	N	Y	vine
BIORETENTION PLANTS	(Plants marked with ** above are acceptable in Bioretention areas)			
Carex deweyana	Dewey's sedge	Y	N	evergreen
Carex obnupta	Slough sedge	Y	N	evergreen
Carex testacea	Orange New Zealand sedge	N	Y	
Juncus effuses var. pacificus	Soft rush	Y	N	

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FIGURES

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803.1 INTRODUCTION

803.1.1 Document Scope

803.1.1.1 This section establishes the design criteria for sustainability. The purpose of integrating sustainability into Sound Transit projects is to implement environmental stewardship and sustainable development, reduce environmental risks and liabilities, ensure regulatory compliance, improve environmental performance with a focus on reducing the impacts of our natural resource use during construction and on the long-term operations and maintenance implications of building approaches and materials, identify cost-effective solutions, and enhance public education and outreach around sustainability with regulators, other agencies, and stakeholders.

803.1.1.2 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 803 owner to determine the technical source for the design criteria.

803.1.2 Regulations, Codes, Standards, and Guidelines

803.1.2.1 International Regulations, Codes, Standards, and Guidelines

803.1.2.1.1 ENVISION, current version

803.1.2.1.2 Green Business Certification (GBCI).

803.1.2.1.3 Institute for Sustainable Infrastructure (ISI).

803.1.2.1.4 International Organization for Standardization (ISO).

803.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

803.1.2.2.1 United States Green Building Council (USGBC).

803.1.2.2.2 Leadership in Energy and Environmental Design (LEED).

803.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines (Not Used)

803.1.2.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

803.1.2.5 Other Jurisdictions (Not Used)

803.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

803.1.2.6.1 Sound Transit Sustainability Checklist.

803.1.3 Abbreviations and Acronyms

803.1.3.1 AC–alternating current

803.1.3.2 EDP–environmental product declaration

803.1.3.3 EMS–energy management system

803.1.3.4 EV–electric vehicle

803.1.3.5 GWP–global warming potential

803.1.3.6 HPD–health product declaration

803.1.3.7 HVAC–heating, ventilation, and air conditioning

803.1.3.8 IFC–issued for construction

803.1.3.9 LID–low impact development

803.1.3.10 LZ–lighting zone

803.1.3.11 ODP–ozone-depleting potential

803.1.3.12 OMF–operations and maintenance facility

803.1.3.13 PV–photovoltaic

803.1.3.14 TCO–total cost of ownership

803.1.4 Definitions and Classifications

803.1.4.1 In addition to the definitions below, reference Set 001 General for definitions.

803.1.4.2 ENVISION: A resource and rating system for professionals involved in the planning, design, building, and maintenance of large civil infrastructure projects. It consists of a broad range of criteria to help project teams make better decisions at each project phase.

803.1.4.3 ENVISION scorecard: A comprehensive framework of approximately 60 criteria that encompass the full range of environmental, social, and economic impacts that should be assessed, arranged into five categories: quality of life, leadership, resource allocation, natural world, and climate and risk.

803.1.4.4 ESMS: Environmental and Sustainability Management System.

803.1.4.5 LEED: Leadership in Energy and Environmental Design. A green building rating system, LEED provides a framework that project teams can apply to create healthy, highly efficient, and cost-saving green buildings and infrastructure. LEED certification is a globally recognized symbol of sustainability achievement.

803.1.4.6 LEED scorecard: A framework of approximately 62 credits arranged into seven categories, with a maximum achievement of approximately 110 points. Sound Transit requires LEED Gold minimum (unless otherwise specified by AHJ or coordinated and approved by Sound Transit) be achieved for LEED-eligible projects, which requires minimum of 60 awarded points from GBCI. The categories include:

i. Location and Transportation
ii. Sustainable Sites
iii. Water Efficiency
iv. Energy and Atmosphere
v. Materials and Resources
vi. Indoor Environmental Quality
vii. Innovation

803.1.4.6.1 All design teams must be familiar with the current version and understand the current points system and the number of points available and required in each section to achieve the proposed level or certification.

Commentary: Envision, LEED, and other scorecard systems are subject to revision and changes in requirements to meet different levels.

803.1.4.7 Total cost of ownership: Lifetime financial costs reflected in the cash flow impact to Sound Transit directly attributable to a proposed action. These include both initial and one-time costs and all lifetime operating costs. Refer to Sound Transit Executive Policy #602.

803.1.5 References (Not Used)

803.2 STAKEHOLDER NEEDS (NOT USED)

803.2.1 Passenger Experience

803.2.2 Operational Needs

803.2.3 Maintenance Needs

803.2.4 Safety Needs

803.2.5 Security Needs

803.2.6 Reliability, Availability and Maintainability Needs

803.2.7 Environmental and Sustainability Needs

803.3 SYSTEM REQUIREMENTS

803.3.1 General Requirements

803.3.1.1 The Sound Transit Sustainable Design Criteria provides guidance for sustainable building and infrastructure and is intended to prioritize the following considerations:

803.3.1.2 Conserve natural resources. Design teams must strive to:

i. Use building approaches and materials that result in reduced use of energy and water over the lifetime of the assets being constructed. Maximize efficiency with a focus on energy and water. Focus on energy efficiency opportunities for lighting, HVAC, and systems; reduce the use of water through low-flow fixtures, plant selection, planting techniques, and irrigation approaches.
ii. Use less. Design facilities and infrastructure to use materials wisely that lower the embodied carbon of the facility. Consider resource conservation in the composition and durability of the materials selected for use. Where possible, utilize salvaged materials, materials with recycled content or materials with low-embodied energy and water contents.
iii. Implement features with restorative functions such as renewable energy production and advanced low-impact development approaches only after conservation efforts have been pursued.

803.3.1.3 Design and build for the long-term. Consider the long-term operations and maintenance impacts of facility and infrastructure designs:

803.3.1.4 Design buildings and infrastructure for long-term use.

803.3.1.5 Evaluate the use of high-quality and long-lasting products in lieu of replacing items over time. Materials must be selected based on durability, design life or service life, and maintenance requirements to minimize replacement and maintenance costs. Consider the TCO when making decisions.

803.3.1.6 Consider sustainable building and infrastructure solutions in coordination with agency transit-oriented development and access improvements.

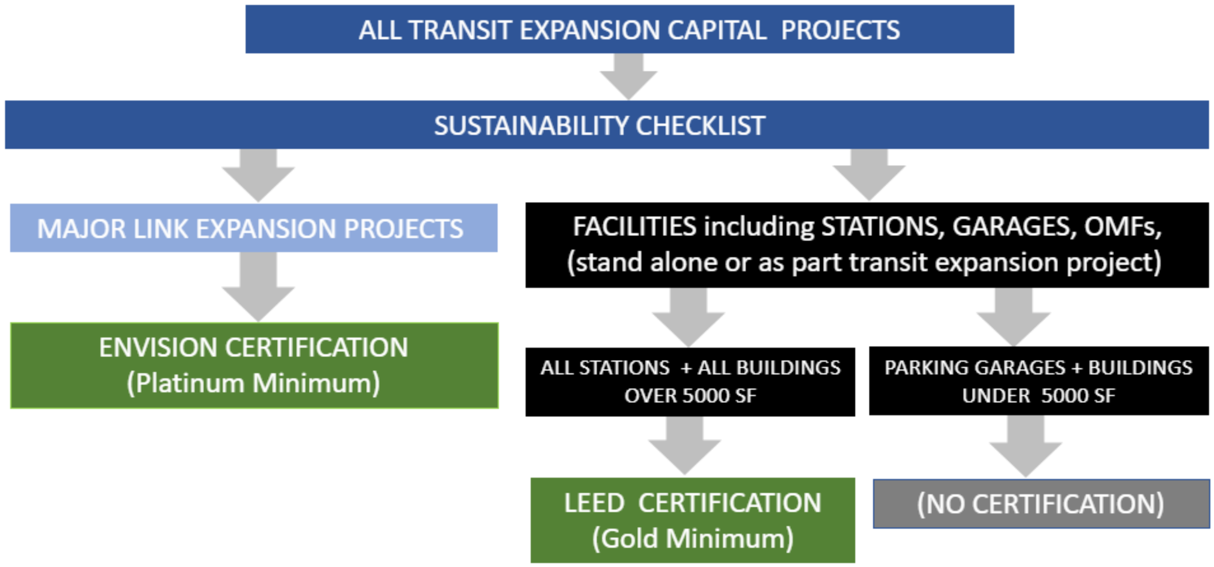
803.3.2 Functional Requirements

Commentary: Sound Transit manages the day-to-day implementation of its sustainability priorities and long- and short-term goals through its ESMS. The agency's ESMS meets the requirements of the internationally recognized ISO 14001:2015 standard and serves as a framework for evaluating and implementing environmental and sustainable recommendations. The ESMS establishes annual objectives and targets that implement the agency's sustainability priorities and goals, including sustainable design and infrastructure. This approach results in improved environmental and sustainability performance.

Commentary: Many project elements are guided by ESMS Procedures. These procedures outline how project implementation follows standard Sound Transit policies and procedures. A major component of the ESMS involves bi-annual environmental compliance and sustainability audits during construction and operations.

803.3.2.1 Design and construction elements must be implemented according to the processes detailed in the ESMS procedures.

Figure 803-1: Criteria for Sustainable Building and Infrastructure



Note: Occupied conditioned space must be 200 square feet or greater to trigger LEED certification requirement.

803.3.3 Sustainability Checklist

Commentary: All sustainability checklist measures are chosen to be achievable, the best value for the measure, and/or a proven technology. Measures on the sustainability checklist have been prioritized based on their alignment to Sound Transit's sustainability goals, and their alignment to third party rating systems.

803.3.3.1 The Set 803 Sustainability Checklist is required for use on all projects and is focused on infrastructure building requirements specific to transit and other agency-identified priorities. The checklist applies regardless of facility type.

803.3.4 Construction Requirements Criteria

Commentary: The Set 803 Sustainability Checklist includes an additional section focused on construction. These required measures are included in the checklist to inform design teams that may be responsible for creating or amending construction specifications.

803.3.4.1 Construction items included in the sustainability checklist must correspond to existing construction specifications or general conditions.

803.3.5 Third Party Certifications

803.3.5.1 Sound Transit has developed the following sustainability criteria for projects, based on nationally recognized third-party sustainable building and infrastructure rating systems as well as the agency's own experience implementing customized sustainability criteria.

803.3.6 ENVISION Certification Criteria

803.3.6.1 All Sound Transit funded corridor projects eligible to meet the ISI's ENVISION rating system for civil infrastructure will be certified, at a minimum, to the Platinum level.

803.3.6.2 A customized Envision Scorecard must be provided by Sound Transit staff to the consultant as part of the procurement process. This scorecard will note the Envision measures required for the corridor. Preferred measures will be indicated to help the consultant prioritize use of the rating system. The consultant must provide documentation of the Envision measures achieved for Sound Transit review and approval. Sound Transit and the consultant must coordinate responsibilities for documenting Envision credits.

803.3.6.3 The consultant is responsible for all documentation and verification associated with Envision certification, including project registration with ISI. Sound Transit's sustainability team liaison will be listed as the Project Leader and have full access to the registration/certification site.

803.3.6.4 The consultant is responsible for all payment of fees associated with certification, including certification, appeals, interpretation requests, and expedited review.

803.3.6.5 When registering a project, designate Sound Transit as the Sustainability liaison for the project, or other Sound Transit staff member as the project owner, with full documentation access and the ability to add viewing or editing access privileges to others. However, Sound Transit's Sustainability lead for the project must be listed at ISI as the project leader with direct control over who has access to the site.

Commentary: Decisions about Envision Certification Criteria are established in the memorandum Envision Platinum – recommendations for Requirements Manual.

803.3.7 LEED Certification Criteria

803.3.7.1 All Sound Transit funded facilities eligible to meet USGBC's LEED BD & C standards must, at a minimum, be certified to LEED Gold standards. Where applicable, the LEED for Transit specific rating system must be used (for stations).

Commentary: LEED Gold is the goal and standard for all stations, however there could be circumstances where LEED Gold or LEED itself is either not possible or extremely difficult. In these rare occasions the design team must coordinate with and get approval from Sound Transit for a lesser level of LEED for Transit or some other sustainability certification. All other Sound Transit facilities eligible must be certified at a minimum to meet LEED BD+ C Gold standard.

803.3.7.2 Eligible facilities must include certain LEED credits as prioritized by Sound Transit (see Section 803 Appendices for Sustainability Checklist, "LEED Credit Equivalents" column). Additional credits above those required by Sound Transit must be proposed by the consultant with a target of a five-point buffer above minimum Gold level. The consultant must provide documentation of the LEED credits achieved for Sound Transit review and approval.

803.3.7.3 The consultant is responsible for all documentation and verification associated with LEED certification, including project registration with GBCI. The consultant is responsible for all payment of fees associated with certification, including certification, appeals, interpretation requests, and expedited review.

Commentary: Decisions about LEED Certification Criteria are established in the memorandum LEED Gold – recommendations for Requirements Manual.

803.3.8 Facilities Not Eligible for Certification

803.3.8.1 All other Sound Transit funded facilities (BRT stations, parking garages, or park and ride facilities without occupied, conditioned spaces) must at a minimum, meet the LEED Version 4 credits as noted on the Set 803 sustainability checklist. Application to USGBC for LEED certification is not required.

803.3.8.2 Parking garages must not seek LEED certification on their own merit and must only be included in LEED applications if located within the LEED boundary of a larger station or facility project.

803.3.9 Defining Requirements and Applicability

803.3.9.1 All LEED, Envision, and Set 803 Sustainability checklist requirements must be integrated into the project without the need for additional evaluation regarding which third-party certification system to follow. The determination of specific LEED credits and Envision measures needed to meet third-party minimum certification standards must be evaluated with total life cycle costs in mind. The design team must provide design services necessary to evaluate and incorporate these elements.

803.3.9.2 Where required measures are not relevant to a particular project, those measures must be marked “not applicable” with justification provided—it is not sufficient simply to mark an item as “not applicable.” Items listed as “not applicable” will be required to be approved as such by Sound Transit staff prior to being removed as a project requirement.

803.3.10 Higher Levels of Sustainability

803.3.10.1 Designers are encouraged to pursue more higher levels of sustainability, and to notify Sound Transit when such measures or additional efficiencies are achievable within the project budget. Sound Transit will collaborate with the design team to determine if such approaches must be included. Any additional measures evaluated must be added to the checklist for documentation.

803.3.11 Submittal Requirements

803.3.11.1 Each contract package during final design will include the section 803 Sustainability Checklist and, as applicable, the corresponding LEED Scorecard. The Envision measures are to be tracked in one Envision scorecard that spans all contract packages. The design team responsible for LEED and Envision documentation and administration will perform these tasks from design through to project completion.

803.3.11.2 For all sustainability components (Section 803 Sustainability Checklist, LEED and Envision), submit documentation as prescribed in EP-03 to help facilitate integration with other disciplines. For projects with multiple design segments and submittals, the checklist submittal schedule must be determined as part of the design scope of work. Construction-related documentation must be regularly monitored and documented during construction phases.

803.3.12 Section 803 Sustainability Checklist

803.3.12.1 Sound Transit sustainability measures will be managed by the design team in the provided Section 803 sustainability checklist. This checklist will report progress on implementing sustainability measures at the agreed upon submittal milestones.

803.3.12.2 When an item on the checklist references a LEED credit, the consultant will provide Sound Transit with the same compliance documentation as required by GBCI for design credits.

803.3.13 LEED Documentation

803.3.13.1 All LEED measures will be managed by the design team through USGBC’s LEED scorecards and the Set 803 sustainability checklist. The scorecards and integrated checklist will report progress on implementing sustainability measures at the agreed upon submittal milestones.

803.3.14 ENVISION Documentation

803.3.14.1 The Envision checklist measures will be managed by the design team via the customized Envision scorecard provided during the procurement process. This checklist will report progress on implementing sustainability measures at the agreed upon submittal milestones.

803.3.15 LEED & ENVISION Management Plans

803.3.15.1 In addition to the Set 803 sustainability checklist, design teams must develop and submit LEED and Envision management plans outlining how certification will be achieved.

Commentary: Achieving a project’s sustainability goals along with all other goals is best served by an integrated process and collaborative team. The management plan is intended to help ensure an integrative process is used.

803.3.15.2 The management plans must be reviewed by Sound Transit and are required to be submitted at predetermined planning and design milestones. As live documents, they are expected to evolve over the course of the project, beginning in final design.

803.3.15.3 During construction, the consultant must maintain and update the necessary records and documentation to demonstrate compliance and attainment of Envision and LEED credits, which must be made available to Sound Transit. This expectation needs to be coordinated with all DB, DBB, and GCCM team members so that responsibilities and costs are expected at start of project.

803.3.15.4 The Envision Management Plan must include:

803.3.15.4.1 Name of Assigned Envision Sustainability Professional: The consultant must utilize an Envision sustainability professional that is responsible for ISI compliance design through final acceptance. This individual may be the same person fulfilling the role of LEED accredited professional if they meet the required expectations. This individual must:

i. Be fully knowledgeable regarding Envision terminology, documentation requirements, and submission protocol and must be effective in communicating and enforcing Envision requirements with their subcontractors and suppliers.
ii. The consultant's lead for achieving Envision certification must be a current Envision certified professional with a leading responsibility for successfully accomplishing Envision certification on at least two previous projects, one of which needs to have achieved at least Gold.
iii. Be responsible for planning, implementing, managing, directing, and documenting the work of this project in conformance with the requirements of the selected Envision credits noted on the Envision scorecard included.
iv. Be experienced and proactive in the planning and implementation of strategies for assuring conformance to Envision certification requirements.
v. Submit documentation as required by ISI and respond to review comments including preparation of any additional documentation.

803.3.15.4.2 Roles and responsibilities for all Envision team members.

803.3.15.4.3 Envision scorecard.

803.3.15.4.4 Narrative describing compliance path for each prerequisite and credit.

803.3.15.4.5 Address site protection plan, including site boundaries, site disturbance, and erosion and sedimentation control.

803.3.15.4.6 Plan for posting and communicating requirements and plans on site.

803.3.15.4.7 Address strategy and subcontractor/worker compliance.

803.3.15.4.8 Address method for submittals and materials tracking.

803.3.15.4.9 Address contractor's photograph documentation process for documenting Envision conformance for each construction measure.

803.3.15.4.10 Include a minimum of a two-hour facilitated lessons-learned debrief with Sound Transit at the end of the design submittal process and construction submittal.

803.3.15.5 The LEED management plan must include:

803.3.15.5.1 Assigned LEED accredited professional: The consultant must utilize a LEED accredited professional or a separate LEED consultant that is responsible for compliance design through final acceptance. This individual may be the same person fulfilling the role of Envision sustainability professional if they meet the required expectations. This individual must:

i. Be fully knowledgeable regarding LEED terminology, documentation requirements, and submission protocol and must be effective in communicating and enforcing LEED requirements with their subcontractors and suppliers.
ii. Have been responsible for successfully being in this role for three previous projects.
iii. Link light rail transit expansion projects, including OMFs, are required to include a LEED proven provider on the consultant team.
iv. Be responsible for planning, implementing, managing, directing, and documenting the work of this project in conformance with the requirements of the selected LEED credits noted on the LEED scorecard included.
v. Be experienced and proactive in the planning and implementation of strategies for assuring conformance to LEED certification requirements.
vi. Submit documentation as required by USGBC and respond to GBCI review comments, including preparation of any additional documentation.

803.3.15.5.2 Include a minimum of a two-hour facilitated lessons-learned debrief with Sound Transit at the end of the design submittal process and construction submittal.

803.3.15.5.3 Roles and responsibilities for LEED team members.

803.3.15.5.4 Name of commissioning authority (owner representative) and commissioning coordinator (contractor appointed). See section 003 for commissioning requirements.

803.3.15.5.5 LEED scorecard.

803.3.15.5.6 Narrative describing compliance path for each prerequisite and credit.

803.3.15.5.7 Address site protection plan, including site boundaries, site disturbance, and erosion and sedimentation control.

803.3.15.5.8 Plan for posting and communicating requirements and plans on site.

803.3.15.5.9 Address strategy and subcontractor/worker compliance.

803.3.15.5.10 Address method for submittals and materials tracking.

803.3.15.5.11 Address contractor’s photograph documentation process for documenting LEED conformance for each construction measure.

803.3.15.5.12 Management plan for meeting the Section 803 sustainability checklist is not required by the consultant; however, the sustainability checklist is required to be submitted at regularly determined intervals as prescribed in EP-03.

803.3.16 Project specific solar power assessments

803.3.16.1 Preliminary solar assessment: Prior to the completion of 30 percent design, every project must complete a solar assessment to gather the information needed to set the solar PV requirements for the project.

803.3.16.2 The assessment will include information that assists Sound Transit to choose between PV-installed system and PV-ready options. PV-ready means that a PV array could be cost-effectively added later as a separate project. See “On-Site Solar Memorandum” for further requirements and guidance on type and size of structures to be evaluated for solar PV installations. The assessment must include:

803.3.16.2.1 Minimum threshold: The site must have sufficient space to host a 30-kilowatt to 100-kilowatt solar array with sufficient clearances and maintenance access. Coordinate maintenance access with Operations to determine clearances and access are sufficient. Eligible areas generally include:

i. Locations that are greater than 20 feet from catenary and tracks.
ii. Walkway canopies.
iii. Parking garage perimeters, walls, and/or roofs (where roofs are installed, not the top parking deck).
iv. Maintenance facility roofs, walls, or canopies.

Commentary: Because of maintenance access restrictions, areas excluded from consideration are station canopies if near catenary and tracks, and over tracks or between tracks.

803.3.16.3 Determine if future development could shade site and impact the power generation.

803.3.16.4 The PV-ready option must include a list of key points needed to minimize the costs of adding PV arrays in the future, like structural requirements to support additional weight of PV array, space needs identified in electrical room for inverters and electrical panels, or electrical pathway and conduit, especially in concrete that would be expensive to add later.

803.3.16.5 Where PVs are provided, a utility production meter must be installed to measure output.

Commentary: Project Specific Solar requirements were developed as part of the research and information outlined in the On-Site solar memorandum. Please consult this memo for additional background on the requirements.

803.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

803.5 SYSTEM INTERFACE REQUIREMENTS

Table 803.1 lists requirement sets that are typically coordinated, and may have dependencies, with this set.

Table 803-1: Interface Between Sustainability and Other Disciplines

SET SERIES	SERIES NAME	SET 803 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	
300	Operational Communications	
400	Vehicle	
500	Track	
600	Fire / Life Safety	
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical / Electrical and Building Systems	X
1100	Technology	
1200	Security	

803.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

803.7 ENGINEERING MANAGEMENT REQUIREMENTS

803.7.1 Interface and Integration Management

803.7.1.1 The design must consider and account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructable documentation and functional designs.

803.7.2 Design Management

803.7.2.1 Provide submittals at identified milestones in EP-03.

803.7.3 Manufacturing and Construction Management

803.7.4 Installation Management

803.7.5 Inspection and Testing Management

803.7.6 Training, Pre-Revenue Operations

803.7.7 Certification Management

803.8 APPENDIX

803.8.1 Sustainability Checklist

Figure 2: Chapter 30 Sustainability Checklist

REQUIRED DESIGN MEASURES				Requirements by Project Type					Operational Considerations	Comments
#	Measure	Spec Section	LEED Credit Equivalent (v4)	Station: Conditioned Space	Station: No Conditioned Space	BRT Station	Parking Garage	O&M Facility		
S1	**Site Assessment:** Assess site conditions before design to evaluate sustainable options to help inform related decisions about the site. Complete the following surveys: Topography, Hydrology, Climate, Vegetation, Soils, and Human Use & Health Effects.		SSc1	Y	Y	Y	Y	Y		
S2	**Bicycle Facilities:** Design project to include easily accessible bicycle parking near structure for both short and long term. Evaluate bicycle parking size to meet expected demand.		LTc6	Y	Y	Y	Y	Y		
S3	**Low Impact Development Rainwater Management:** Using natural site hydrology processes to manage on site (through infiltration or evapotranspiration) the runoff for the 95th percentile regional rainfall event, using LID strategies.		SSc4	Y	Y	Y	Y	Y		
S4	**Balance Earthwork:** Balance the excavated earthwork on site in a manner to reduce trips to/from site, and to use as efficiently as possible the excavated materials on site.		*N/A*	Y	Y	Y	Y	Y		
S5	**Weather Protection Design:** Design and orient occupied external spaces and outdoor waiting areas so that daylighting is maximized, and occupants are adequately protected from weather elements.		*N/A*	Y	Y	Y	Y	Y		
S6	**Limits of Disturbance:** Ensure construction documents clearly define limits of disturbance during construction. This includes area impact limits, landscape tree protection and other site-sensitive areas.		*N/A*	Y	Y	Y	Y	Y		
W1	**Outdoor Water Use Efficiency:** Reduce landscape outdoor potable water use requirements through efficient landscape design. Select adapted drought-tolerant species and irrigation system efficiency. Target **50%** potable water use reduction compared to a spray-irrigation baseline, through drip irrigation.		WEc1	Y	Y	Y	Y	Y		
W2	**Indoor Water Use Efficiency:** Reduce indoor potable water use by minimum **35%** through use of low-flow and flush fixtures and aerators.		WEc2	Y	N	N	Y	Y		
W3	**Water Metering:** Sub-meter the following systems, where applicable to the project (water systems may be sub-metered together as appropriate): 1. System Irrigation (coordinate with DCM Chapter 10) 2. Indoor Plumbing Fixtures 3. Domestic Hot Water 4. Reclaimed Water/process water		WEc4	Y	Y	N	Y	Y		
E1	**Fundamental Commissioning:** Engage with commissioning authority to review project OPR, BOD prior to construction. Cx Authority & Coordinator will witness functional testing, prepare Cx Plan, functional checklists, Cx Report, and Systems Manual.		EAp1	Y	Y	Y	Y	Y		
E2	**Post-Occupancy Commissioning**: Conduct a post-occupancy evaluation of electric, HVAC, and plumbing (including irrigation) systems. Document issues as noted, including path for issue resolution.		EAc1	Y	Y	Y	Y	Y		

Figure 2: Chapter 30 Sustainability Checklist

REQUIRED DESIGN MEASURES				Requirements by Project Type					Operational Considerations	Comments
#	**Measure**	**Spec Section**	**LEED Credit Equivalent (v4)**	**Station:** Conditioned Space	**Station:** No Conditioned Space	**BRT Station**	**Parking Garage**	**O&M Facility**		
E3	**Energy Metering:** Install energy metering for the project. Meters must have the following characteristics: Record at intervals of 1 hour or less, store data for minimum 36 months, be remotely accessible, and electricity meters to record both consumption and demand. Refer to SETS 1004 BUILDING MONITORING AND CONTROL and 1005 ELECTRICAL POWER for meter characteristics.		EAc3	**Y**	**Y**	**Y**	**Y**	**Y**		
E4	**Refrigerant Management:** Select refrigerants to minimize their ozone-depleting potential (ODP) and global warming potential (GWP)		EAc6	**Y**	**N**	**N**	**Y**	**Y**		
E5	**Renewable Energy PV Analysis:** Evaluate the potential for solar photovoltaic (PV) installation (30-100 kW) at all non-station structures. Identify and prioritize preferred locations within sustainability report prior to 30% design		*N/A*	**Y**	**Y**	**N**	**Y**	**Y**		
M1	**Storage & Collection of Recyclables:** Provide dedicated areas for the storage & collection of recyclables. Area must be sized to adequately provide storage for: paper, cardboard, metals, glass, plastics.		MRp1	**Y**	**Y**	**Y**	**Y**	**Y**		
M2	**Recycled Content in Materials:** Ensure specifications include language requiring use of materials with high levels of recycled content. Examples include: All metals minimum 35% recycled; Concrete minimum 5% fly ash.		MRc3	**Y**	**Y**	**Y**	**Y**	**Y**		
M3	**Red Listed Interior Materials:** Provide language in specifications to avoid materials containing the following: 1. Resilient Flooring: avoid PVC, halogenated organic compounds 2. Carpets: avoid PVC 3. Upholstery: avoid PVC 4. Gypsum products: avoid mildewcides, antimicrobials 5. Insulation: avoid mildewcides, antimicrobials, asbestos, urea-formaldehyde 6. Floor & Wall Tiles: avoid PVC, mildewcides, antimicrobials		*N/A*	**Y**	**N**	**N**	**N**	**Y**		
AQ1	**Environmental Air Quality Control:** Design outdoor air intakes to avoid the intake of fumes and emissions by placing them at least 15 feet away from possible contaminants locations (such as tobacco smoke and exhaust)		IEQp2	**Y**	**Y**	**N**	**Y**	**Y**		
AQ2	**Indoor VOC Tracking: Adhesives / Sealants / Paints / Coatings:** Do not exceed VOC limits for applicable wet-applied product according to the SQAQMD Rule 1113 (paints & coatings) and Rule 1168 (adhesives & sealants).		IEQc2	**Y**	**Y**	**N**	**Y**	**Y**		
AQ3	**Indoor Air Quality – During Construction:** Develop & implement an IAQ Plan for enclosed facilities prior to the start of construction. Meet or exceed SMACNA IAQ Guidelines for Occupied Buildings Under Construction, 2nd Edition 2007.	018119	IEQc3	**Y**	**N**	**N**	**Y**	**Y**		

PREFERRED DESIGN MEASURES				Requirements by Project Type					Operational Considerations	Comments
#	Measure	Spec Section	LEED Equivalent	Station: Conditioned Space	Station: No Conditioned Space	BRT Station	Parking Garage	O&M Facility		
S8	**Protect & Restore Habitat:** Maintain existing native vegetation to the maximum extent feasible. Where new plantings are added, ensure vegetation selected is native or adapted to Pacific Northwest climate.	015639	SSc2	Y	Y	Y	Y	Y		
S9	**Site Excavated Material Reuse:** Reduce the import and export of excavated soils from the project site. Examples include savings topsoil for reuse, or saving and crushing concrete materials for reuse.	015713	*N/A*	Y	Y	Y	Y	Y		
S10	**Heat Island Effect:** <u>For roof areas</u>: use materials with a SRI value >83 at installation. <u>For non-roof areas</u>: Use trees/structures to provide shade for 50% of pedestrian hardscape within 5 years of project completion. Use paving materials with a SRI value >29 at installation. Parking roof decks are excluded from this calculation per LEED definitions/interpretations.		SSc5	Y	Y	Y	Y	Y		
S11	**Light Pollution Reduction:** Comply with LEED credit BUG area method for light pollution reduction. Meet uplight and light trespass requirements as determined the lighting zone (LZ).		SSc6	Y	Y	Y	Y	Y		
S12	**Reduced Parking Footprint:** Do not exceed the minimum local code requirements for parking capacity. Provide carpool and vanpool preferred parking near ADA stalls as benefits.		LTc7	Y	Y	N	N	Y		
E6	**Renewable Energy Production On Site:** Dependent on results from PV assessment (required measure), Sound Transit and design team will coordinate addition of photo-voltaic array to project design, or create PV-ready structures.		EAc5	Y	Y	N	Y	Y		
M5	**Material Transparency:** Ensure a min of 20 Material Environmental Product Declarations (EPDs) are collected for project. Ensure a min of 20 Material Health Product Declarations (HPDs) are collected for project.		MRc2-3	Y	N	N	N	Y		
AQ2	**Natural Ventilation: Operable Windows:** In projects with areas above-grade, and where air quality is not detrimental, provide operable windows to promote natural ventilation and improve indoor occupant air quality.		IEQc1	Y	N	N	N	Y		

REQUIRED CONSTRUCTION MEASURES				Requirements by Project Type					Operational Considerations	Comments
#	Measure	Spec Section	LEED Equivalent	Station: Conditioned Space	Station: No Conditioned Space	BRT Station	Parking Garage	O&M Facility		
C1	**Construction Staging Areas:** Avoid placing construction staging areas within 100 feet of stormwater discharge areas, wetlands, stream buffers, or other ecologically sensitive areas (where feasible)	015500	*N/A*	Y	Y	Y	Y	Y		
C2	**Construction Activity Erosion Control:** Ensure project specifications include section on Erosion & Sediment Control, and that ESC Plan is in civil drawings. The plan must conform to the erosion & sedimentation requirements of the 2012 US EPA CGP, or local equivalent.	015713	SSp1	Y	Y	Y	Y	Y		
C3	**Construction Waste Management:** Ensure contractor complies with King County Readily Recyclable Construction & Demolition practices: Clean wood, cardboard, metal, gypsum, bricks, and concrete are banned from landfill. Mixed C&D from job sites may only be sent to KC designated C&D Facilities.	017400	MRc5	Y	Y	Y	Y	Y		

REQUIRED CONSTRUCTION MEASURES				Requirements by Project Type					Operational Considerations	Comments
#	Measure	Spec Section	LEED Equivalent	Station: Conditioned Space	Station: No Conditioned Space	BRT Station	Parking Garage	O&M Facility		
C4	**Vehicle Idling – During Construction:** Avoid excessive construction vehicle idling by educating all staff and sub-contractors, and providing adequate signage on the site to ensure vehicle idling is kept to a minimum. Contractor must self-report and track.	015715	*N/A*	Y	Y	Y	Y	Y		
C5	**Water Reuse – During Construction:** Where feasible, avoid use of new potable water on construction sites for use in wheel washing, dust control, etc. Look for opportunities to reuse water through a closed loop approach.	015713	*N/A*	Y	Y	Y	Y	Y		

LEGEND					
Sites	Water	Energy	Materials	Air Quality	Construction

END SET - 803

804 FALL PROTECTION

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SET - 804 FALL PROTECTION

804.1 INTRODUCTION

804.1.1 Document Scope

804.1.1.1 This set covers the selection and design of fall protection systems for the purpose of safely servicing and maintaining facilities, including equipment, devices, and the facility structure itself, across all modes. It also identifies the means of access to facility elements.

804.1.1.2 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 804 owner to determine the technical source for the design criteria.

804.1.1.3 Refer to EP-03 for Fall Protection System design processes and design procedures in order to right-size systems for individual station environments.

804.1.2 Regulations, Codes, Standards, and Guidelines

804.1.2.1.1 International Regulations, Codes, Standards, and Guidelines

804.1.2.1.1.1 IBC - International Building Code.

804.1.2.1.2 Federal and National Regulations, Codes, Standards, and Guidelines

804.1.2.1.2.1 ANSI ASC A14.3 American National Standards for Ladders – Fixed – Safety Requirements.

804.1.2.1.2.2 ANSI Z359 – Fall Protection & Arrest Standards.

804.1.2.1.2.3 ANSI Z359.6 – Specifications and Design Requirements for Active Fall Protection Systems.

804.1.2.2 State and Local Regulations, Codes, Standards, and Guidelines

804.1.2.2.1 Washington Administrative Code § 296-880 – Unified Safety Standards for Fall Protection.

804.1.2.2.2 Washington Administrative Code § 296-876 – Ladders, Portable and Fixed.

804.1.2.2.3 Washington Administrative Code § 296-878 – Safety Standards for Window Cleaning.

804.1.2.2.4 Washington Administrative Code § 296-24-88050 – Appendix C – Personal fall arrest system.

804.1.2.2.5 Washington Administrative Code § 296-880-40020 – Personal fall arrest system requirements.

804.1.2.2.6 Washington Administrative Code § 296-880-40005 – Guardrail systems.

804.1.2.2.7 Washington Administrative Code § 296-876-60080 – Ladder safety devices.

804.1.2.3 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

804.1.2.4 Other Jurisdictions (Not Used)

804.1.2.5 Sound Transit Regulations, Codes, Standards, and Guidelines

804.1.2.5.1 2018 Sound Transit Standard Specifications, with amendments.

804.1.3 Abbreviations and Acronyms (Not Used

804.1.4 Definitions and Classifications

804.1.4.1 Refer to Washington Administrative Code § 296-24-88050 – Appendix C for definitions.

804.1.5 References (Not Used)

804.2 STAKEHOLDER NEEDS

804.2.1 Passenger Experience (Not Used)

804.2.2 Operational Needs (Not Used)

804.2.3 Maintenance Needs

804.2.3.1 Overhead equipment and devices must be safely accessible.

804.2.3.2 Canopy design must provide ease of maintenance.

804.2.3.3 Canopies must allow easy and safe cleaning of glazing, roof material, gutters, and downspouts.

804.2.3.4 Avoid sloped wall surfaces that are difficult to access for maintenance.

804.2.3.5 Avoid placement of ceiling-mounted devices directly over equipment.

804.2.3.6 Ceiling-mounted devices above cable trays and wireways are prohibited.

804.2.3.7 Areas that have a fall hazard and require ladders for maintenance access must include fall protection.

804.2.3.7.1 Provide permanent maintenance access stairs, ladders, and walkways.

804.2.3.8 Provide the ability to access equipment for service. Provide maintenance stairs, ladders, working platforms, and so forth to equipment areas requiring service. Provide access protocol to define the method anticipated for on-going maintenance.

804.2.3.9 Station design must avoid the need for specialized maintenance access, such as bosun’s chair.

804.2.3.10 Fall protection systems must be designed to minimize the need to switch between different fall protection mechanisms when moving from one area to the next.

804.2.4 Safety Needs

804.2.4.1 Provide applicable fall protection as needed for access to photovoltaics.

804.2.4.2 Provide applicable fall protection as needed for access to sump pumps.

804.2.4.3 Where means of access is by a lift, ensure that sufficient unobstructed floor space is available and that adequate means of access (e.g., passageways, elevators) is provided to deliver the lift to the location.

804.2.5 Security Needs (Not Used)

804.2.6 Reliability, Availability and Maintainability Needs

804.2.6.1 Structural supports must be provided for fall protection.

804.2.6.2 Fall protection must be coordinated with equipment access points.

804.2.7 Environmental and Sustainability Needs (Not Used)

804.3 SYSTEM REQUIREMENTS

804.3.1 General Requirements

804.3.1.1 The following outlines the acceptable hierarchy of fall protection, in descending order of preference:

i. Hazard elimination—preferred solution that eliminates exposure to the fall hazard.
ii. Passive fall protection—fixed physical barriers.
iii. Fall restraint systems—use of personal protective equipment to restrict the worker's range of movement so they cannot fall.
iv. Fall arrest systems—use of personal protective equipment to arrest a fall within acceptable force and clearance margins.

Commentary: Examples of passive fall protection include guardrails around unprotected edges and covers over holes. Fall restraint requires training for use of the system. Fall arrest requires training and rescue planning for use of the system. Administrative controls, such as work practices or procedures that increase a worker's awareness of a fall hazard, is not permitted.

804.3.1.2 Fall arrest or restraint is required above for adjacent to dangerous or hazard equipment and elevated work at four or more feet in all workplaces. Refer to WAC 296-880-20005 for additional information.

804.3.1.3 Fall arrest systems must have enough fall clearance from the ground and other obstructions so the system and equipment can fully stop the fall before contact with the ground or other object.

804.3.1.4 When determining fall distance, the calculation must use the maximum potential fall distance, such as falls over the guardrail or falls beyond the immediate level below.

804.3.1.5 Maintenance and repair areas must have a continuous safe means of access.

Commentary: This includes areas containing MEP equipment that require periodic access for inspection.

804.3.1.6 Areas accessed by portable equipment must have set-up and maneuvering clearance as recommended by the manufacturer of that portable equipment.

Commentary: Examples of portable equipment include ladders, elevating work platforms, or powered platforms.

804.3.1.7 Means of access to fall protection must not obstruct travel paths or access points to utilities or equipment.

Commentary: An example would be configuring a fixed ladder so that it does not obstruct access to a drain.

804.3.1.8 Comply with Table 804-1 and Set 1007 Electrical Lighting for fall protection and means of access for light fixtures at stairs and escalators.

804.3.1.9 Provide structural supports for fall protection systems. Comply with Set 720 Building Structures for additional requirements.

804.3.2 Roof Access

804.3.2.1 Roof areas must be accessible by moveable ladder, fixed ladder, and/or roof hatch.

804.3.2.2 Roof access points must be within a maximum distance of 24 inches from the roof fall protection system.

Commentary: An example of this condition would be the top of a ladder that is within 24 inches maximum from the first anchor post on a horizontal lifeline system.

804.3.2.3 Fixed ladders must be provided for all transitions between roof levels where another means of accessing roof levels is not provided.

804.3.2.4 Fall protection must be provided for all roof areas and other locations where needed to access the roof and areas not protected by guardrails. Fall protection must include both fall restraint for maintenance and fall arrest where required. All fall protection must meet WAC, Washington State Department of Safety and Health, and ANSI/ASSE Z359.1 Fall Protection Code standards. Attachment systems must be coordinated to accept standard Sound Transit maintenance equipment.

804.3.2.5 Ladder tie offs meeting Washington State Department of Safety and Health standards must be provided where access by ladder is required for frequent cleaning, equipment maintenance, and fixture relamping.

804.3.2.5.1 Consider adjacent materials at ladder tie-offs and detail tie-off anchors to fit into the architecture inconspicuously.

804.3.2.5.2 Where ladder tie offs are used adjacent to guardrails, raise heights of guards to reduce fall hazards from the ladder.

804.3.2.6 When horizontal lifelines are used, the system must be continuous and allow the user to transition through intermediate anchor posts without unclipping from the system.

804.3.2.7 Provide roof access and fall protection tie-off points for any roof that is not protected by the parapet, guardrail, or vehicle barrier. The design must provide roof access routes with the tie off point, fall restraints, and fixed ladders and platform wherever required per WAC and associated details.

804.3.3 Window Washing System

804.3.3.1 Provide window washing attachment systems as needed to access and clean all glazing. Window washing attachment systems must be provided for all roof areas and other locations to access windows where ladder access and tie-offs are not a reasonable or safe option. Alternatively, access by a scissor lift may be permitted if the lift is located at the facility.

804.3.3.2 Independent fall arrest systems must be provided alongside window washing suspension systems.

804.3.3.3 Areas of glass must be unobstructed to provide reasonable and safe access for cleaning. Placing structural elements such as cross bracing in front of glazed areas must be avoided.

804.3.3.4 Window washing systems must comply with WAC 296-878 requirements.

804.3.4 Portable Lift Access

804.3.4.1 There must be adequate space for a portable lift to access all necessary areas of a facility. Adequate space is determined by the portable lift needed which is driven by the height of the building.

804.3.4.2 A margin of error of 4 feet must be added to the space access calculation.

804.3.4.3 The supporting surface must be rated to support the weight of the applicable portable lift.

804.3.4.4 Coordinate level surface for portable lifts and landscaping locations to ensure area is provided. Refer to Set 802 Landscaping for additional requirements.

804.3.5 Performance Requirements

804.3.5.1 The horizontal lifeline must be designed for a minimum of two employees to work at the same time. The lifeline must start at the access point.

Commentary: Starting the horizontal lifeline at the access point allows employees to attach to the lifeline without added risk.

804.3.5.2 Refer to Section 11 24 29 Fall Protection in the Sound Transit Standard Specifications for additional requirements.

804.3.6 Horizontal Lifeline

804.3.6.1 Horizontal lifelines must comply with the applicable requirements of WAC 296-880-40020 and ANSI Z359.6.

804.3.6.2 The horizontal lifeline must be no less than 4 feet from the edge.

804.3.7 Guardrail

804.3.7.1 Guardrails must be designed to meet WAC 296-880-40005 and/or the IBC, when applicable.

804.3.7.2 Guardrails must be able to accommodate a temporary toeboard for periodic field work where a hazard would be created.

804.3.7.3 At maintenance facilities or at permanent service platforms, guardrails with a standard toeboard must be provided in accordance with WAC 296-24-75011 wherever:

i. Beneath the open sides.
ii. Persons can pass.
iii. There is moving machinery.
iv. There is equipment with which falling materials could create a hazard.

804.3.8 Fixed Ladders

804.3.8.1 Fixed ladders 24 feet or more must have a ladder safety system that meets the requirements of WAC 296-876-60080. An employee must be able to safely attach and disengage from the ladder safety system without added fall risk during the process. The ladder safety system must start no more than 3 feet from the bottom of the ladder.

804.3.8.2 The max fall distance must be used when determining if a ladder safety system is required, such as falls over an edge or guardrail which go beyond the lower level in relation to the fixed ladder.

804.3.8.3 Ladder safety systems must be affixed to the fixed ladders.

804.3.8.4 Fixed ladder must meet ANSI ASC A14.3 requirements.

804.3.9 Portable Ladders

804.3.9.1 Portable ladders require stable surfaces at the bottom and clearance for setup and maneuvering. Coordinate setup area with landscaping locations. Refer to Set 802 Landscaping for additional requirements.

804.3.9.2 Extension ladders require surfaces sized for a setup angle. Ladders must have room to extend 3 feet beyond the landing.

804.3.10 Openings

804.3.10.1 Openings on walking surfaces with a fall hazard must be guarded by covers or perimeter guardrails per WAC 296-880-40015.

Commentary: Examples of opening on walking surfaces include floor and roof access hatches.

804.3.11 Fall Through Hazards

804.3.11.1 Fall through hazards must be rated for walking or guarded to prevent accidental fall through.

Commentary: A skylight is an example of a fall through hazard. It is preferred to eliminate fall through hazards in the design.

804.3.12 Anchor Points

804.3.12.1 Anchor points must be designed to meet the applicable requirements of WAC 296-880-40020 and ANSI Z359.6.

804.3.12.2 Anchor points must be rated to support 5,000 pounds. Alternatives to the 5,000-pound rating must be approved by Sound Transit. Submit stamped calculations by the fall protection system designer for review and approval by Sound Transit structural engineer or delegate. Refer to Sound Transit Standard Specification 11 24 29 Facility Fall Protection for additional requirements.

804.3.13 Fall Protection System and Means of Access by Element

804.3.13.1 Comply with the following table which identifies the applicable fall protection system and means of access for common facility elements.

Table 804-1: Fall Protection System and Means of Access

Element	Applicable Fall Protection System	Access to Fall Protection
Station and facility canopies	Horizontal lifeline	1. **Up to 15 ft:** Portable ladders 2. **Over 15 ft:** Fixed ladders
Pedestrian bridge roofs	Horizontal lifeline	1. **Preferred:** Via interior access hatch/door (standard 36” x 36”) with fixed ladders. Hatch must have guardrails on the sides with a swing gate at the entrance. 2. **Alternate (up to 15 ft):** Access hatch/door (standard 36” x 36”) with portable ladders is acceptable.
Roofs on buildings (parking garages, maintenance facilities, stations)	**Preferred:** Guardrails or equivalent (such as a parapet wall of equivalent height). **Alternate:** Horizontal lifeline	1. **Preferred:** Interior stairs. 2. **Alternate:** Interior access hatch/door (standard 36” x 36”) with fixed ladders.
Elevator tower roofs	Anchor points within 2 feet of roof access. Additional anchor points added every 6 feet on center down the middle	Fixed ladders from lower surface. Lower surface must also be accessible.
Multi-level interior and exterior maintenance platforms	Guardrails around the perimeter of platform with access points driven by the maintenance tasks on the platform	1. **Preferred:** Stairs 2. **Alternate:** Fixed ladders
Stations and other structures—exterior cleaning	**Preferred**: Boom access for entire exterior surfaces. **Alternate**: Anchor points for suspension must meet ANSI/IWCA 1-14.1-2001 and separate anchor points for fall arrest spaced 4 feet on center. Overall design must meet all applicable window washing regulation WAC 296-878 and ANSI/IWCA standard	Alternate option will require access to the anchor points via: 1. Stairs (preferred) 2. Fixed ladders with a hatch (alternate)
Multiple level roofs (on the same structure)	Horizontal lifeline	Fixed ladders for accessing multi-levels
Ceiling elements at landings within enclosed stairways	**Preferred:** Permanent service platforms, or portable lifts where there is elevator access. **Alternate:** Tie-offs and wall anchors	Alternate option will require access to the tie-offs via portable ladders

Element	Applicable Fall Protection System	Access to Fall Protection
Ceiling elements at open stairways	Portable lifts	
Interior equipment, Systems and devices between 4 feet and 15 feet above finish level	**Preferred:** Portable lift **Alternate:** Tie-offs and wall anchors	Alternate option will require access to the tie-offs via portable ladders
Interior equipment, systems, and devices higher than 15 feet above finish level	**Preferred:** Portable lift **Alternate:** Tie-offs and wall anchors	Alternate option will require access to fixed ladders
Elevated guideway	Guardrails or equivalent	

Notes:

1. See criteria identified in Section 804.3 for each fall protection system.
2. Refer to Set 805 Vertical Transportation, Set 821 Station Layout – Commuter Rail, Set 822 Station Layout – Light Rail, Set 830 Parking Facility Layout, and Set 1007 Electrical Lighting for additional information.
3. Refer to Set 721 Bridge and Elevated Structures for additional fall protection information at elevated guideways.

804.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

804.4.1 System Breakdown Structure

804.4.1.1 The fall protection design must include the following elements:

i. Means of access
   a. Fixed ladder
   b. Portable ladder
   c. Access hatch
   d. Stairs
   e. Boom lift
   f. Scissor lift
ii. Structural support
   a. Anchor point
   b. Tie-off
   c. Monorail
iii. Types of fall protection systems
   a. Hierarchy
   b. Passive
      i. Guardrail
   c. Fall restraint system
      i. Horizontal lifeline
   d. Fall arrest system
      i. Horizontal lifeline
iv. Window washing system

804.4.2 System Sites and Locations

804.4.2.1 Fall protection is applied to all modes in the following facility types:

i. Facility area
ii. Station
iii. Parking garage
iv. Operations and maintenance base or facility

804.4.2.2 Locations include:

i. Roofs
ii. Canopies
iii. Top decks of parking garages
iv. Floor openings
v. Maintenance platforms
vi. Confined spaces

804.5 SYSTEM INTERFACE REQUIREMENTS

Table 804-2 lists requirement sets that are typically coordinated, and may have dependencies, with this set.

Table 804-2. Interface Between Architecture and Other Disciplines

SET SERIES	SET NAME	SET 804 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	
500	Track	
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical/Electrical and Building Systems	X
1100	Technology	
1200	Security	

804.5.1 Fire/Life Safety

804.5.1.1 Coordinate safe access to testing fire detection systems.

804.5.2 Structures

804.5.2.1 Coordinate structural load requirements.

804.5.3 Civil

804.5.3.1 Coordinate fencing along track and associated fall protection.

804.5.4 Mechanical/Electrical and Building Systems

804.5.4.1 Coordinate access to equipment and devices.

804.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

804.7 ENGINEERING MANAGEMENT REQUIREMENTS

804.7.1 Interface and Integration Management

804.7.1.1 The design must consider and account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructable documentation and functional designs.

804.7.2 Design Management

804.7.2.1 Evaluate facilities during the design phase to determine if fall hazards exist for maintenance and repair tasks. Evaluate identified fall hazards to determine if eliminating the fall hazard is feasible.

Commentary: An example of fall hazard elimination is installing equipment at ground level instead of on the roof.

804.7.2.2 Evaluate portable ladder set up rules per WAC 296-876-400 including ladder angle and proximity to floor level change to ensure safe portable ladder use is possible where it is the primary means of providing safe access. Provide representative diagrams to demonstrate compliance.

804.7.2.3 Fall protection system, including extents, configuration, access points, and attachment points, must be submitted for Sound Transit review and approval during preliminary engineering and final design. The review must include Sound Transit Operations. Refer to EP-03 for milestone design review information.

804.7.2.4 Structural supports must be coordinated with the facility design and Set 720 Building Structures. Comply with Sound Transit Standard Specifications for additional requirements.

804.7.2.5 The fall protection system designer must provide shop drawings, selection of devices, and certification of system safety.

804.7.2.6 Horizontal lifelines must be designed, installed, and used under the supervision of a qualified person as part of a complete personal fall arrest system which maintains a safety factor of at least two. Refer to Definitions and Specification 11 24 29 Fall Protection in the Sound Transit Standard Specifications for qualified personnel requirements.

804.7.3 Manufacturing and Construction Management (Not Used)

804.7.4 Installation Management (Not Used)

804.7.5 Inspection and Testing Management

804.7.5.1 The design must adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

804.7.5.2 Coordinate requirements with Specification 11 08 00 Commissioning of Equipment for fall arrest system verification.

804.7.6 Training, Pre-Revenue Operations (Not Used)

804.7.7 Certification Management (Not Used)

804.8 APPENDICES (NOT USED)

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805 VERTICAL TRANSPORTATION

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SET - 805 VERTICAL TRANSPORTATION

805.1 INTRODUCTION

805.1.1 Document Scope

805.1.1.1 This set establishes the design criteria for elevators and escalators as well as stairs and ramps. This set defines the functional, design, reliability, and maintenance requirements for passenger elevators, freight elevators, escalators, stairs, and ramps.

805.1.1.2 These criteria cover the elevators, escalators, stairs, and ramps for stations, the operations control center, maintenance facility, and other facilities throughout the system. The design of the elevators and escalators must incorporate the design criteria for all related systems.

805.1.1.3 The procurement documents must include requirements for quality assurance, reliability, maintainability, and safety. In addition, the design documents must provide for the delivery of owner’s manuals and the definition and inclusion of a maintenance program.

805.1.1.4 Reference Set 822 Station Layout and Set series 300 Operational Communications. See Sound Transit Standard Specifications for additional information regarding elevators and escalators requirements.

805.1.1.5 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 805 owner to determine the technical source for the design criteria.

805.1.2 Regulations, Codes, Standards, and Guidelines

805.1.2.1 International Regulations, Codes, Standards, and Guidelines

805.1.2.1.1 International Organization for Standardization (ISO), International Building Code (IBC).

805.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

805.1.2.2.1 APTA-RT-EE-RP-001-02 Heavy Duty Transportation System Escalator Design Guidelines.

805.1.2.2.2 APTA-RT-EE-RP-002-03 Heavy Duty Transportation System Elevator Design Guidelines.

805.1.2.2.3 American Society for Testing and Materials (ASTM)- ASTM A-276, A-240, A-446, A526, A123, A153, A 385, A386.

805.1.2.2.4 American Society of Mechanical Engineers (ASME) A17.2 Guide for Inspection Of Elevators, Escalators, And Moving Walks Includes Inspection Procedures For Electric Traction And Winding Drum Elevators, Hydraulic Elevators, Inclined Elevators, Limited-Use/Limited-Application Elevators, Private Residence.

805.1.2.2.5 American Society of Mechanical Engineers (ASME) A17.5 Committee on Elevator and Escalator Electrical Equipment and as amended by the State of Washington Administration Code.

805.1.2.2.6 American Society of Mechanical Engineers (ASME) A17.1 Safety Code for Elevators and Escalators and as amended by the State of Washington Administration Code.

805.1.2.2.7 American Welding Society (AWS).

805.1.2.2.8 Anti-Friction Bearing Manufacturers Association (ABMA), Std. 9, “Load Ratings and Fatigue Life for Ball Bearings,” and Std. 11, “Load Ratings and Fatigue Life for Roller Bearings.”

805.1.2.2.9 National Fire Protection Association (NFPA) 130- Standard for Fixed Guideway Transit and Passenger Rail Systems.

805.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

805.1.2.3.1 Washington Administrative Code (WAC).

805.1.2.3.2 Washington State Energy Code.

805.1.2.3.3 IBC with state amendments.

805.1.2.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

805.1.2.5 Other Jurisdictions (Not Used)

805.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines (Not Used)

805.1.3 Abbreviations and Acronyms

805.1.3.1 BMS–building management system

805.1.3.2 CCTV–closed-circuit television

805.1.3.3 L&I– Washington State Department of Labor and Industries

805.1.3.4 LCC–Link control center

805.1.3.5 MTBF–mean time between failures

805.1.3.6 MTTR–mean time to repair

805.1.3.7 PET–passenger emergency telephone

805.1.4 Definitions and Classifications (Not Used)

805.1.5 References (Not Used)

805.2 STAKEHOLDER NEEDS

805.2.1 Passenger Experience

805.2.1.1 Vertical Transportation elements must provide passengers with an intuitive, easy-to-use, and reliable means of transportation between all levels where passengers are allowed access.

805.2.1.2 Vertical Transportation elements must be positioned along clear lines of flow to provide the most direct route between the entrance and any mezzanine or platform level.

805.2.1.3 It is acceptable to switch escalators, particularly in deeper stations, but they should be aligned to minimize additional travel between escalators.

805.2.1.4 Elevators must provide a single ride between the surface level and the platform to minimize the need to switch elevators. An exception would be allowed where the fare paid zone is on a mezzanine, the elevator to the mezzanine is outside the FPZ, and the elevator to the platform is inside the FPZ, but this should be avoided.

Commentary: A direct elevator trip provides the best possible passenger experience, particularly for people with mobility needs who depend the most on elevators. It is inconvenient and time consuming to switch elevators, and the need to do so must be avoided.

805.2.2 Operational Needs

805.2.2.1 Vertical Transportation elements must run reliably and efficiently to meet the needs of Sound Transit passengers with minimal downtime. Elevators providing access to station and parking garage levels for passengers must be designed for redundancy; there must be at least two elevators available for every level passengers need to access by elevator. Refer to Set series 1000 Facilities Mechanical-Electrical and Building Systems.

805.2.2.2 The design of all vertical circulation elements, including elevators and escalators, must consider the requirements of fire/life safety, ridership, passenger flow, material flow, and movement of staff and maintenance equipment to any level requiring specific equipment.

805.2.3 Maintenance Needs

805.2.3.1 All warranty and maintenance work must be performed by a company that has a current code compliant maintenance control program on file with L&I.

805.2.3.2 The installer or vendor chosen by the Sound Transit Vertical Transportation team must provide continuous maintenance from the time of installation until 1 to 5 years after revenue service begins. See Sound Transit Standard Specifications for additional information.

805.2.3.3 Warranty maintenance must be provided for the adjustment, repair, or replacement of all components that fail to operate properly in accordance with terms outlined in the standard specifications. The warranty period must be a minimum of one year from contractor's project acceptance and 1 to 5 years after start of revenue service. See Sound Transit Standard Specifications for additional information.

805.2.3.4 Warranty and maintenance work must be performed during non-revenue hours if time allows, or during revenue hours that are off-peak commute hours, if redundant units are available and operational. Should the work not be completed in this period, the work must continue during subsequent non-revenue hours until completion to minimize disruption.

805.2.4 Safety Needs

805.2.4.1 All equipment must be placed into operation through a formal commissioning procedure per the general testing and commissioning plan.

805.2.4.2 The commissioning procedure must include the operation of all communication interfaces and environmental controls, elevator fire service, accessible means of egress, and occupant evacuation elevators where provided.

805.2.4.3 The equipment must be fully commissioned, including the running of escalators in both directions, prior to inspection by L&I. Provide temporary connections while the commissioning of elevator equipment is in process.

805.2.5 Security Needs

805.2.5.1 The design of hoistway walls, cab and layout within stations, parking garages, and maintenance facilities must be coordinated with Sound Transit Security and Safety staff to ensure CPTED guidelines are followed.

805.2.6 Reliability, Availability, and Maintainability Needs

805.2.6.1 Elevator and escalator reliability is a major priority for Sound Transit. Elevators and escalators must be provided to make the system accessible to all.

805.2.6.2 The system service life of elevators, escalators, and associated equipment, including total cost of ownership, must be a requirement in the selection of the equipment design, finishes, and installation to achieve improved reliability and reduced maintenance cost.

Commentary: Reliability is a key element in escalator operation because of its impact on passenger flow. Projected usage for the escalators is 140 hours per week which is substantially higher than usage factors for commercial installations. This could result in decreased reliability unless specific reliability requirements are established.

805.2.6.3 State-of-the-art MTBF and MTTR must be investigated to establish a realistic reliability goal to be included as part of the procurement documents.

805.2.6.4 Considerations in maintenance predictions must include four different maintenance functions as listed below. The first two consist of scheduled services and the last two of unscheduled services.

i. Examination hours
ii. Repair hours
iii. Lead time for supply of replacement parts
iv. Call back, regular time
v. Call back, overtime

805.2.6.5 Examination hours must be used to lubricate, adjust, and clean the equipment and its components during non-revenue service.

805.2.6.6 Repair hours must consist of time spent in replacing worn or damaged parts. Components such as handrails, drive chains, and step chains must be replaced periodically or when they wear out.

805.2.6.7 Emergency and call-back service on a 24 hours-per-day basis must be provided and consist of time spent returning the equipment to service following service interruptions caused by activation of safety circuits, overload protection, or other interruption of operation.

805.2.6.8 During the warranty maintenance period, the up and down escalators must be operated in both directions to balance wear and to maintain versatility of operation.

805.2.7 Environmental and Sustainability Needs

805.2.8 Sustainability Needs

805.2.8.1 See Set 803 Sustainability for sustainability needs.

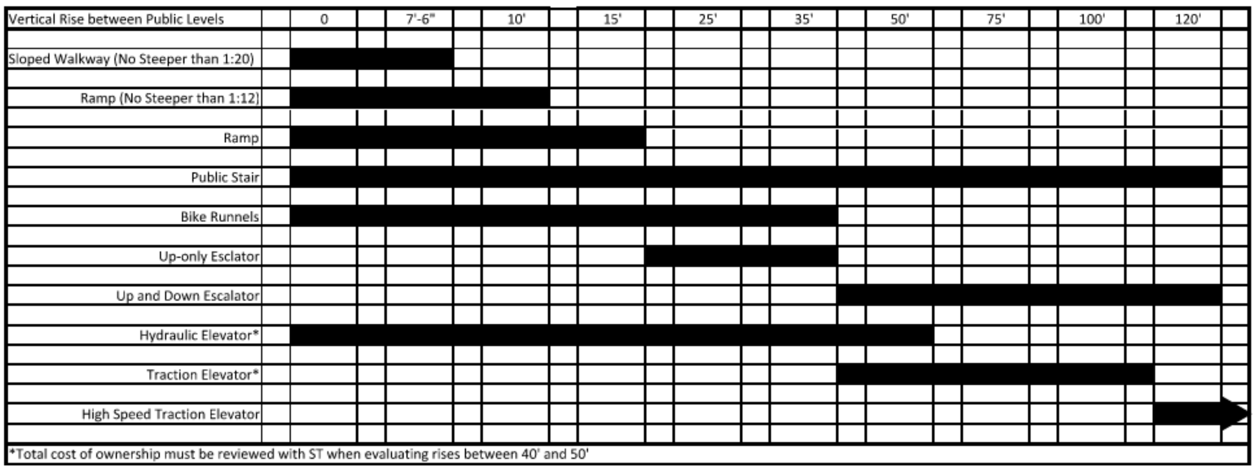
805.3 SYSTEM REQUIREMENTS

805.3.1 Elements of Vertical Transportation

805.3.1.1 In facilities that are to be constructed through use of multiple construction contracts, elevator, and escalator requirements, such as pits, hoistways, overhead clearances, machine rooms, block outs, sleeves, embedded conduit, structural embeds, must be accommodated and coordinated with follow-on contracts prior to initial construction.

805.3.1.2 Use figure 805-1 to determine the constraints for the primary vertical circulation elements. See Set 601 Fire–Life Safety for additional requirements.

Figure 805-1: Primary Vertical Circulation Constraints



805.3.1.3 Where stations are anticipated to have over 8,000 passengers a day, regardless of the rise between public levels, provide escalators for both upward and downward movement.

805.3.1.4 Provide stairs as required to meet exiting requirements. See Set 601 Fire/Life Safety for requirements.

805.3.1.5 Provide public stairs where escalators or elevators are provided.

Commentary: It is preferred that public stairs are adjacent to escalators and designers must make it a priority to meet this requirement. Deviation must be reviewed and agreed upon with Sound Transit.

805.3.1.6 The architectural treatment of stairs, escalators, and visual openings may include the use of parapets. The top of the parapet must be designed to slope away from vertical circulation elements and visual openings to prevent objects being placed upon them.

805.3.2 Surge Zone

805.3.2.1 Elevator, escalator, and stair surge zones must be free of all obstructions and must not conflict with passenger flow. The surge zones are:

i. Elevator surge zone is defined as a 10 feet x 10 feet area in front of the elevator door.
ii. Stair and escalator surge zones must be 15 feet long (measured from end of handrail) and, where conditions permit, 5 feet wider in each direction than the width of the stair or escalator.

805.3.2.2 Surge zones of elevators must not overlap surge zones for stairs/escalators.

805.3.3 Ramps and Sloping Walks

805.3.3.1 Ramps must meet the requirements of applicable codes.

805.3.3.2 Sloping walks must be less than 4.75 percent.

Commentary: This percentage accounts for construction tolerances to achieve less than or equal to the maximum 5 percent.

805.3.3.3 Sloping walks are preferred over ramps and must be used whenever possible.

805.3.3.4 Vertical changes of less than 18 inches must use ramps or sloping walks. Do not use fewer than three stairs.

805.3.4 Stairs

805.3.4.1 Stairs that are primary circulation elements in stations must include the following:

i. Stairs adjacent to an escalator must be parallel to the angle of inclination of the escalator (30 degrees). Stairs with treads of approximately 11.50 inches and risers with approximately 6.64 inches risers will comply.
ii. The minimum headroom clearance is 9 feet measured vertically from stair tread and escalator step nosings, however 12 feet headroom clearance is preferred.
iii. The maximum riser height is 7 inches.
iv. The minimum tread depth is 11.50 inches.
v. The riser and read dimensions must be consistent for each step in a given stairway.

805.3.4.2 Main public access stairs must be 72 inches wide minimum between handrails. While the building codes limit allowable exit width to within 30 inches between handrails, main public stairs must be at least 72 inches wide for ease of use by patrons in both directions. Public stairs may be 60 inches wide minimum when combined with escalators on either side.

805.3.4.3 The width of emergency exit stairs must be 66 inches minimum. The minimum length of landing for straight-line stairs must be per code. Larger dimensions must be provided where high patronage may require more space. Means of egress stairs (exit and public where used) must meet required code widths. See Set 601 Fire–Life Safety for requirements.

805.3.4.4 Height between landings must not exceed 12 feet. Where a stair is adjacent to escalator(s), landings must be distributed to mirror the slope of the escalator.

805.3.4.5 Tactile warning cues for the visually impaired must be provided with a distinct visual contrast between tread edges and treads. Where this is not possible, a visual contrast between treads and risers must be provided. Tactile warning must be yellow in color and at all tread and landing edge or nosing.

805.3.4.6 Treads must have non-slip finish.

805.3.4.7 Stairs and landings must be sloped to allow for drainage and not allow water from cleaning to collect. Stair tread surface must be clear of guard or handrail supports for ease of cleaning. Exit stairs that are not covered must have a drainage path that does not allow water from upper stairs and landings to drip onto lower landings. See Sets 801, 820, 821, 822, 830, and 836 regarding weather protection at station and facility entrances.

805.3.4.8 Bike runnels must be provided on at least one public stair accessing mezzanines, landings, and/or platforms where stairs are less than 30 feet in height and the clear width of stairs is a minimum of 72 inches, or as determined by Sound Transit.

805.3.4.9 Bike runnels must be provided on both sides of a straight run stair and the outside of a switchback stair when they are provided. See Standard Drawing STD-ATD222.

805.3.4.10 Where bike runnels are provided, adjacent stair guardrail must not be glass or painted steel below the height of the handrail. Solid wall or stainless-steel mesh infill panels are acceptable.

805.3.4.11 Runnels are prohibited on public stairs with center handrails within 48 inches of the outside handrail/guardrail assembly or at emergency egress stairs. See Set 807 Bike Program and Sound Transit Standard Drawings.

805.3.4.12 Open stair risers are prohibited.

805.3.4.12.1 Where stairs are open to the public, the spaces created under stairs with a clearance height of less than 7 feet above the walking surface must be closed to prevent public access with a solid wall, screen, or other method.

805.3.4.12.2 Refer to Set 801 Architectural Materials, Elements, and Furnishings for stair material requirements.

805.3.4.13 Provide a unique identifier number for each stair, regardless of whether it is an egress or public stair.

Commentary: Providing duplicate numbers such as "Egress Stair 1" and "Stair 1" can create challenges in an emergency situation.

805.3.5 Elevators

805.3.5.1 Provide an elevator(s) connecting each level at passenger stations, parking garages, and maintenance facilities where access between public levels requires vertical travel greater than 10 feet.

805.3.5.2 Elevator car equipment must be designed for use by individuals with disabilities and comply with ADA standards.

805.3.5.3 Elevator machine rooms must be located as near as possible to hoistways, but clear of public walking and landing areas.

805.3.5.4 A second elevator or alternate accessible path must be provided where one elevator is provided for public access to rail or bus platforms, and all other intermediate levels including pedestrian bridges used to access stations or parking facilities. In parking facilities, a second elevator or accessible path is required for all levels above and below grade that contain accessible parking.

Commentary: This provides redundancy for passenger access to stations if an elevator is out of service for maintenance or other reasons.

805.3.5.5 Elevators intended for use in moving equipment to and from equipment rooms must be sized and rated to accommodate the intended equipment and maintenance equipment used in the work and other maintenance (e.g., lifts). See Set 1000 Mechanical/Electrical and Building Systems for requirements for moving and installing new equipment.

805.3.5.6 Refer to Set 801 Architectural Materials, Elements, and Furnishings for elevator material requirements.

805.3.5.7 All passenger elevators must be fully automatic.

805.3.5.8 Passenger elevators must be electric traction or hydraulic type application.

805.3.5.9 Machine room less elevator is prohibited.

805.3.5.10 Determine the type of elevator based on required performance and an evaluation of most appropriate elevator types and review with Sound Transit.

805.3.5.11 Acceptable electric traction applications are traction with adjacent machine room and traction with overhead machine-room. Where traction elevators are used, use gearless machines. Where hydraulic elevators are selected, in-ground type are required up to 40 feet maximum total travel distance.

805.3.5.12 Where site conditions for the installation of in-ground hydraulic elevators prove to be cost prohibitive or technically infeasible, single or two-stage hole-less hydraulic elevators are acceptable up to 40 feet total travel distance. Refer to Elements of Vertical Circulation table 805-1.

805.3.5.13 The elevators must be designed, as applicable, for the movement of passengers, staff, equipment, and vehicle parts. They must be sized to accommodate wheelchairs and emergency stretchers.

805.3.5.14 The speed of passenger elevators based on a hydraulic elevator application must be 150 feet per minute, and the speed of passenger elevators based on electric traction elevator application must be 200 feet per minute. See specifications sections 14 21 00 and 14 21 00.

805.3.5.15 Passenger elevator loading capacity must be as follows:

i. All passenger elevators for transit patrons must have Class C-1 loading.
ii. Passenger elevators in the accessible route of travel for pedestrian bridges must have Class C-1 loading.
iii. Where parking garages have an accessible route of travel through two or more levels, all passenger elevators serving those floors must have Class C-1 loading capacity. Where parking garages have ADA parking stalls on the same level as the station and elevators are not required for the accessible route of travel, Class A elevators must be provided.
iv. At maintenance and other facilities with restricted access, passenger elevators must have Class A loading. Provide freight elevators as required elsewhere in this set.
v. All Class A elevators must have a minimum loading capacity of 4,000 pounds.
vi. All Class C-1 elevators must have a minimum loading capacity of 4,500 pounds or as otherwise directed by Sound Transit.
vii. Elevator doors must be single speed center opening.
viii. At exceptionally deep stations, 120 feet or deeper, where occupant evacuation rated elevators are required, elevators will be sized and provided in sufficient quantity to accommodate egress loads. Maintenance at deep underground stations must be designed for replacement and regular maintenance. See Set 601 Fire–Life Safety for additional clarification.

805.3.5.16 All freight elevators must be fully automatic. The minimum capacity of each freight elevator must be 8,000 pounds or as otherwise directed by Sound Transit. The minimum speed of freight elevators must be 100 feet per minute.

805.3.5.17 Elevators must be provided between each platform and the street level, or between each platform and the mezzanine and between the mezzanine and the street level.

805.3.5.18 Elevators must serve non-public levels containing equipment rooms and other levels as required to provide fire department and maintenance access. Public access to these non-public levels must be prevented.

805.3.5.19 The location of elevators at street level must be near a passenger vehicle loading zone whenever possible. In addition, at stations with parking facilities, passenger elevators must be located with easy access to the accessible parking stalls.

805.3.5.20 Provide bollards sufficient to protect passengers from impact by vehicles at all levels where traffic interfaces or is adjacent to the elevator waiting area and surge zone and has the potential to access the waiting area. See Set 801 Architectural Materials, Elements, and Furnishings for additional bollard requirements.

805.3.5.21 Elevators and associated equipment must not produce steady-state and transient noise levels in excess of the noise levels prescribed for elevators in Set 007 Noise and Vibration.

805.3.6 Escalators

805.3.6.1 The necessity, direction, and capacity of escalators must be determined by a combination of factors including, rise, expected patronage, and total cost of ownership. In general, the greater the patronage and rise, the more "weight" is given to including escalators. Each entrance must be considered separately. All escalators must have a nominal tread width of 40 inches. The designers must recommend if "future" or "optional" escalators are to be initially included for Sound Transit's determination.

805.3.6.2 Escalators in transit use operate under conditions substantially more severe than in commercial establishments, handling thousands of patrons on a daily basis and generally in large groups. Provide heavy-duty transit-grade escalator designed for continuous operation in a transit environment with a minimum 20-year lifespan, as described by the APTA Standards Development Program, Heavy Duty Escalator Design Guidelines. See specifications section 14 31 00 for additional qualifications.

805.3.6.3 Escalator design, materials, construction clearances, workmanship and tests must conform to the requirements of the codes and regulations listed in this set.

805.3.6.4 Escalators must be transit class equipment suitable for use in mass transportation. The escalator design must incorporate finishes, materials, and components to deter and resist vandalism.

805.3.6.5 All escalators supplied within a contract unit description or construction package must be the products of a single manufacturer.

805.3.6.6 All escalators must have weather protection, both canopy coverage and full-height side walls and windscreens to protect equipment from weather.

805.3.6.7 All adjacent paving surfaces must slope away from the escalator. Given the exterior conditions of stations, all escalators must meet requirements for an external installation.

805.3.6.8 Escalators must be capable of operating with fully specified performance capability while exposed to the climatic and environmental conditions. Escalators must be designed to operate under general elements of weather including sunlight, rain, slush, snow and ice, all conditions of relative humidity while exposed to salt, deicing chemicals, airborne dust, and debris, and corrosive elements, and in a dry-bulb temperature range of -10 to 105 degrees Fahrenheit.

805.3.6.9 Material joints along the side walls of escalators must be plumb.

Commentary: Material joints oriented to the slope of the escalator can cause disorientation and dizziness for passengers. Orienting the joints plumb helps to mitigate this condition.

805.3.6.10 Escalators and associated equipment must not produce noise levels in either free-running or under full load conditions in excess of the noise levels prescribed for escalators in Set 007 Noise and Vibration.

805.3.6.11 Factory Visit

805.3.6.11.1 Sound Transit may elect to visit the factory where the escalator is being manufactured. All travel related costs for the factory visit will be the responsibility of the manufacturer. Allow for up to three Sound Transit representatives to visit the factory.

805.3.6.11.2 The escalator must be manufactured in the United States. All components and sub-components must be assembled and tested in a factory in the United States.

805.3.6.11.3 The escalator manufacturing company must be the installing company.

805.3.6.11.4 The escalator factory in the United States must be ISO 9001 certified.

805.3.6.11.5 The escalators must be tested in the factory with the controller to be shipped with the escalator. If Sound Transit chooses to visit the factory, the Sound Transit representative must observe the steps and chain in operation and test all safety devices.

805.3.6.11.6 Escalator trusses will be marked and identified for connection points to ensure that alignment of the truss in the factory during testing is equal to what is installed in the field and inspected.

805.3.6.11.7 The escalator must be tested in the final condition of manufacturing and all rated loads must be tested in the factory with certified and measured results to meet code.

805.3.6.11.8 All factory testing must be video recorded in full, and the results shown in the video, and recorded on submitted and approved commissioning and quality documentation.

805.3.6.11.9 A final quality inspection report will be delivered with all final calibration results recorded.

805.3.6.11.10 Certificates for all certified welders on the escalator truss must be delivered with the escalator quality inspection report.

805.3.6.11.11 Escalator must not ship from the factory until all factory test reports and documentation is submitted and approved by Sound Transit.

805.3.6.11.12 Wall surfaces adjacent to escalators in the touch zone must use solid materials without the potential for pinching, scraping, or catching hazards.

Commentary: Perforated metal is an example of a material that may pose a hazard at these locations.

805.3.7 Elevators

805.3.7.1 Elevators must provide vertical transportation between station levels for passengers, including individuals who have disabilities, passenger bicycles, and maintenance equipment. Elevators must be designed to accommodate the anticipated loads of maintenance equipment.

805.3.7.2 Passengers must not have difficulty in orienting themselves in the system. Preference is for elevators with one door in lieu of doors in front and back for ease of use. Elevators must be oriented so that passengers will not need to move against traffic flow.

805.3.7.3 All elevator entries must be covered and protected from weather.

805.3.7.4 Floor areas outside elevator doors and elevator shaft must slope away from elevator.

805.3.7.5 Provide trench drains outside elevator doors.

Commentary: Continue slope away from trench drain outside elevator doors to area floor drain so that water does not accumulate in front of elevator waiting area. Nearest floor drain must be outside the surge zone of elevators. This is to prevent water build up in front of elevators due to washing of doors and floor area in front of the elevators.

805.3.7.6 Coordinate location of drain with accessible waiting pad. Place tile between trench drain and elevator threshold. Slope tile to drain. See Sets 1002 Mechanical–Plumbing and 801 Architectural Materials, Elements, and Furnishings.

805.3.7.7 Elevator car call buttons must indicate floor levels consistent with Sound Transit's standard floor identification as follows:

i. P = Platform Level (at stations)
ii. M = Mezzanine Level (1, 2, 3, etc. at stations)
iii. B = Basement Level (B1, B2, B3, etc.)
iv. G= Garage Level (G1, G2, G3, etc.)
v. S = Surface Level

Figure 805-2: Parking Garage Elevator Car Call Button Key

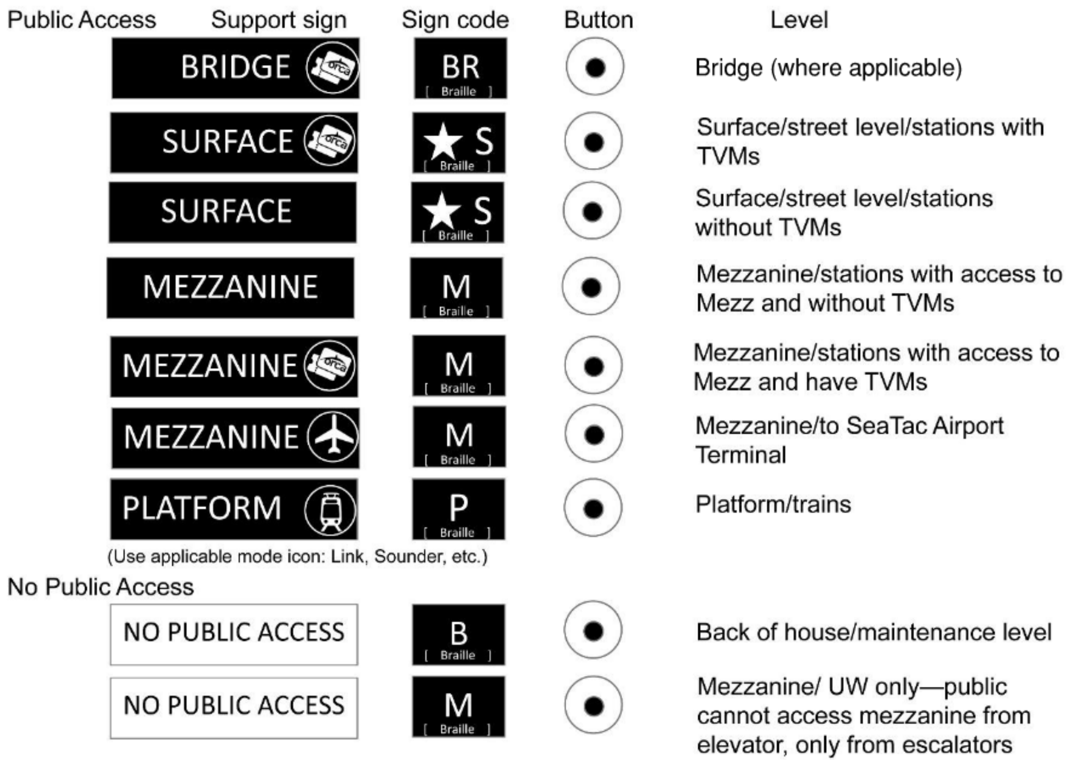
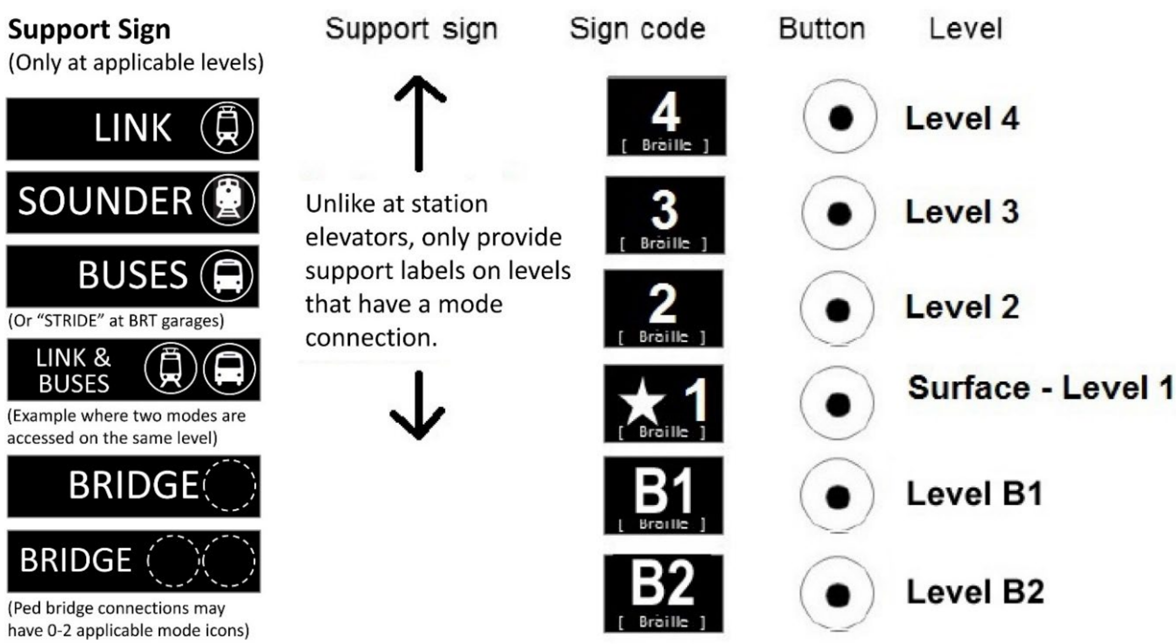


Figure 805-3: Station Elevator Car Call Button Key



805.3.7.8 Elevators must have the ability to cycle on their own, especially during colder months, to ensure their operation.

805.3.7.9 All floors of elevators must be fully within or outside of fare paid zone.
Commentary: Passengers should not have to transfer elevators to pay fares.

805.3.8 Escalators

805.3.8.1 The escalators must be capable of operating under full load as defined by ASME A17.1.

805.3.8.2 Hours of operation must be considered as 20 hours per day, seven days per week.

805.3.8.3 Direction of travel must be as established per figure 8051 in this set and as established in project requirements. Units designated as “up and down escalators” must be up-and-down reversible.

805.3.8.4 Reversible units must have variable frequency regenerative drive that supplies electrical energy to the building electrical system.

805.3.8.5 Escalator must include sleep mode function to reduce energy use and wear on equipment.

805.3.8.6 Escalators must be provided with Knaq Live Monitoring Hardware.

805.3.8.7 Escalator maintenance access must be from above except where the station design allows for direct access from a room below the escalator landings.

805.3.8.8 All escalators must consist of a corrosion resistant truss assembly (galvanized), step-drive units, steps and step chains, driving machine and controller, safety devices, comb and deck plates, handrails and deck trim, newels and balustrades, balustrade lights, and other accessories and appurtenances.

805.3.8.9 The sides and underside of the truss, exterior of the escalator, and machinery spaces must be enclosed.

805.3.8.10 Provide overhead shield above sump area if head height is less than 6 feet.

805.3.8.11 Provide applicable fall protection for maintenance of escalators. See Set 804 Fall Protection.

805.3.8.12 Refer to Set 601 Fire/Life Safety for requirements for escalators as a means of egress.

805.3.8.13 Landing floor plates and step treads must be illuminated to meet code requirements.

805.3.8.14 All lighting for escalators must be easily accessible for maintenance without shutting down escalators for lengthy periods of time. The design must prioritize maintenance that can be done during non-revenue hours.

805.3.8.15 Reference Set 1007 Electrical Lighting and ASME 17.1 for required level of illuminance and other requirements.

805.3.8.16 Escalators must be provided with gravity drains in pits to prevent accumulation of water.

805.3.8.17 Drains must run to remote sump behind or adjacent to escalator pit for removal by pump or connection to drainage system after oil separation. Sump and any pump must be accessible without shutting down or disassembling of escalator.

805.3.8.18 Reference Set 1002 Mechanical – Plumbing for plumbing and drainage, Set 1006 Electrical Raceways for electrical and power, Set 601 Fire–Life Safety for fire/life safety and Set 1004 Building Monitoring and Control for systems and alarm interface with the BMS.

805.3.8.19 Escalators must not be located over a public right of way.

Commentary: Maintenance and replacement are adversely impacted when locating escalators in this way.

805.3.9 Elevator Cars

805.3.9.1 The elevator car must be developed specifically for Sound Transit's needs and architectural requirements.

805.3.9.2 The car must be sized to accommodate the larger of either one 24 inch by 84-inch stretcher or the largest unit of maintenance equipment to be transported, including a 6-foot by 3-foot scissor lift for C-1 elevators and 24-inch by 84-inch stretcher for Class A elevators.

805.3.9.3 The car of elevators serving underground tunnel stations must be sized to accommodate one 30-inch by 84-inch stretchers without turning plus attendants.

805.3.9.4 Freight elevators must be sized to accommodate the largest part or piece of maintenance equipment to be moved between the levels to be served. Coordinate equipment requirements with Sound Transit. See Set 1002 Mechanical –Plumbing.

805.3.9.5 All metal wall and ceiling cladding, railings, and trim must be stainless-steel.

805.3.9.6 Wall finishes must be glass or stainless-steel with a random orbital finish.

805.3.9.7 Window mullions must be stainless-steel or extruded aluminum.

805.3.9.8 Window glazing in hoistway must be accessible from exterior for maintenance and replacement.

805.3.9.9 Passenger elevators must have a continuous chemical and stain resistant floor finish with integral base. Wood construction is prohibited. Reference Set 801 Architectural Materials, Elements, and Furnishings for acceptable finishes.

805.3.9.10 Freight elevators must have a stainless-steel checkered plate floor.

805.3.9.11 Finished elevator car ceiling heights must be a minimum of 8 feet to permit ceiling mounted CCTV cameras with coverage of entrances to provide coverage of the car and to discourage vandalism of lights and camera equipment.

805.3.9.12 Energy efficient light fixtures must be provided in the car above the ceiling and not easily accessible by the public. All fixtures must be above the ceiling and not allow removal without special tools. The light fixtures must be controlled by a key operated switch in the car operating panel. Reference Set 1007 Electrical Lighting for required level of illuminance.

805.3.10 Elevator Car Entrance

805.3.10.1 The car entrance for passenger elevators must be provided with horizontal sliding doors that are center aligned.

805.3.10.2 The minimum required door width is 4 feet.

805.3.10.3 The car entrance for freight elevators must be provided with either horizontal or vertical opening doors that maximize the opening.

805.3.10.4 Ensure elevator doors are not affected by sunlight interfering with door sensors. Mechanical sensors are preferred when sunlight may be an issue.

805.3.10.5 Elevator door thresholds must be level and flush with adjacent floor finishes. Concrete slab and finish material must be extended all the way to the door. Metal sill extensions are prohibited.

805.3.10.6 Where building expansion joints are in proximity to elevator doors, the expansion joint covers must be flush with the elevator car floor.

805.3.11 Elevator Shafts

805.3.11.1 Elevator shafts with exposed structure and framing must avoid the creation of ledges or eliminate all ledges created by the structure through caps or enclosure such that nothing can be placed on them. This includes cross bracing. If cross bracing is required, ensure no horizontal ledges or shelves are created due to the structure. Round pipe may be used, but when horizontal will be considered as a ledge by L&I and will need a cap or other device to prevent it being used as a ledge to place objects or stand upon.

805.3.11.2 Where a shaft is exposed to view via glazing in elevator cab, the surface of the shaft must receive an architectural finish.

805.3.11.3 Temperature load calculations must be provided for the shaft by 30% design to confirm that the loads will fall within design parameters for the selected equipment. If the design temperatures are too high or too cold, the shaft must be redesigned to bring the temperatures within operating range.

805.3.12 Glazing

805.3.12.1 Subject to limitations imposed by local codes, elevator cars and hoistway enclosures must be provided with one wall of glass, and glass in the doors, providing cross view through the entire cab to enhance both actual and perceived security of the elevator and passengers. Coordinate final layout with Sound Transit.

805.3.12.2 Elevator shaft plan and elevations must be coordinated with Sound Transit Safety and Security to ensure conformance with CPTED principles.

805.3.12.3 Where glass is not permitted in the walls due to code requirements, glass/view panels in the door must be provided.

805.3.12.4 Where an elevator shaft is fire-rated, meet requirements of the IBC and ASME A17.1 for Vision Panels.

805.3.12.5 Where an elevator shaft is not fire-rated, larger glass panels are allowed. The size of a glass panel must maximize visibility into and out of the car. See Set 601 Fire–Life Safety for additional requirements.

805.3.12.6 Glass design of hoistway enclosures, elevator cab walls or doors must meet the requirements of the IBC and ASME A17.1. Individual or single windows are not permitted in the hoistway per ASME A17.1.

805.3.12.7 Where full panels of glass are used, the panels must be constructed of laminated glass.

805.3.12.8 Where wall panels are wider than 12 inches, provide a handrail or framing designed to guard the opening should the panel become detached.

805.3.12.9 Mount glazing in the structure so that the assembly withstands the required elevator tests without damage. All glazing must be fully fixed and inoperable.

805.3.12.10 Glazing design and layout must account for potential impact of solar gain on equipment and mechanical systems and minimize solar gain and heat loads while still meeting CPTED requirements described above.

805.3.12.11 Fenestration system including frame, glazing, gaskets, spandrel or other solid panels, vents and all other associated components must work as a cohesive unit to prevent water intrusion into the shaft.

805.3.13 Elevator Pits

805.3.13.1 Pits must be constructed to prevent the entry of ground water into the elevator and to prevent the release of fluids from the pit.

805.3.13.2 Pit must meet L&I requirements for size, or 6 feet minimum depth.

805.3.13.3 Provide minimum sump hole size of 24 inches by 24 inches by 12 inches in each elevator pit located to not interfere with elevator equipment. Include a sump hole cover designed to withstand a load of 300 pounds per square foot.

805.3.13.4 Pits must be equipped with water sensors tied to a remote alarm. The BMS must notify LCC if water has exceeded capacity of sump.

805.3.13.5 The hoistway entrance must be designed to minimize the likelihood of water entering the pit, including water from rainfall or maintenance activities such as pressure washing.

805.3.13.6 Sumps must be provided with gravity drains that comply with local plumbing code and provide the separation of oil from the water prior to being discharged into the drainage system.

805.3.13.7 Sumps will be provided with pumps per section 1002.6.1.4.0. where required by code or when site conditions prevent a drain from being sufficient. Pumps must comply with ASME A17.1 and AHJ plumbing code requirements. Pumps must be accessible during normal operation of the elevators.

805.3.13.7.1 According to IBC CH. 30 and ASME A17.1-2016/CSA B44-16, where elevators are required for fire service access and/or occupant evacuation elevators, a drain or pump is required to remove or drain water at a minimum of 50 gallons per minute per elevator. Pits are not classified as a hazardous location per the NEC. Standard electrical equipment is permitted.

Commentary: See IBC 3007 for further clarification. The intent of this requirement is to provide protection where needed from water intrusion into the hoistway from sprinklers and firefighting equipment. This requirement originates from IBC Chapter 30 and only applies to fire service access elevators and occupant evacuation elevators. Most of ST elevators are neither so this would not apply. The design must confirm this is an approved method. Many methods are acceptable (see IBC code commentary).

805.3.13.8 Reference set 1002 Mechanical – Plumbing for plumbing and drainage, Set 1006 Electrical Raceway for electrical and power, Set 601 Fire/Life Safety for fire/life safety and Set 1004 Building Monitoring and Control for systems and alarm interface with the BMS.

805.3.13.9 Review L&I requirements and confirm compatibility. Reference ASTM 17.1 and NFPA requirements.

805.3.14 Elevator Machine Rooms

805.3.14.1 Hydraulic elevator machine rooms must be located as near as possible to hoistways and clear of public walking and landing areas. Hydraulic lines must be straight runs, preferably within 40 feet of, but no more than 100 feet between the elevator hoistway and machine room. All pipe sections must be secured to each other with the threaded connections.

805.3.14.2 Traction elevator machine rooms and controller rooms must be located above or adjacent to the hoistway unless physical constraints or zoning height limits dictate alternate solutions.

805.3.14.3 Machine and controller rooms must be directly accessible from the exterior to permit direct access by L&I and non-Sound Transit elevator maintenance personnel where feasible.

805.3.14.4 If machine room locations require access through other spaces, minimize the number of doors that need to be entered to reach the machine rooms. All other doors off the corridor leading to the machine room must be locked to prevent unauthorized personnel from entering.

805.3.14.5 Provide elevator Knox box with access cards and keys to access the machine room. All equipment, conduit and associated connection boxes serving access card readers must be outside the machine room or embedded in the wall. Access to such boxes must be from outside the machine room.

805.3.14.6 Machine and controller rooms and their access doorways must have adequate space for the installation and maintenance of the equipment. Only elevator related equipment must be located in the rooms.

805.3.14.7 Lighting, heating, ventilation, and air conditioning must be provided to meet manufacturer's recommendations, code requirements, and Sound Transit criteria. Access to heating, ventilation and air conditioning equipment must be from outside the elevator machine room whenever possible. Reference Sets 1002 Mechanical – Plumbing and 1003 Mechanical–HVAC for additional requirements.

805.3.14.8 Lockable 82-inch by 48-inch by 24-inch metal cabinets must be provided in each machine room for the storage of special tools and necessary spare parts. Coordinate location with machine room equipment. All equipment in machine room must serve the operation of the elevator (or escalator) and must be confirmed with L&I requirements. Any variations must be confirmed to be acceptable with L&I.

805.3.14.9 ITCs must be located outside the machine room on an adjacent wall in an equipment room or closet. No equipment including conduit, pipes, or ducts unrelated to the running of the elevator may pass through the room.

805.3.14.10 Sprinklers serving the machine must terminate in the machine room and fire alarm circuits must be limited to those required for devices located in the machine room.

805.3.14.11 Elevator system elements must include guide rails, speed governors, safety brakes, hydraulic lifts, pipes and pumps, cars, and landing doors, all as appropriate to the particular design selected.

805.3.15 Elevator Electrical Equipment

805.3.15.1 For the elevator drive systems, provide 480 volts, 3 phase, 3 wire, 60 hertz terminating in a disconnect switch within sight of the controller as demarcation between facility power and the elevator equipment. All power within elevator apparatus, pit and equipment room must be worked on or supervised only by qualified elevator technicians. See Set series 1000 Mechanical–Electrical and Building Systems for further electrical and mechanical requirements.

805.3.15.2 Elevator Signal Equipment

805.3.15.3 An emergency alarm bell must be provided in conformance to the requirements of ASME A17.1 and must be connected to a plainly marked pushbutton in the car operating panel.

805.3.15.4 A "Door Open" bell must be provided on the car. It must be connected to the direction buttons in the car and landing pushbutton stations. The bell must ring when any button is pressed if any door is opened.

805.3.15.5 Car and landing must be equipped with illuminated and tactile pushbuttons. Hall lanterns that are visible from the side and bells must be provided at each floor level centered above or next to each elevator entrance. Hall lanterns must be in NEMA 4 boxes in all locations.

805.3.15.6 Call buttons and control devices must be in NEMA 4 boxes in all locations. Shaft wiring must be waterproof.

805.3.16 Elevator Communications and Security Equipment

805.3.16.1 Reference Set series 300 Operational Communications for additional requirements.

805.3.16.2 The elevator controller must use a programmable logic controller to control and monitor the status of the elevator. The controller must have the ability to interface with SCADA via discrete points terminated on a common interface terminal strip. The discrete points must be coordinated for monitoring capabilities.

805.3.16.3 A pushbutton-activated, vendor provided telephone must be provided in each elevator car for use by the public and employees. The phone equipment must be fully recessed in car panels and provide communication capability between the car and a location in the building and between the car and a Sound Transit identified control center.

Commentary: Analogue phone is the standard, however in some jurisdictions VOIP may be preferred or required and the vendor should be free to provide the telephone system that will meet the local AHJ and code requirements. This was an issue on LLE for the Lynnwood Station Garage as required by Snohomish County.

805.3.16.4 Where a voice system is provided to meet the IFC for EVACS, provide a fire alarm speaker (or PA speaker when the PA is used for EVACS) in elevator cars. Speakers are to be on separate paging zones per the IFC and each elevator group must be a separate zone.

805.3.16.5 CCTV cameras must be provided in the elevator cars for security.

805.3.16.6 Where elevators serve non-public floors, access card readers will be provided to permit staff only access to non-public levels. Where elevators are not secured by a security gate during after-hours or non- revenue service, a card reader must be provided to limit public access during that time period.

805.3.16.7 The elevator car traveler cable must include appropriate cabling to accommodate all required interfaces with the LCC. Coordinate with owner supplied network switch. Coordinate with Set series 300 Operational Communications.

805.3.16.8 The elevator must be equipped with Knaq Live Monitoring Hardware.

805.3.17 Car and Hoistway Ventilation

805.3.17.1 Car ventilation must be supplied by a single-speed exhaust blower located above the plenum and mounted to the car top. The ceiling grille must match the finished ceiling surface.

805.3.17.2 Provide ventilation and/or air conditioning as appropriate to keep equipment in operating range temperatures and keep car at an operating temperature designed for 72 degrees Fahrenheit with an operating range of 66 degrees Fahrenheit minimum and 78 degrees Fahrenheit maximum. See specifications.

805.3.17.3 Hoistway ventilation must account for tunnel pressures and how it affects cab door openings and must be coordinated with Set 601 Fire/Life Safety.

Commentary: Ventilation can create as much as 0.5 inches w.c. positive or negative pressure that the cab doors must operate against.

805.3.18 Elevator Emergency Power / Standby Power

805.3.18.1 Where emergency or standby power provides elevator operation in the event of normal power supply failure as required by local code, the power system must meet the requirements of ASME A17.1 and local code.

805.3.18.2 Where emergency or standby power system for elevator operation is not provided:

i. Provide a power system for the auxiliary lighting, the alarm bell, and the emergency communication devices in the car.
ii. Provide battery lowering device with hydraulic elevators to lower the car to the lowest level of recall and open the doors to permit passengers to exit the elevator.
iii. Provide battery rescue device with traction elevators to automatically run the car at inspection speed to the nearest landing, up or down, depending upon load in the car upon loss of power. Upon arrival at the nearest landing, the elevator doors must open automatically and remain open until regular door time has expired. The elevator must then become deactivated. The standby power source must be provided via a 12-volt DC battery unit installed in the control room, including solid-

state charger, inverter, fail safe controls, and testing means mounted in a common metal container. Battery must be rechargeable nickel cadmium with a ten-year life expectancy.

805.3.19 Fire Protection for Elevators

805.3.19.1 Fire sprinkler protection must be provided for elevator hoistways, pits, and machine rooms when required by code. Refer to Set 601 Fire/Life Safety for further requirements.

805.3.20 Elevator Operation

805.3.20.1 Operation must be "selective-collective" automatic pushbutton without attendant.

805.3.20.2 The elevator must be controlled automatically by means of pushbuttons in the car numbered to correspond to the public levels served and by "Call" pushbuttons at landings. “Up” and “Down” call buttons must be located at each hoistway landing as required by applicable code.

805.3.20.3 During revenue service hours, elevators must be operable by patrons by using the car controls and the call buttons.

805.3.20.4 During non-revenue hours, public access to and use of the elevators must be restricted. The elevators must be provided with a lockout key to shut down elevators during non-revenue hours and enable operation during non-revenue hours.

805.3.20.5 The system interfacing with the elevators (and escalators) must be fail safe such that when a failure occurs, the system defaults to allow emergency operation. See Set 1000 Mechanical–Electrical and Building Systems and Set 1004 Building Monitoring and Control.

805.3.20.6 Provision for the operation and control of the elevators must be provided in buildings with a fire command center.

805.3.20.7 Where elevators serve non-public floors, elevator controls must not permit public access to these levels and card readers must be provided to enable staff to access these levels.

805.3.20.8 An adjustable time delay, non-interference feature must be incorporated in the control circuit to allow ample time for opening the car and hoistway doors before the car can be dispatched to another landing.

805.3.20.9 Each passenger elevator car must have a control panel in a locked cabinet in the car wall with a key switch for operator control and a key switch for fire department use. Keys are to be kept in the machine room.

805.3.20.10 Hydraulic Elevators must be provided with a soft start feature to prolong the life of the components. Traction elevators must have VVVF drive with regenerative braking.

805.3.21 Elevator Emergency Operation

805.3.21.1 Emergency operation must be in conformance with ASME A17.1 and a three-position key-operated switch must be located at the designated level.

805.3.21.2 The designated and alternate floors for elevator recall must be per NFPA 72 and approved by the local AHJ. Primary and secondary recall levels must be indicated in design documents. Deferring this to the contractor can cause confusion and delay.

805.3.21.3 Lock boxes must be provided adjacent to elevator machine rooms with keys to the elevator machine room. Lock box style and keying must comply with state and local requirements. Within the machine room, keys must be provided for access into the elevator car and for all equipment, including escalator keys. Provide four keys to Sound Transit. See Set 801 Architectural Materials, Elements, and Furnishings for lock box information.

805.3.21.4 Reference Set 601 Fire/Life Safety for all fire/life safety requirements.

805.3.22 Escalator Structural Requirements

805.3.22.1 The structural design of the escalator must accommodate all live, dead, and seismic loads. It must accommodate all wind and snow loads unique to its location and all superimposed dead loads such as cladding or other items supported by the escalator.

805.3.22.2 Escalators must be designed with provisions for thermal expansion and contraction of complete escalator assemblies and for any movement of the facility caused by trains braking when the train is fully loaded.

805.3.22.3 Provide escalator truss mounting angles and intermediate truss supports with attachments, sized as required to install escalators into wellway structural support system shown on the contract drawing.

805.3.22.4 Escalator intermediate support points must be provided where required to support truss efficiently.

805.3.22.5 Provide reaction loads on contract documents.

805.3.22.6 Seismic designs must be based on actual story drift data from the structural engineer.

805.3.22.7 Welding must be performed in accordance with the requirements of the AWS. Welders must produce evidence of current certification by the AWS.

805.3.23 Escalator Dimensional and Loading Criteria

805.3.23.1 Inclination: Not to exceed 30 degrees.

805.3.23.2 Nominal step width: 40 inches.

805.3.23.3 Speed: Not to exceed 100 feet per minute.

805.3.23.4 Flat steps: Three, four when rise is greater than 32 feet 10 inches.

805.3.23.5 Maintenance speed: No greater than 10 percent of rated speed per APTA recommendations

805.3.23.6 Upper track radius: 8 feet 10 inches minimum.

805.3.23.7 Lower track radius: 6 feet 6.75 inches minimum.

805.3.23.8 Loading: Static brake, dynamic brake, motor duty and step chain load must conform to APTA guidelines noted below:

805.3.23.8.1 Static brake load (load per step on the total number of exposed steps on the incline):
- i. 1000 millimeters step: 306 kilograms (674 pounds).
- ii. 800 millimeters step: 245 kilograms (540 pounds).

805.3.23.8.2 Dynamic brake load (load per step running in down direction on exposed steps on the incline)
- i. 1000 millimeters step: 145 kilograms (320 pounds).
- ii. 800 millimeters step: 116 kilograms (256 pounds).

805.3.24 Escalator Materials

805.3.24.1 Stainless-steel

805.3.24.1.1 Shapes and bars: ASTM A-276, type 304 or 316, A-554 for tubes.

805.3.24.1.2 Plate sheet and strip: ASTM A-240. Type 316 for exterior installations.

805.3.24.2 Fasteners

805.3.24.2.1 Fasteners must be compatible with materials being fastened. Fasteners must be furnished with self-locking nuts or retaining rings (spring washers, toothed discs).

805.3.24.2.2 Fasteners must be equal to or of greater corrosion resistance than the most corrosion resistant metals being fastened.

805.3.24.3 Exposed Finishes

805.3.24.3.1 Stainless-steel: Random orbital finish for all elements visible to the public. No. 4 finish on escalator skirt panel and elsewhere.

805.3.24.3.2 Aluminum castings and extrusions: Commercial mill finish.

805.3.24.4 Galvanizing:

805.3.24.4.1 Sheet steel: ASTM A446 or A526, as applicable. Coating designation G185.

805.3.24.4.2 Other galvanizing: ASTM A123, ASTM A 153, ASTM A 385 or ASTM A 386, as applicable.

805.3.24.4.3 Galvanizing touch-up: Zinc dust coating, MIL-P-21035 or MIL-P-26915.

805.3.24.5 Paint and corrosion protection (minimum):

805.3.24.5.1 After welding, the truss must be hot dipped galvanized with a coating in accordance with ASTM A90, or a 100 percent zinc thermal spray coating to ASNI/AWS C.18-93 is an acceptable alternative.

805.3.24.5.2 Cast metal parts such as gear housings, chain sprockets and return station half circles must be painted with a rust inhibitor primer coat after preparation by sandblasting.

805.3.24.5.3 Steel parts that are not specified to be galvanized or provided with a zinc thermal spray coating must be painted to meet High Performance Coating requirements. Bright or uncoated axles, shafts, etc. must be protected by zinc chromate or chrome plating.

805.3.24.6 Other

805.3.24.6.1 No wood or wood products are to be used in escalators.

805.3.24.6.2 Oil collector chutes and collection trays must be galvanized steel.

805.3.25 Escalator Truss

805.3.25.1 The deflection of the loaded truss must not exceed one-thousandth of the span under live load of 320 pounds per 40 inches.

805.3.25.2 The contract documents must define clearly how to provide cladding on the escalator truss. Coordination on weight and fastening methods is required, including signage and other elements intended to be attached to the escalator. Generally, welding and drilling into the escalator truss should be avoided. Coordinate with structural engineer and specified manufacturer to determine truss cladding installation methods to minimize impact on the truss integrity. If access is desired into the truss with an access panel, coordinate with manufacturer as required.

805.3.26 Step Chain

805.3.26.1 The designer must investigate use of low lubrication or self-lubricating chain and provide recommendation to Sound Transit.

805.3.27 Escalator Cladding

805.3.27.1 Escalator cladding must consist of enclosing the sides and bottom of the escalator. It is critical to ensure that this work is specified in the appropriate section. Ensure weight of cladding material is designed for and identified in contract documents for escalator trusses.

805.3.28 Electrical Requirements

805.3.28.1 Coordinate all escalator electrical requirements with Sets 1004 Building Monitoring and Control, 1005 Electrical Power, 1006 Electrical Raceway and 1007 Electrical Lighting.

805.3.28.2 Require contractor to provide temporary power with the same characteristics as the permanent power (must be made available to the installer at the time of the setting of the truss). Permanent power must be made available for commissioning and testing.

805.3.28.3 For the escalator drive systems, provide 480 volts, 3 phase, 3 wire, 60 hertz terminating in a disconnect switch within sight of the controller as a demarcation between station power and the escalator equipment. All power within escalator apparatus, pit and equipment room must be worked on only by qualified escalator technicians.

805.3.28.4 For pit lighting and GFCI receptacles, provide wet label fixtures, 120 volts, 1 phase, 3 wire, 60 hertz terminating in the escalator truss.

805.3.28.5 Provide power for motor heaters and comb plate heaters.

805.3.28.6 Provide power for demarcation lights and balustrade lights. Balustrade lighting must be designed for compliance with emergency means of egress illumination.

805.3.28.7 Escalators must have continuous LED skirt lighting that illuminates step treads to a lighting intensity of not less than 50 lx (5 fc).

805.3.29 Escalator Controller

805.3.29.1 Escalator controllers are not permitted in the upper or lower pits. Remote controller locations within an escalator equipment room or combined in an elevator equipment room must be coordinated with the overall station design.

805.3.29.2 The main controller must monitor the status of the escalator.

805.3.29.3 The controller must have the ability to interface with SCADA via discrete points terminated on a common interface terminal strip. The discrete points must be coordinated for monitoring capabilities and appropriate emergency over-rides capabilities through the Sound Transit BMS. Alternatively, it must be usable for programming purposes or for access to remote programmers via modems.

805.3.30 Operating Devices

805.3.30.1 Escalators must have the ability to be controlled by the LCC for possible implementation at a future date. Appropriate conduit and controls must be provided. Reference Set 1004 Building Monitoring and Control and Set series 1100 Technology for additional requirements. A variance may be required by the AHJ and L&I to achieve this. While remote and automatic starting and stopping of escalators is not currently permitted by the AHJ, for future capability escalators must have the ability to be remotely controlled by the BMS and/or station fire alarm system including remote control from the LCC. Appropriate conduit and controls must be provided but not connected unless specifically directed in a project requirement or equal. Reference Sets 601 Fire/Life Safety and 1100 Technology.

805.3.31 Sleep Mode

805.3.31.1 Provide sleep mode function for escalators. Determine current best method for sensor location and operation and radar proximity. Sensors from the front-end plates are the preferred method. Stanchions with sensors are not to be provided due to conflict with pedestrian traffic.

805.3.31.2 Provide a timer function to program escalators to run continuously during peak period times.

805.3.31.3 Activation of sleep mode and setting of the sleep delay and sleep speed parameters must be performed on the programmable logic controller's LCD display. The LCD display's main screen must indicate if the escalator is in sleep mode operation and what the sleep delay and sleep speed parameters are.

805.3.31.4 Provide an auxiliary drive to allow variation of speed conforming to the following requirements:

i. The acceleration/deceleration rates must not exceed 1.0 foot per second squared.
ii. The rated speed is not exceeded.
iii. The minimum speed must be not less than 10 feet per minute.
iv. The speed must not automatically vary during inspection operation.

805.3.31.5 Automatic deceleration must not occur before a period of time has elapsed since the last passenger detection that is greater than three times the amount necessary to transfer a passenger between landings.

805.3.31.6 Means must be provided to detect failure of the passenger detection once external sensors are triggered and must cause the escalator to operate at full speed only.

805.3.31.7 Confirm the sleep mode operation meets current ASME A17.1 version adopted by L&I.

805.3.32 Commissioning, Testing and Training

805.3.32.1 All equipment must be placed into operation through a formal commissioning procedure. Refer to Set 000 General on commissioning requirements.

805.3.32.2 The commissioning procedure must include the operation of all communication interfaces.

805.3.32.3 The equipment must be fully commissioned, including the running escalators in both directions, prior to inspection by L&I.

805.3.33 Field Testing

805.3.33.1 Provide all instruments, materials, and labor required for tests.

805.3.33.2 Testing must be performed in accordance with ASME A17.2.3 procedures with the following additions or adaptations.

805.3.33.3 No-load tests: The installer must perform the following tests on each escalator without load:

i. The comb impact device must be tested and calibrated with an appropriate scale at both ends of the escalator in both the horizontal and vertical directions. No adjustments must be permitted in between measurement of vertical and horizontal calibration.
ii. Measure braking deceleration rate with no load over five consecutive stops in the down direction using test equipment designed to obtain this information.
iii. The escalator must be tested to meet vibration requirements of APTA Guidelines. The meter and the method must be identical for all tests.

805.3.34 Full-load tests

805.3.34.1 The installer must perform the following tests on each escalator under full load:

805.3.34.1.1 Each escalator must have a full dynamic brake load as defined in APTA guidelines and dynamic brake test performed on it. The stopping distance in the down direction must meet all requirements of ASME A17.1.

805.3.34.1.2 The escalator must operate continuously for 40 hours after the acceptance test with no faults. If any fault occurs that shuts the escalator down, the fault must be corrected, and a new 40-hour test must begin.

805.3.34.1.3 If either the no-load or full-load brake tests fail, both tests must be repeated with the same torque setting on the brake for both no load and full load.

805.3.34.1.4 Provide temporary connections while escalator equipment is being commissioned.

805.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

805.5 SYSTEM INTERFACE REQUIREMENTS

Table 805-1 lists requirement sets that are typically coordinated, and may have dependencies, with this set.

Table 805-1: Interface Between Architecture and Other Disciplines

SET SERIES	SERIES NAME	SET 805 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	
300	Operational Communications	X
400	Vehicle	
500	Track	
600	Fire / Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical / Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

805.5.1 Operational Communications

805.5.1.1 Refer to Set series 300 Operational Communications.

805.5.2 Architecture

805.5.2.1 Coordinate space allocation at stations and other facilities.

805.5.3 1000 Mechanical/Electrical and Building Systems

805.5.3.1 Coordinate power requirements.

805.5.4 1100 Technology

805.5.4.1 Coordinate data requirements.

805.5.5 Security

805.5.5.1 Coordinate CCTV requirements and layout for CPTED concerns.

805.5.6 Civil

805.5.6.1 Coordinate bicycle access requirements.

805.5.7 Structures

805.5.7.1 Coordinate structural requirements.

805.5.8 Fire Life Safety

805.5.8.1 Coordinate Fire Life Safety requirements.

805.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

805.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

805.7.1 Interface and Integration Management

805.7.1.1 The design must consider and account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructable documentation and functional designs.

805.7.2 Design Management

The location of elevators and escalators must be indicated on the design drawings. The design must provide status and control interfaces for all facilities as well as equipment required for the integration of the Link light rail communications system at elevators and escalators in Link Stations. VT units at non-Link facilities will be monitored under the contract of the maintenance vendor. Indicate location of all devices for the equipment, including smoke detectors, CCTV, PET, and connections to BMS. Provide infrastructure to permit the future application of remote stop for escalators.

805.7.3 Manufacturing and Construction Management (Not Used)

805.7.4 Installation Management (Not Used)

805.7.5 Inspection and Testing Management

805.7.5.1 The design must adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

805.7.6 Training, Pre-Revenue Operations (Not Used0

805.7.7 Certification Management (Not Used)

805.8 APPENDICES (NOT USED)

END SET - 805

806 SIGNAGE

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SET - 806 TABLE OF CONTENTS

TABLES

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SET - 806 SIGNAGE

806.1 INTRODUCTION

806.1.1 Document Scope

806.1.1.1 This set establishes criteria for regulatory and room signage. It also includes interface requirements for customer signage.

806.1.1.2 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Sound Transit Design Requirements Set 806 owner to determine the technical source for the design criteria.

806.1.2 Regulations, Codes, Standards, and Guidelines

806.1.2.1 International Regulations, Codes, Standards, and Guidelines

806.1.2.1.1 International Building Code (IBC) with state and local amendments.

806.1.2.1.2 International Code Council/American National Standards Institute (ICC/ANSI) A117.1 Accessible and Usable Buildings and Facilities.

806.1.2.1.3 International Fire Code (IFC) with state and local amendments.

806.1.2.1.4 International Mechanical Code (IMC) with State and local amendments.

806.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

806.1.2.2.1 American National Standards Institute (ANSI).

806.1.2.2.2 National Electrical Code (NEC) with state and local amendments.

806.1.2.2.3 National Fire Protection Association (NFPA).

806.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

806.1.2.3.1 Washington Administrative Code (WAC) 51-50.

806.1.2.3.2 IBC Chapter 11 and Appendix E.

806.1.2.3.3 Other standards when applicable as adopted by reference in IBC Chapter 35, IFC Chapter 80, IMC Chapter 15, and the NEC.

806.1.2.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

806.1.2.5 Other Jurisdictions (Not Used)

806.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

806.1.2.6.1 Sound Transit Customer Signage Design Manual.

806.1.2.6.2 Sound Transit Equipment and Facilities Numbering Standard.

806.1.3 Abbreviations and Acronyms

806.1.3.1 ANSI–American National Standards Institute

806.1.3.2 BCB—between car barriers

806.1.3.3 IBC–International Building Code

806.1.3.4 NFPA–National Fire Protection Association

806.1.3.5 PA—public audio

806.1.3.6 PIMS—passenger information management system

806.1.3.7 PPE–personal protective equipment

806.1.3.8 VMS—variable message signs

806.1.3.9 WAC–Washington Administrative Code

806.1.4 Definitions and Classifications

806.1.4.1 Customer signage: Standardized and modular family of signs, documented in the Sound Transit Customer Signage Design Manual, that communicate information for passengers throughout the system. Signs are typically owner-furnished with infrastructure designed and provided by projects.

806.1.4.2 Operational signage: See Set 001 General for definition.

806.1.4.3 Regulatory signage: Regulatory and facility signs for identification and instructions as required by AHJ. Excludes systems and operational signage.

806.1.5 References (Not Used)

806.2 STAKEHOLDER NEEDS

806.2.1 Passenger Experience

806.2.1.1 Provide wayfinding consistent with the Sound Transit Station Experience Design Guidelines.

806.2.1.2 Provide signage at decision points consistent with the Sound Transit Customer Signage Design Manual.

806.2.1.3 Provide visual and tactile signage at bus stops and paratransit stops, in coordination with tactile wayfinding path, and as located per the Sound Transit Customer Signage Design Manual.

806.2.1.4 Ensure signage does not encroach circulation path clearances.

806.2.1.5 Locate tactile signage to allow a user to safely read the sign.

806.2.1.6 Coordinate space allocation for various elements in the same areas, including signage, artwork, and advertisements per the Sound Transit Customer Signage Design Manual.

806.2.2 Operational Needs

806.2.2.1 Any third-party signage must be coordinated with Sound Transit.

806.2.2.2 Provide power and data infrastructure for digital signage.

806.2.3 Maintenance Needs

806.2.4 Safety Needs

806.2.4.1 Provide signage alerting personnel of hazards in the area.

806.2.4.2 Provide required illumination levels for signage.

806.2.5 Security Needs (Not Used)

806.2.6 Reliability, Availability and Maintainability Needs (Not Used)

806.2.7 Environmental and Sustainability Needs (Not Used)

806.3 SYSTEM REQUIREMENTS

806.3.1 General Requirements

806.3.1.1 Comply with Table 806-1 which lists various signs Sound Transit utilizes throughout its facilities.

Table 806-1: Sound Transit Signage

Sign Category	Sign Type	Description	Designation	Furnished By	Infrastructure By	Design Criteria
Customer	Identification	Confirms destinations, creates landmarks, helps establish recognition (e.g., station identification, bus bay numbering, main entrance signs)	A – Station Identification B – Platform Identification E – Bus F – Facility Amenity	Sound Transit	Project	Sound Transit Customer Signage Design Manual and Set 806 Signage for infrastructure and coordination
	Directional	Guides both vehicles and pedestrians to destinations. The design and implementation of directional systems are often referred to as “wayfinding” (from highway, street, and parking – to amenities, platform, and vehicles)	D – Directional G – Guide W – WSDOT G – Guide			
	Information & Maps	Communicates knowledge concerning destinations, facts, and circumstances (e.g., transit information including, fare/ ticketing, schedules, line and area maps, neighborhood information, directories)	C – Customer Information			
	Regulatory (Agency)	Displays rules of conduct, safety/warning, and facility regulations (e.g., “stop” and “no parking” signs)	R – Regulatory (Agency)			
	Vehicle	Displays line maps and rules of conduct (e.g., Line Maps, Regulatory and Bicyclist Conduct)	V – Vehicle			
	Operations	Provides direction to staff to assist in the safe and efficient operations of the system (e.g., Train Stopping Markers)	X – Operations			
Regulatory (AHJ)	Building / Station, Building Code	Signage as required by building code: Safe dispersal area, delayed egress doors, elevator emergency signs, elevator machine room, exit signs, “not an exit” signs, fire doors, stairway identification, speed limit and maximum height at parking garages, floor loads, occupant load (assembly), fire-rated wall identification (placard), two-way communication systems, and other as	J – Regulatory (AHJ)	Project	Project	Set 806 Signage, Set 601 Fire/Life Safety, Set 302 Telephony, Sound Transit Equipment and Facilities Numbering Standard (for facility and room numbering convention)

Sign Category	Sign Type	Description	Designation	Furnished By	Infrastructure By	Design Criteria
		required. *See note a.*				
	Building / Station, Accessibility	Signage as required by the WAC, IBC, and ANSI A117.1 standard: Areas of refuge/evacuation assistance, accessible means of egress, parking, elevator, stair, station entrances, station name, and other as required by accessibility codes. *See note b.*	J – Regulatory (AHJ)	Project and Sound Transit. See Customer Signage Design Manual for Sound Transit-furnished signs	Project	Sound Transit Customer Signage Design Manual, Set 806 Signage
	Building / Station, Fire Code	Signage as required by fire code: Evacuation route maps, electrical control (room sign), automatic sprinklers, standpipes, fire alarm, clean agent hydrogen detection, fire alarm room, sprinkler riser room, fire extinguishers, emergency responder equipment room, fire department connection, photo voltaic emergency shutdown, no smoking, storage tanks, fire access roads, energy storage systems, hazard identification signs (NFPA 704 diamond), physical address, and other as required by fire code	J – Regulatory (AHJ)	Project	Project	Set 806 Signage, Set 601 Fire/Life Safety
	Guideway	Fire Department access, Fire Department connection, emergency access doors/gates, fire protection control and isolation valves, and other as required	J – Regulatory (AHJ)	Project	Project	Set 806 Signage, Set 601 Fire/Life Safety
	Worker Safety	Danger, Warning, Caution, Notice and other permanent worker safety signs: Fall protection required, confined space, rotating equipment, high voltage, PPE required, emergency washing, other worker safety signs as required	J – Regulatory (AHJ)	Project	Project	Set 804 Fall Protection, Set 010 Operations, Set 806 Signage for coordination
Operational	Access, Directional, Warning, Markers, Clearance, Standpipe, Stop, Cross Passage, Yard Limit, Speed, Radio Channel, Work Zone, Confined Space	Mandatory and site-specific “non-customer facing” signage placed in the right-of-way for the operations of the light rail system	See Set 010 Operations	Project	Project	Set 010 Operations and Set 806 Signage for coordination

Sign Category	Sign Type	Description	Designation	Furnished By	Infrastructure By	Design Criteria
Equipment	Location Numbering, Equipment Codes	Defines the identification convention for equipment and facility identification labels. Applies to station and line sections, as well as architectural, electrical, traction power, mechanical, fire systems, signaling, and communication systems. *See note c.*	Y - Operations	Project	Project	Sound Transit Equipment and Facilities Numbering Standard
a. Each stair must have a unique numerical designation for firefighting operations. *Commentary: This is direction from the Fire Department. For example, there should not be a public stair 1 and egress stair 1.* b. Accessibility signs may be combined with other regulatory signage. Confirm with Sound Transit. c. Equipment ID signs must not be combined with other signs.						

806.3.1.2 Comply with the Sound Transit Customer Signage Design Manual for system-wide customer signage.

806.3.1.3 The designer must become familiar with the customer sign types and their intended use and must locate the signage in the facility for Sound Transit review. Refer to EP-03 for milestone review requirements.

806.3.1.4 Provide the necessary elements to accommodate the installation of customer signage, such as backing, steel plates, and concrete foundations for attachment of the signage, whenever the customer signage is owner-furnished and owner-installed.

806.3.1.5 Signage must be designed and positioned to provide effective passenger guidance.

806.3.1.6 Signs must be located for maximum visibility at or before all decision points within facilities.

806.3.1.7 Landscaping, in-ceiling elements such as cameras and speakers, architectural elements, and lighting must not obstruct clear sightlines to signage.

806.3.1.8 Signs must be placed at frequent enough intervals so that the infrequent or new user can readily find their way without assistance.

806.3.1.9 The pattern of signs must be predictable and therefore consistent from station to station.

806.3.1.10 Map space must be provided immediately adjacent to fare collection equipment and at other decision points such as platform areas. Maps within surge zones are prohibited.

806.3.1.11 Walls at ends of passageways, opposite major entrances, or leading to exits, must be kept free of miscellaneous doors and advertisements so that they may be used for customer signage information graphics.

806.3.1.12 Station identification signs must be located so they may be easily seen by both sitting and standing passengers in transit vehicles.

806.3.1.13 Relate passengers to the surrounding community with appropriate signage.

806.3.1.14 Comply with Set 720 Building Structures for signage structural requirements and Sound Transit Standard Drawings for mounting details.

806.3.1.15 Lighting for signage must be provided in accordance with Set1007 Electrical Lighting.

806.3.1.16 Coordinate signs with other elements of the station to provide clear legibility.

806.3.2 Regulatory and Room Signs

806.3.2.1 Provide signs as required by Table 806-1.

806.3.2.2 Comply with Sound Transit Standard Specifications for regulatory sign types.

806.3.2.3 Tactile signs on doors, gates, or other moveable surfaces are prohibited.

Commentary: Passengers with low or no vision must touch the sign to read the braille. If the tactile sign is mounted on a door or gate in operation, passengers may not have access to the sign. In some cases, it may create an unsafe environment if the door or gate swung toward the passenger.

806.3.2.4 Provide signs for the following rooms. Coordinate with Set 601 Fire/Life Safety.

i. Sprinkler riser room
ii. Fire alarm control panel room
iii. Emergency responder equipment room

806.3.2.5 Provide identification signs for rooms and spaces consistent with the convention in the Sound Transit Equipment and Facilities Numbering Standard.

806.3.2.6 Provide safety signage ahead of rooms or areas that have any of the following condition or equipment:

i. Fall hazard
ii. Confined space
iii. High-voltage electrical equipment. Refer to Set 1005 Electrical Power for requirements.
iv. Other extremely dangerous or unique hazard

806.3.2.7 Comply with Set 601 Fire/Life Safety for occupant load and building address sign requirements.

806.3.3 Operational Train Stopping Markers

806.3.3.1 Train stopping markers are pole mounted signs to be mounted beyond the truncated domes on the platform side within 6 inches of the back edge of the truncated dome pavers. See Sound Transit Customer Signage Design Manual for additional requirements.

806.3.3.2 Identify location for train stopping markers on each platform to be placed at the leading edge of a four-car consist, and a four-car reverse running consist to align vehicle doors with tactile train waiting areas. See Set 801 Architectural Materials, Elements, and Furnishings for tactile wayfinding provisions.

806.3.3.3 Train stopping marker location must be coordinated with Sound Transit Operations during installation.

806.3.4 Between Car Barriers

806.3.4.1 Comply with Sound Transit Customer Signage Design Manual and Sound Transit directive drawings for BCB requirements.

806.3.5 Signage at At-Grade Crossings

806.3.5.1 Comply with Set 120 At-Grade Crossings for signage related to crossings.

806.3.6 Signage at Terminus Stations

806.3.6.1 At terminus stations, provide locations for a “Next Train” sign to be installed on an interim basis to indicate which train will leave the station first.

806.3.6.2 Provide a finish at attachment points that can be easily repaired or supports that can be removed when the sign is removed.

806.3.6.3 For center platform, stations signs must be located near the ends of the platform and near the midpoint of the station where they can be viewed from general circulation patterns.

806.3.6.4 For side platform stations, locate the signs in the best location for passengers to easily recognize which platform to use.

806.3.6.5 Provide structural support, power, and data connections to these sign locations.

806.3.6.6 Provide a key switch on the platform for staff to override the system when necessary.

806.3.6.7 Sound Transit may use the PA/VMS for “Next Train” signs.

806.3.7 Public Audio and Variable Message Signs (PA/VMS)

806.3.7.1 Provide double-sided PA and VMS signs at the following locations:

i. Station entries.
ii. Three points along the station platform per train direction, at minimum. A total of six points for center platforms.
iii. At concourses, where required by Sound Transit.
iv. At other platform locations in terminus stations when PA/VMS signs are used for “Next Train” messaging. See Signage at Terminus Stations section for additional information.

806.3.7.2 Signs must be located at a vertical angle of articulation for optimum passenger visibility entering and exiting the vehicle.

806.3.7.3 Placement of signage and VMS should be considered to avoid obstructing sight lines and accessibility for maintenance. Coordinate PA and VMS signs with Sound Transit Wayfinding & Signage.

806.3.7.4 Two sizes of VMS may be used. Flat panel screen signs are typically larger and used where ceiling or canopy height is not restricted, such as entries below elevated stations. Variable message bar signs must be used when canopy height is restricted to maximize weather protection for the passengers, such as at-grade or elevated stations. Comply with Set 1102 Passenger Information Management Systems on size, weight, and display type of flat panel signs and variable bar signs.

806.3.7.5 Provide structural support, power, and data connections to these locations.

806.3.7.6 Canopies must cover the PA/VMS to prevent direct weather and glare on the face of the sign.

806.3.7.7 Refer to Sound Transit Customer Signage Design Manual and Set 1102 Passenger Information Management System for additional requirements.

806.3.7.8 In conjunction with Sound Transit, review potential additional PA and VMS signs at off-site bus facilities near light rail stations, in structured parking facilities, and along the path from parking facilities to the station.

806.3.8 Dynamic Passenger Information Signs

Commentary: Dynamic passenger information signs are changeable electronic signs providing passenger information in the touch zone.

806.3.8.1 Provide a four-foot-wide cavity wall at dynamic passenger information sign locations for conduit stub ups and structural mounting of the sign.

806.3.8.2 Provide dynamic passenger information signs at each fare vending area.

806.3.8.3 In conjunction with Sound Transit, review potential additional dynamic passenger signs at off-site bus facilities near light rail stations, in structured parking facilities, and along the path from parking facilities to the station.

806.3.8.4 Provide structural support, power, and data connections to dynamic passenger information sign locations.

806.3.8.5 Canopies must cover the signs to prevent direct weather and glare on the face of the sign.

806.3.9 Equipment and Facilities Numbering Standard

806.3.9.1 Equipment and room numbering must be based on the Sound Transit Equipment and Facilities Numbering Standard.

806.3.10 Operational Signage

806.3.10.1 Provide operational signage based on requirements in Set 010 General.

806.3.11 Customer Signage

806.3.11.1 Provide infrastructure, including structural supports, in accordance with Sound Transit Customer Signage Design Manual.

806.3.12 Third-Party Signage

806.3.12.1 Provide infrastructure, including structural supports, in accordance with Sound Transit Customer Signage Design Manual.

Commentary: Transit partners may request to install signage on Sound Transit property to provide rider information. Requests are routed to and coordinated by Wayfinding & Signage.

806.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

806.4.1 System Breakdown Structure

806.4.1.1 Signage must include the following elements:

- i. Customer signage
  - a. Attachment
  - b. Placement
  - c. Static and tactile information
  - d. PA/VMS
  - e. Dynamic passenger information
    - i. Clearance
    - ii. Location
    - iii. Structural support
    - iv. Power
    - v. Data
    - vi. Weather protection
  - f. Third-party
  - g. Terminus station
    - i. Location
    - ii. Structural support
    - iii. Power
    - iv. Data
    - v. Override
- ii. Operational signage
- iii. Regulatory and room signage
- iv. Operational train stopping marker
- v. BCB
- vi. Infrastructure
  - a. Structure support
  - b. Power
  - c. Data
- vii. Lighting
- viii. Weather protection

806.4.2 System Sites and Locations

806.4.2.1 Signage is required for all modes in the following facility types:

- i. Station
- ii. Parking facility
- iii. Operations and maintenance base and facility

806.4.2.2 Signage is applied to:

- i. Surrounding facility areas
  - a. Off-street bus stop and bus loops
  - b. Paratransit stop
  - c. Path between facilities
- ii. Rooms
- iii. Platform
- iv. Station entry
- v. Mezzanines
- vi. Terminus station

vii. Canopies
viii. Fare vending area

806.5 SYSTEM INTERFACE REQUIREMENTS

Table 806-2 lists requirement sets that are typically coordinated, and may have dependencies, with this set.

Table 806-2: Interface Between Architecture and Other Disciplines

SET SERIES	SERIES NAME	SET 806 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	
300	Operational Communications	
400	Vehicle	X
500	Track	
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical / Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

806.5.1 Vehicle

806.5.1.1 Coordinate signage placement with vehicle clearances.

806.5.2 Fire/Life Safety

806.5.2.1 Coordinate public audio and exit signage requirements.

806.5.3 Structures

806.5.3.1 Coordinate structural infrastructure for overhead signage.

806.5.4 Civil

806.5.4.1 Coordinate signage at gates and fences.

806.5.5 MEP

806.5.5.1 Coordinate signage for electrical equipment.

806.5.5.2 Coordinate electrical requirements for digital signage.

806.5.5.3 Coordinate illumination levels for signage.

806.5.6 Communications/Technology

806.5.6.1 Coordinate communication requirements for digital signage.

806.5.6.2 Coordinate PIMS requirements.

806.5.7 Security

806.5.7.1 Coordinate signage and closed-circuit television placement.

806.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

806.7 ENGINEERING MANAGEMENT REQUIREMENTS

806.7.1 Interface and Integration Management

806.7.1.1 The design must consider and account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructable documentation and functional designs.

806.7.2 Design Management

806.7.2.1 Coordinate placement of regulatory and customer signage to ensure no conflicts.

Commentary: Regulatory signage is provided by the project, while customer signage is owner-furnished. This has led to location conflicts, particularly on walls by emergency exits.

806.7.2.2 Review customer signage locations, infrastructure, and sightlines, within and outside facilities with Wayfinding and Signage division at milestones identified in EP-03.

Commentary: Infrastructure for owner-furnished signage, such as foundations for freestanding signage in plazas, must be provided.

806.7.2.3 Review code and room sign locations with Operations and Architecture divisions at milestones identified in EP-03.

806.7.2.4 Refer to Standard Specification 10 14 00 Signage for additional requirements and deliverables.

806.7.3 Manufacturing and Construction Management (Not Used)

806.7.4 Installation Management (Not Used)

806.7.5 Inspection and Testing Management

806.7.5.1 The design must adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

806.7.6 Training, Pre-Revenue Operations (Not Used)

806.7.7 Certification Management (Not Used)

806.8 APPENDICES (NOT USED)

END SET - 806

807 BIKE PROGRAM

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SET - 807 TABLE OF CONTENTS

TABLES

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SET - 807 BIKE PROGRAM

807.1 INTRODUCTION

807.1.1 Document Scope

807.1.1.1 The purpose of this set is to establish requirements for bicycle parking and access within the station area owned by Sound Transit. It details different classes of parking, locations, and interface with other facilities as well as the material qualities and requirements of bike parking equipment.

807.1.1.2 Related requirement sets include the following:

i. 800 Architecture
ii. 1000 Mechanical Electrical and Building Systems
iii. 1200 Security
iv. Stations
v. Maintenance facilities
vi. Parking facilities

807.1.1.3 Applicable modes include all Sound Transit modes where bike parking is provided at stations. Associated station areas, plazas, maintenance facilities, and parking facilities are included in the scope.

807.1.1.4 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 807 owner to determine the technical source for the design criteria.

807.1.2 Regulations, Codes, Standards, and Guidelines

807.1.2.1 International Regulations, Codes, Standards, and Guidelines

807.1.2.1.1 International Building Code (IBC) with local amendments.

807.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

807.1.2.2.1 NACTO National Association of City Transportation Officials Urban Bikeway Design Guide.

807.1.2.2.2 ADA Standards for Transportation Facilities (DOT) (ADA Standards), Washington State Accessibility Standards.

807.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines (Not Used)

807.1.2.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

807.1.2.5 Other Jurisdictions (Not Used)

807.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

807.1.2.6.1 Sound Transit Bicycle Program.

807.1.2.6.2 Sound Transit Directive Drawings.

807.1.3 Abbreviations and Acronyms

807.1.3.1 AHJ–authority having jurisdiction

807.1.3.2 AISAP–Access, Integration, and Station Area Planning (a group within Sound Transit)

807.1.3.3 CCTV–closed-caption television

807.1.3.4 CPTED–Crime Prevention Through Environmental Design

807.1.3.5 P3–public-private partnership

807.1.3.6 TOD–transit-oriented development

807.1.4 Definitions and Classifications

807.1.4.1 See Set 001 for definitions.

807.1.5 References (Not Used)

807.2 STAKEHOLDER NEEDS

807.2.1 Passenger Experience

807.2.1.1 Provide storage for bicycles that is safe, secure, and intuitive to use for both short- and long-term use.

807.2.2 Operational Needs

807.2.2.1 The bicycle storage facilities must be easy to operate, durable, and dependable regardless of weather.

807.2.3 Maintenance Needs

807.2.3.1 Minimize maintenance impacts through use of durable low-maintenance equipment that is secure, vandal resistant, and supported by the selected vendor.

807.2.4 Safety Needs

807.2.4.1 Bicycle storage equipment must be safe for both the users of the equipment and any other transit passengers or members of the public that encounter it. It must not impede or obstruct the general flow of passengers within the station area, at the station entrance, or within the station.

807.2.5 Security Needs

807.2.5.1 The equipment must provide secure storage for users. It must follow Crime Prevention Through Environmental Design (CPTED) principles and be coordinated with the facility layout to not impede movement, block sightlines, or create pockets of hidden space.

807.2.6 Reliability, Availability and Maintainability Needs

807.2.6.1 The bicycle storage equipment must be accessible for use by the public. It must reliably provide access to any rooms, lockers, or racks and be easily maintainable by Sound Transit staff and approved vendor(s).

807.2.7 Environmental and Sustainability Needs

807.2.7.1 Bicycle equipment must meet the environmental and sustainability needs established in this document and Set 803 Sustainability.

807.3 SYSTEM REQUIREMENTS

807.3.1 General Requirements

807.3.1.1 Provide signage, pavement markings, and other wayfinding cues to ensure bicyclists are directed towards bicycle parking and platforms.

807.3.1.2 Provide bicycle parking that is easily accessible from bicycle paths or trails adjacent to the station.

807.3.1.3 Where bicyclists share space on pedestrian paths or trails, provide a minimum of 5 feet of clear space per direction of travel to ensure safety and comfort of pedestrians and bicyclists.

807.3.1.4 Where cycle paths intersect with or transition into pedestrian paths and/or plazas, provide visual and tactile cues in the travel surface to indicate the change in purpose of the pathway.

807.3.1.5 Provide bicycle storage at all facility locations to the extent determined by the AISAP group which facilitates the Bike Program at Sound Transit. Designers must reference current Sound Transit bicycle and access policies, the Sound Transit Standard and Directive Drawings, and Station Experience Design Guidelines.

807.3.1.6 Bicycle parking must be a combination of Class One and Class Two parking. The AISAP group will determine proportions during preliminary engineering. See Classification of Bicycle Parking in this set for requirements.

807.3.1.7 The number of bicycle parking spaces to be accommodated (including future expansion) will be provided by the AISAP group. The quantity will be determined during the preliminary engineering phase of the project by means of a bicycle ridership projection methodology and considering station, land use, and access typologies. Quantities will be coordinated with local requirements from AHJ and peer agency provisions. Designers must notify Sound Transit if any of the requirements in this set conflict with any municipal codes.

807.3.1.8 Bicycle parking facilities must be located in close proximity to station entrances, streets, and bicycle routes to support safety and ease of access. Access routes and points should avoid bicyclist conflicts with motorized vehicles, including buses.

807.3.1.8.1 Current and planned jurisdictional bicycle routes must be considered when station bicycle parking is designed to eliminate conflicts between bicyclists and other passenger movement.

807.3.1.8.2 Avoid conflicts with station entries, emergency exits, pedestrian routes, fare collection, and transit vehicle loading areas. Bicycle parking must not be located on the platform or in conflict with circulation to the platform, fare vending areas, signage, or emergency exits. Avoid conflict with landscaping.

807.3.1.8.3 Avoid conflict with mechanical, electrical, and other equipment and access to that equipment for maintenance.

807.3.1.8.4 Bicycle parking facilities must be given preference in proximity to the station entrance over private motor vehicle parking facilities as to location. The Station Experience Design Guidelines should be followed to incorporate additional placement and design considerations to provide an intuitive and thoughtful passenger experience.

807.3.1.8.5 Placement of bicycle parking must avoid areas that require bicycles to travel over stairs. Where stairs cannot be avoided and are the only means of access, designers must incorporate runnels into the edge of the stairs. See Set 805 Vertical Transportation for requirements on vertical travel distance requiring runnels.

807.3.1.8.6 As part of a TOD or P3, bike parking may be developed as a joint development project in lieu of specific Class One and Class Two bicycle parking, where required by AHJ or Sound Transit for bicycle riders.

807.3.1.8.6.1 The party responsible for the TOD or P3 must coordinate an agreement with Sound Transit that defines a viable path to integrating the bicycle parking into the TOD or P3 that meets the needs of transit customers.

807.3.1.8.6.2 If permanent bike parking is to be provided by the TOD or P3, the transit project must determine the type (racks, lockers, room), location, and quantity of any interim bike parking that must be provided onsite to serve transit customers prior to the permanent parking being provided.

807.3.1.8.6.3 If a permanent bike parking facility is to be in a TOD or P3, the project must include a cost in its budget to purchase easements, build the permanent facility, and furnish all equipment and systems required.

807.3.1.9 A minimum of 10% of bicycle parking (or as determined by the AISAP group and project team) must accommodate oversized bicycles, such as longtail cargo bikes, Dutch style Bakfiets cargo bikes, or tandems. Provide at least two freestanding racks to accommodate oversized bikes that meet requirements for Class One parking or two appropriately sized bike lockers.

807.3.1.10 Design teams must work with Sound Transit staff, including the AISAP group, Sound Transit Safety and Security, and Operations, to identify locations for personal (and shared, if applicable) micromobility parking at or near stations with initial decisions by the 30 percent design phase. Micromobility includes free-floating bike share, e-scooters, and other small-scale commercially available personal mobility devices; see Set 001 for definition.

807.3.1.11 Charging is not permitted in bicycle parking areas.

807.3.2 Classification of Bicycle Parking

807.3.2.1 Any non-standard facilities, products, or installation must be reviewed by the AISAP group and Operations prior to submitting a deviation request.

807.3.2.2 Sound Transit defines types of bicycle parking as “Class One” and “Class Two.”

807.3.2.2.1 Class One bicycle parking is the most secure and weather-protected type of bicycle storage. It is typically associated with long-term (all-day or overnight) bicycle parking.

807.3.2.2.2 Class One bicycle parking must be one or a combination of the following:

i. Secure bike room.
ii. Individual bicycle lockers with on-demand, electronic access.
iii. Pre-manufactured secure and weather-protected bicycle storage areas may be permitted as Class One bicycle parking. Review these conditions with Sound Transit’s Bicycle Program before seeking a deviation request.

807.3.2.2.3 Designers must evaluate whether bicycle lockers, a bike room, or a combination of the two make the most sense based on cost, maintenance, and spatial constraints. Station size, station layout, land use, and means of access must also be evaluated when determining the type of Class One bicycle storage.

807.3.2.2.4 Where a bike room is provided, it must include:

i. A bicycle storage area that provides 100 percent canopy coverage and protection from windblown rain on all sides over a group of on-demand bicycle lockers or free-standing racks that are fully enclosed, access-controlled, and monitored. Ideally, the bike room is integrated within the station structure.
ii. Walls, screens, or fences must extend to the ceiling with no gaps, while also maintaining visibility.

iii. No solid doors should be used to enclose the space; doors must provide visibility into and out of the space.
iv. Doors or gates must be composed of perforated metal (or other material approved by Sound Transit) to allow both visibility into and out of the room and prevent the ability for push bars to be accessed and actuated from the exterior.
v. Doors and gates must have a 24-inch metal plate centered on the push bar with horizontal plates above and below to prevent actuation of the push bar from the exterior. There must be no gaps in the fence and frame adjacent to the door that allow access to the push bar from the exterior.
vi. Bicycle storage area must provide CCTV, be well lit, and use CPTED principles.
vii. Provide a 6-foot bench close to and within view of CCTV.

807.3.2.2.5 Class Two bicycle parking provides a lower level of security than Class One and is typically associated with short-term parking.

807.3.2.2.5.1 Class Two bicycle parking must be bicycle racks.

807.3.2.2.5.2 Class Two bicycle parking must provide a minimum of 50 percent bicycle parking spaces with canopy coverage. Bicycle parking spaces which are located under an elevated guideway without additional canopy structures do not count toward the 50 percent canopy coverage. Bicycle parking under other station areas may count if the floor to ceiling height is such that it provides sufficient rain protection using the 15-degree rain angle. This must be confirmed and coordinated with Sound Transit for acceptance.

807.3.3 Functional Requirements

807.3.3.1 Bicycle storage facilities must be constructed on hard and nominally level surfaces.

807.3.3.2 Facility designs must direct roof and site drainage away from bicycle parking and bicycle lockers.

807.3.3.3 Bicycle storage areas must be well-lit. See design standards for guidance on lighting.

807.3.3.4 Facility designs must provide sufficient space between parking areas so that access is possible by a person walking alongside a bicycle. See Set series 800 Architecture.

807.3.3.5 Where CCTV is provided at new facilities, provide CCTV surveillance for bicycle parking and bicycle storage areas, including future designated bicycle parking and storage areas.

807.3.3.6 Location of the bicycle storage area and routes for entering and exiting the facility must be depicted by signage and/or pavement markings at all locations. Signs must be placed within site of or adjacent to entrances in an intuitive and easy to locate manner.

807.3.3.7 All bicycle parking areas must be shown with bicycle route information in signage/maps per the Sound Transit Customer Signage Design Manual (C type panels).

807.3.3.8 Placement of bicycle parking elements must conform to ADA Standards.

807.3.3.9 Bicycle parking expansion space must be clearly indicated in all new facility design documents.

807.3.3.10 Bicycle parking elements and their installation must comply with Sound Transit's ESMS.

807.3.3.11 At bicycle storage areas, designs must include electrical and data infrastructure for future potential power and communications, lighting, and CCTV. Conduit must not be exposed - see Set 1006 Electrical Raceway. During final design, Sound Transit's bicycle parking vendor must review the bike storage area at design milestones identified in EP-03.

807.3.3.12 Where bicycle lockers are installed, each group of on-demand (pay per use) lockers must include electrical and data conduit for future power and communications connections (e.g., for smart card readers). The AISAP group will determine the quantity of on-demand lockers.

Commentary: Current lockers can function remotely via battery and cellular Wi-Fi, but there is a desire for futureproofing by providing conduit to locker locations.

807.3.4 Bike Lockers

807.3.4.1 The bike lockers must meet the following design criteria:

i. Minimum 18-gauge stainless-steel, including center divider panels
ii. Roof that drains
iii. Waterproof and leak-proof enclosure
iv. Each locker space must accommodate a single standard two-wheel bicycle and accessories such as a helmet and panniers.
v. Locker units must be modular
vi. Must have walls and roofs that resist theft, vandalism, and fire
vii. Must have a tamper-resistant door that recesses into the jamb
viii. Must have a multi-point locking mechanism
ix. Must be secured to the mounting surface with tamper-resistant fasteners

807.3.4.2 Install bike lockers with a 6-foot minimum clearance on each side containing a door.

807.3.4.3 Approved products include rectangular, quad, and wedge models by eLock Technologies LLC.

807.3.5 Bicycle Rack

807.3.5.1 The bicycle rack design must meet the following criteria:

i. Must provide at least two points of contact with the bike frame.
ii. The rack high point must be at least 32 inches above ground level.
iii. Users must be able to lock a bike frame and at least one wheel to the rack using a cable lock or U-lock.
iv. Racks must be resistant to breaking and withstand general vandalism (including kicking) without structural failure.
v. Racks must be stainless steel or per Table 801-4.
vi. Hardware must be non-corrosive and have theft-deterrent lockable bolts.
vii. Rack surface must not damage bicycles (e.g., scratch their finish).

807.3.5.2 Security

807.3.5.2.1 Racks must be installed and anchored so they cannot be stolen with bicycles attached. The preferred installation is to embed in concrete. Otherwise, use tamper-resistant fasteners and secure anchorage into concrete.

807.3.5.2.2 Rack material must resist being cut or detached using common hand tools, especially those that can be concealed in a backpack such as bolt cutters, pipe cutters, wrenches, and pry bars.

807.3.5.3 Safety

807.3.5.3.1 Racks must have openings that are less than four inches *or* greater than eight inches in width.

Commentary: These dimensions prevent children from trapping their heads in the rack openings. Less than 4 inches is too small for a head to pass through and greater than 8 inches is large enough for a head to not get stuck.

807.3.5.3.2 Install a cane-detectable rack at the ends of rack groupings.

Commentary: A cane-detectable rack allows passengers with impaired vision to detect racks along circulation paths.

807.3.5.3.3 Sharp edges are prohibited.

807.3.5.4 Provide approved products per Table 807-1.

Table 807-1: Bicycle Rack Products

Application	Model & Manufacturer	Size
All	• "Tofino No Scratch" by Sportworks • "Cane Detectable Tofino No Scratch" by Sportworks • Approved equal by ST Bicycle Program	Standard size to accommodate two bicycles
High-Density (Enclosed Cage or Space Only)	• Dero Model "Dero Decker", wall or floor mount • Approved equal by ST Bicycle Program	Modular units to accommodate up to 24 bicycles
Retrofit (Parking Space Conversion Only)	• Dero Model "Cycle Stall" • Approved equal by ST Bicycle Program	Standard size to accommodate 10 bicycles

807.3.5.5 Location on Site

807.3.5.5.1 Racks must be located and installed in coordination with other facility elements in accordance with manufacturer's printed instructions and Table 807-2.

Table 807-2: Bicycle Rack Clearances

Fixed Object	Minimum Distance to Bicycle Rack
Street Encroachments	24"
Light Pole	30"
Sidewalk Obstructions	36"
Transit Boarding Areas, Loading Zones, Disabled Parking, Curb Ramps, Crosswalks, and Storm Drain Inlets	48"
Fire Hydrants	60"

807.3.5.5.2 High-density rack style must be installed in enclosed areas only.

807.3.5.5.3 Retrofit rack style must only be used when automobile parking spaces are converted to bicycle parking.

807.3.5.5.4 Install a cane-detectable rack at the ends of rack groupings.

Commentary: The cane-detectable rack allows passengers with impaired vision to detect racks along circulation paths. Not all racks need this cane rail, only the end racks in a linear group as the end racks would be detected prior to the inner racks in a grouping.

807.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

807.5 SYSTEM INTERFACE REQUIREMENTS

Table 807-3 lists requirement sets that are typically coordinated, and may have dependencies, with this set.

Table 807-3: Interface Between Architecture and Other Disciplines

SET SERIES	SERIES NAME	SET 807 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	
300	Operational Communications	
400	Vehicle	
500	Track	
600	Fire / Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical / Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

807.5.1 Architecture

807.5.1.1 Coordinate space allocation at stations and other facilities.

807.5.2 1000 Mechanical/ Electrical

807.5.2.1 Coordinate power requirements.

807.5.3 1100 Technology

807.5.3.1 Coordinate data requirements.

807.5.4 Security

807.5.4.1 Coordinate CCTV requirements.

807.5.5 Civil

807.5.5.1 Coordinate bicycle access requirements such as bike/pedestrian bridges, paths, and other routes providing access to the station and within the station area.

807.5.6 Structures

807.5.6.1 Coordinate structural requirements.

807.5.7 Fire Life Safety

807.5.7.1 Coordinate Fire Life Safety requirements for bike rooms.

807.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

807.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

807.7.1 Interface and Integration Management

807.7.2 Design Management

807.7.3 Manufacturing and Construction Management

807.7.4 Installation Management

807.7.5 Inspection and Testing Management

807.7.6 Training, Pre-Revenue Operations

807.7.7 Certification Management

807.8 APPENDICES (NOT USED)

END SET - 807

808 SOUND TRANSIT ART PROGRAM (START)

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SET - 808 SOUND TRANSIT ART PROGRAM (START)

808.1 INTRODUCTION

808.1.1 Document Scope

808.1.1.1 This set provides the requirements to integrate artwork developed by the Sound Transit Art Program (STart) into the design and construction of Sound Transit capital projects.

808.1.1.2 Operational Environment

808.1.1.2.1 STart develops artwork for Sound Transit capital projects in collaboration with the design teams for individual capital projects. Artists' services and the design of artwork are not included in any design team's scope of work, but those design teams are responsible for integrating artwork into Sound Transit capital project designs.

808.1.1.2.2 STart projects are always presented to and reviewed internally by Sound Transit Operations and Safety and Security. Other Sound Transit departments will review STart projects as needed based on the characteristics of the projects. STart further works with boards, commissions, and staff to seek advice and consent for artwork in each jurisdiction in which Sound Transit capital projects are placed.

808.1.1.3 STart Overview

808.1.1.3.1 Artwork enlivens transit capital projects by bringing human-scale local character and unique features to transit stations and other capital projects. As Sound Transit's capital projects become more standardized, artworks will serve as points of distinction within a system that otherwise requires continuity. Artists commissioned by Sound Transit are often tasked with responding to the local character of neighborhoods; in other situations, the artwork may be less specific to a place and intended to support wayfinding or simply inspire delight.

808.1.1.3.2 A successful artwork must be a prominent feature of a station, work harmoniously with, but independent of, the surrounding architecture and complement Sound Transit's signage-wayfinding and fare paid zone systems. Art must not be placed in locations that block passenger or LRV operator sightlines or obstruct passenger flow, decision points, surge, or mixing zones. Artwork locations must conform to CPTED and Sound Transit Safety guidance and, with rare exceptions, allow for maintenance access during revenue service hours.

808.1.1.3.3 STart is solely responsible for managing the development of opportunities for artwork, hiring artists, and managing the fabrication and installation of those artworks.

808.1.1.4 Procurement of Artist Services

808.1.1.4.1 STart procures artist services for Sound Transit projects based on requests for qualifications rather than requests for proposals. Submitted qualifications are then reviewed by artist selection panels assembled by Start which typically include representatives from partner jurisdictions, community stakeholder groups, design teams, and other art and design professionals.

808.1.1.4.2 Once selected for a project, artists are under contract with Sound Transit. Such contracts are distinct from the overall capital project contracts to which their projects are related.

808.1.1.5 Artwork Design Review and Approval

808.1.1.5.1 To the extent possible artwork designs are included in their related capital project's design documents and public presentation materials. Sound Transit artists' scopes of work include collaboration with design teams, presentations to community groups, and meetings with jurisdictional staff and committees.

808.1.1.5.2 Artwork design review processes for each jurisdiction must be established at the end of conceptual engineering. Sound Transit conducts its own internal artwork review and approval process, focusing on engineering, maintenance, safety, passenger experience, and appropriateness to the overall planned Sound Transit capital project. STart is the final decision-maker regarding artwork and endeavors to commission artwork that is responsive to the criteria of its partner jurisdictions, communities, and stakeholders.

808.1.1.6 Artwork Funding

808.1.1.6.1 Sound Transit's Board-adopted Resolution 2010-21 (Sound Transit Art Program Policy) sets aside one percent of most construction budgets from voter-approved initiatives for artwork. These funds are independent from individual capital project budgets.

808.1.1.7 Overall Project Relationships

808.1.1.7.1 Scope Management

808.1.1.7.1.1 STart is responsible for developing the general scopes of work for the integration of artwork. STart coordinates all collaborative efforts between Sound Transit artists and design teams. The specific communication protocols for each capital project must be negotiated and agreed-upon with design teams by those projects' Corridor Design or Design-Build Project Management Teams.

808.1.1.7.2 Final design in design-bid-build or general contractor/construction manager projects.

808.1.1.7.2.1 The scope of work for artwork integration must be documented in the request for proposals for the final design phase of the project.

Commentary: A range of possible artwork opportunities may be included in the request for proposals for design services. These identified opportunities do not preclude others that may be developed during final design.

808.1.1.7.3 Final Design in Design-Build Projects

808.1.1.7.3.1 The scope of work for artwork integration must be documented in the project requirements issued in the request for proposals.

Commentary: Specific artwork opportunities will be included in the project requirements. Alternatives to these identified opportunities may be proposed by design builders if their overall project proposals include substantial alterations to the capital project's pre-designs as described in the project requirements.

808.1.1.7.4 Contractor Scope

808.1.1.7.4.1 Contractor's scopes of work for the construction and/or installation of artwork will be during final design.

808.1.2 Regulations, Codes, Standards, and Guidelines

808.1.2.1 International Regulations, Codes, Standards, and Guidelines

808.1.2.1.1 International Fire Code with local amendments.

808.1.2.1.2 National Fire Protection Association (NFPA).

808.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

808.1.2.2.1 The Visual Artists Rights Act of 1990 (VARA), (Pub.L. 101–650 title VI, 17 U.S.C. § 106A), is a United States law granting certain rights to artists. In short, VARA protects an artist's "moral rights," which means that Artwork commissioning bodies are bound to protect artwork from alterations or destruction as much as is reasonable. In developing artwork, Sound Transit strives to identify locations for such artwork that are unlikely to require future modifications.

808.1.2.2.2 Art in Transit: Federal Transit Administration Policy Circular 9400.1A.

808.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

808.1.2.3.1 Municipal and Special District Codes and Standards.

808.1.2.3.2 Municipal Codes and Comprehensive Plans, as applicable.

808.1.2.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

808.1.2.5 Other Jurisdictions (Not Used)

808.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

808.1.2.6.1 Regional Transit Authority Board Motion No. 40: Commitment to Public Art.

Commentary: A motion of the Board of the Regional Transit Authority for the Pierce, King, and Snohomish Counties region committing to the integration of public art in the implementation of the Sound Transit system.

808.1.2.6.2 Regional Transit Authority Board Resolution 98-1: Sound Transit Art Program Establishment.

Commentary: A resolution of the Board of the Regional Transit Authority for the Pierce, King, and Snohomish Counties region establishing Sound Transit Art Program guidelines and adopting a budget policy.

808.1.2.6.3 Sound Transit Board Resolution R2010-21: Sound Transit Art Program Policy.

Commentary: Adopted an art policy and superseded Resolution No. 98-1, with a renewed Board commitment to integrating artwork in ST2 capital projects.

808.1.2.6.4 Sound Transit Board Resolution R2019-2: Sound Transit Art Program Extension

Commentary: Adopted an art policy and superseded Resolution R2010-21, continuing the Board's commitment to integrating public art in the implementation of ST3 capital projects.

808.1.3 Abbreviations and Acronyms (Not Used)

808.1.4 Definitions and Classifications

808.1.4.1 STart: the Sound Transit Art Program, part of Sound Transit's Design, Engineering, and Construction Management division.

808.1.4.2 Artist: An artist or artist team commissioned by Sound Transit to create one or more works of art for a Sound Transit capital project. Artists may subcontract the fabrication and installation of the artwork they have designed.

808.1.4.3 Artwork: Any feature or finish created by an artist under contract with Sound Transit. Artwork may be fabricated and installed by the artist, Contractors building Sound Transit capital projects or a combination of those parties.

808.1.4.4 Art Coordinator: A member of a design or construction team identified as the principal point-of-contact with STart.

808.1.4.5 Design Team: For the purposes of this set, design teams are the architects, landscape architects and civil, structural, and systems engineers associated with a specific capital project, regardless of the project's delivery method.

808.1.4.6 Contractor: For the purposes of this set, contractors are the parties building any capital project.

808.1.5 References (Not Used)

808.2 STAKEHOLDER NEEDS

808.2.1 Passenger Experience

808.2.1.1 Artwork sites must be in prominent, unobstructed, and well-lit places heavily used by passengers and contribute to passenger wayfinding.

808.2.1.2 Communities and Authorities Having Jurisdiction (AHJs)

808.2.1.2.1 Artwork must be in prominent places within Sound Transit capital projects and contribute to an impression of civic importance to the project.

808.2.2 Operational Needs

808.2.2.1 Artworks must not interfere with train operations, bus operations, or complicate pedestrian traffic. Artwork must support, but not compete with, essential system wayfinding or informational signage and security features.

808.2.2.2 Artwork Site Maintenance Requirements

808.2.2.2.1 Artwork, associated support structures, and electrical components must be:

i. Accessible for maintenance during revenue service hours.
ii. Accessible from the ground or using scissor lifts or aerial work platforms.
iii. Out of locations that would require maintenance personnel and equipment to be within the 10-foot circumference safety zone around OCS wires.

808.2.3 Safety Needs

808.2.3.1 Artwork sites must conform to Sound Transit’s safety standards.

808.2.3.2 Artwork must be made of non-combustible materials.

808.2.3.3 Artwork must be anchored to ensure structural stability.

808.2.4 Security Needs

808.2.4.1 Artwork sites must conform to Sound Transit’s security standards.

808.2.5 Reliability, Availability and Maintainability Needs

808.2.5.1 Artwork must be designed and fabricated for a predicted lifespan of at least 25 years.

808.2.6 Environmental and Sustainability Needs (Not Used)

808.3 SYSTEM REQUIREMENTS

808.3.1 General Requirements

808.3.1.1 Artwork is developed using a variety of means and methods, each requiring different unique design and construction considerations.

808.3.1.2 Using structural loads and other information provided by STart, design teams must engineer and design artwork infrastructure, including foundations, structural attachments, metal panel details, electrical circuits, data cable routing, and conduit runs in the design documents.

808.3.1.3 Artwork incorporating any electronic media will be considered very rarely.

Commentary: If included in a capital project's design documents, infrastructure supporting the installation of Artwork must be provided by the capital project's Contractor. Artwork that contains combustible material must comply with NFPA130. Jurisdictions may require review and approval for both temporary and permanent installations.

808.3.1.4 Artwork must be designed for ease of inspection.

Commentary: Consider inspection when designing fasteners so they are visible without the use of special equipment.

808.3.2 Artwork Lighting

808.3.2.1 Artwork must be illuminated with ambient light rather than artwork-specific fixtures.

808.3.2.2 If artwork-specific lighting is required because of insufficient ambient light, design teams must specify lighting designs in the capital project design documents that:

i. Illuminate only the artwork.
ii. Does not direct light towards the sky.
iii. Does not direct light towards roadways.
iv. Does not cause glare or obstruct LRV operators' vision.
v. Uses fixtures specified for other locations in the capital project.

808.3.3 Owner Furnished – Owner Installed Artwork Types

808.3.3.1 This section describes design milestone requirements of artwork that is designed, fabricated, and installed by STart artists and/or their subcontractors.

808.3.4 Sculptural Objects

808.3.4.1 If a capital project includes three-dimensional artwork manufactured by ST artists or specialty fabricators, design teams must design artwork foundations based on details and loads provided by STart at the 60 percent design milestone.

808.3.5 Owner Furnished – Contractor Installed Artwork Types

808.3.5.1 This section describes design milestone requirements of artwork furnished by Sound Transit artists and installed by a capital project's contractor.

808.3.6 Laminated Interlayer and Frit-Printed Glass

808.3.6.1 If a capital project includes artwork made of commercially manufactured laminated glass with printed interlayers, design teams must complete the following at the project's 60 percent final design milestone. Artwork must not be designed for or installed in any elevator hoistway glazing systems.

i. Specify curtainwall and storefront systems that accept panels up to 5/8 inches thick.
ii. Create a separate designation for art glass in design drawings, glazing schedules and the project specifications.

808.3.7 Specialty Glass

808.3.7.1 If a capital project includes artwork made of artisan-manufactured glass panels, design teams must complete the following at the project's 60 percent final design:

i. Specify curtainwall and storefront systems that accept panels up to 1 inch thick.
ii. Provide structural engineering for curtainwall and storefront systems if the proposed specialty glass panels are substantially heavier than non-art glazing specified elsewhere in the design documents.

808.3.8 Porcelain Enamel, Painted or Printed Panels

808.3.8.1 If a capital project includes artwork made of porcelain enamel, painted, or printed metal panels design to conform to a capital project's metal panel system, design teams must complete the following at the project's 60 percent final design milestone:

i. Structural engineering of the panel systems, detailing structural attachments and embedded infrastructure.
ii. Specific fabrication details of all panel systems to guide the development of the STart-provided shop drawings.

808.3.9 Mosaic and Ceramic Tile

808.3.9.1 If a capital project includes artwork made of glass or ceramic mosaics, the design team must complete the following at the project's 60 percent final design milestone:

i. Structural engineering of all panel systems, detailing structural attachments and embedded infrastructure.
ii. Specific fabrication details of all panel systems to guide the development of STart-provided shop drawings.

808.3.10 Painted Murals

808.3.10.1 If a capital project includes hand-painted artwork on contractor installed panels (cementitious or other), design teams must provide the following at the project's 60 percent final design milestone:

i. Structural engineering of panel installation structures, detailing structural attachments and embedded infrastructure.

808.3.11 Functional Objects

808.3.11.1 If a capital project includes benches, balusters, fences, and other objects fabricated by artists and installed as functional components of stations, the design team must complete the following at the project's 60 percent final design milestone:

i. Engineering services to design footings and anchorages using the artworks' structural loads furnished by STart.
ii. Specific code-based design specifications to guide the artist(s)' design and fabrication of the artwork.

808.3.12 Owner Furnished Design – Contractor Furnished and Installed Artwork Types

808.3.12.1 This section describes design milestone requirements of artwork designed by ST artists to be fabricated and installed by a capital project's contractor.

808.3.13 Perforated Metal Panels

808.3.13.1 If using commercially-manufactured perforated metal panels finished with shop-applied high-performance coatings, the design team must provide the following at the project's 60 percent final design milestone:

i. Structural engineering of the panel systems, detailing structural attachments and embedded infrastructure.
ii. Specific fabrication details of the panel systems to STart.

808.3.13.2 At the project's 90 percent final design milestone, design teams must show the perforation patterns in the design documents.

808.3.14 Integrated Architectural Finishes

808.3.14.1 If using specialty architectural materials and finishes (e.g., terrazzo, specialty concrete, stone, ceramic tile, brick, paint) designed by Sound Transit artists and included in a capital project's design documents, design teams must specify materials and finishes that:

i. Are durable and able to withstand heavy use and weather.
ii. Can be maintained using conventional cleaning and replacement techniques.

808.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

808.4.1 System Breakdown Structure (Not Used)

808.4.2 System Sites and Locations (Not Used)

808.5 SYSTEM INTERFACE REQUIREMENTS

Table 808-1 lists requirement sets that are typically coordinated, and may have dependencies, with this set.

Table 808-1: Interface Between STart and Other Disciplines

SET SERIES	SERIES NAME	SET 801 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	
500	Track	
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical / Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

808.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

808.7 ENGINEERING MANAGEMENT REQUIREMENTS

808.7.1 Interface and Integration Management

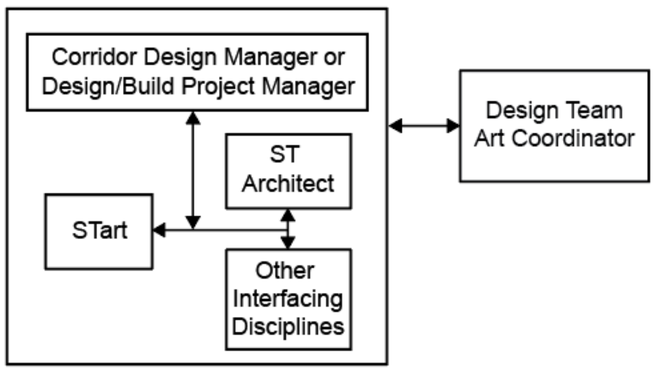
808.7.1.1 Personnel

808.7.1.1.1 Design teams must assign personnel and allocate resources to collaborate with STart and Sound Transit artists. This must include assigning staff to serve as art coordinators, providing architectural services, engineering services, and convening regular meetings with STart and its commissioned Sound Transit artists.

808.7.1.2 Communications During Final Design

808.7.1.2.1 The Sound Transit senior design manager, design manager, or design/build project manager, will negotiate communication protocols for the collaboration between STart and design teams at the start of final design.

Figure 808-1: Typical Communications Pathways During Final Design



808.7.2 Design Management

808.7.2.1 General

808.7.2.1.1 Design teams are responsible for the engineering and design of all artwork infrastructure, including foundations, structural attachments, metal panel details, electrical circuits, data cable routing, conduit runs, and any related technology needs in the design documents.

808.7.2.2 Design Review

808.7.2.2.1 Using agreed-upon protocols, STart will submit artwork design and engineering documents to the related design teams for review at negotiated milestones during the project's Final Design. STart will manage the in-house Sound Transit reviews of all artwork fabrication and installation details for safety, maintainability, structural integrity, and content.

808.7.2.3 Schedule

808.7.2.3.1 The design of all artwork and related infrastructure must conform to the related capital project's design development schedule. This requires ongoing communication and coordination between design and construction Teams and STart to ensure any necessary integration into the project's design documents. Design teams must immediately inform STart of changes to the design development schedule.

808.7.2.3.2 Timelines for Deliverables

808.7.2.3.2.1 During Final Design, Design Teams must provide:

i. At the 30 percent milestone:
   a. Preliminary designs for required artwork infrastructure.
   b. Identified site, code, or other restrictions that will affect artwork designs.
ii. At the 60 percent milestone:
   a. Refined designs for required artwork infrastructure.
   b. Preliminary project specifications affecting the planned artwork.
iii. At the 90 percent milestone:
   a. Final designs for required artwork infrastructure.
   b. Final project specifications affecting the planned artwork.

808.7.3 Manufacturing and Construction Management

808.7.3.1 Personnel

808.7.3.1.1 Contractors and construction management teams must assign personnel and allocate resources to collaborate with STart and artists. This may include assigning staff to serve as art coordinators and convening regular meetings with STart and its commissioned Sound Transit artists.

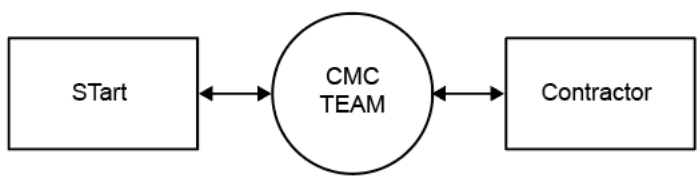
808.7.3.2 Schedule

808.7.3.2.1 Contractors must provide a task-specific construction schedule to the Construction or Design-Build Project Management Team clearly defining artwork installation periods. Contractors must notify STart of schedule changes in writing.

808.7.3.3 Communications During Construction

808.7.3.3.1 During construction, STart will communicate with contractors through the capital project's Resident Engineer or Design Build Project Manager. The Resident Engineer or Design Build Project Manager may instruct STart to work directly with the contractor using approved communication protocols.

Figure 808-2: Typical Communications Pathways During Construction



808.7.3.4 Permits

808.7.3.4.1 Sound Transit is responsible for procuring artwork-related building or trades permits.

808.7.3.5 Site Management

808.7.3.5.1 Contractors must coordinate construction activities adjacent to artwork sites to avoid conflicts with Artwork installations. Contractors must protect finished artwork from damage.

808.7.3.5.2 Owner Furnished – Owner Installed Artwork

808.7.3.5.3 Contractors must provide:

i. Site access, traffic control permits, and traffic control personnel for the installation of artwork.

ii. Secure on-site staging areas for owner furnished owner installed artwork and provide site access to electricity, water, and toilets.

iii. Safety orientations/trainings for all owner and artist personnel.

808.7.3.5.4 Owner Furnished – Contractor Installed Artwork

808.7.3.5.5 Contractors must provide:

i. 12-month, 6-month, and 1-month notices for required delivery of artwork for contractor installation.

ii. Work plans for all contractor installed artwork for review and approval by STart 2 months in advance of the scheduled installations. Work plans must include unloading, staging, rigging, and hoisting requirements for specific artwork installations.

iii. All labor and equipment needed to offload owner-furnished artwork upon delivery to pre-approved sites.

iv. Secure storage and delivery of the artwork to the site at the time of installation if the Artwork is stored off site by the contractor. The contractor is liable for damage to the Artwork while in storage.

v. Labor, supervision, hardware, consumables, materials, and equipment to install the Artwork.

808.7.3.6 Construction Requirements by Artwork Type

808.7.3.6.1 Laminated Interlayer and Frit-Printed Glass

808.7.3.6.1.1 Contractor must provide curtainwall/storefront shop drawings, glass specifications and confirmed glass panel sizes at least 12 weeks in advance of scheduled delivery deadlines.

808.7.3.6.2 Specialty Glass

808.7.3.6.2.1 Contractor must provide as-built measurements of installation sites at least 16 weeks in advance of scheduled delivery deadlines.

808.7.3.6.3 Porcelain Enamel, Painted or Printed Metal Panels

808.7.3.6.3.1 Contractors must provide clean finished surfaces and structures for the planned Artwork and install the Artwork as described in the design documents.

808.7.3.6.4 Perforated Metal Panels

808.7.3.6.4.1 Contractors must:

i. Submit required shop drawings for review and approval by STart and Sound Transit artists.

ii. Provide at least one full-scale fully finished mockup panel with a representative artwork design for review and approval by STart and Sound Transit artists.

iii. Manufacturer artwork panels as described in the shop drawings.

iv. Install artwork panels as described in the shop drawings.

808.7.3.6.5 Sculptural Objects

808.7.3.6.5.1 Contractors must construct concrete footings, structural supports, and lighting associated with Artworks as described in the design documents.

808.7.3.6.6 Integrated Architectural Finishes

808.7.3.6.6.1 Contractors must:

i. Provide at least one full-scale fully finished mockup panel with a representative artwork design for review and approval by STart and Sound Transit artists.

ii. Procure and install all Sound Transit artist-designed finishes as described in the design documents.

808.7.4 As-Built Measurements

808.7.4.1 The contractor must provide as-built measurements of Artwork installation sites and/or embedded attachments within 2 weeks of the completion of those sites and/or embedded attachments.

808.7.5 Installation Management (Not Used)

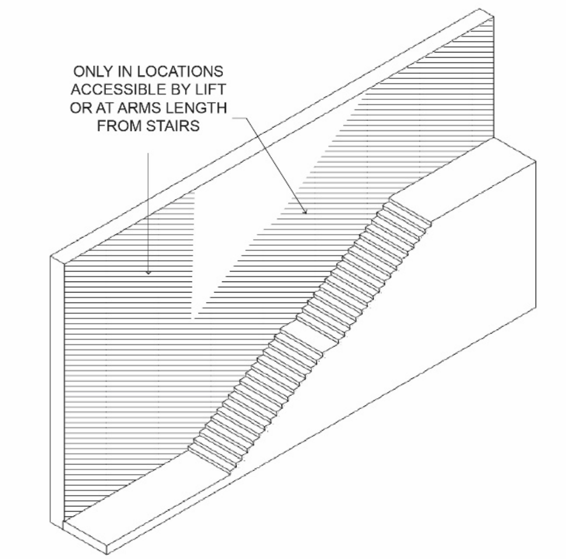
808.7.6 Inspection and Testing Management (Not Used)

808.7.7 Training, Pre-Revenue Operations (Not Used)

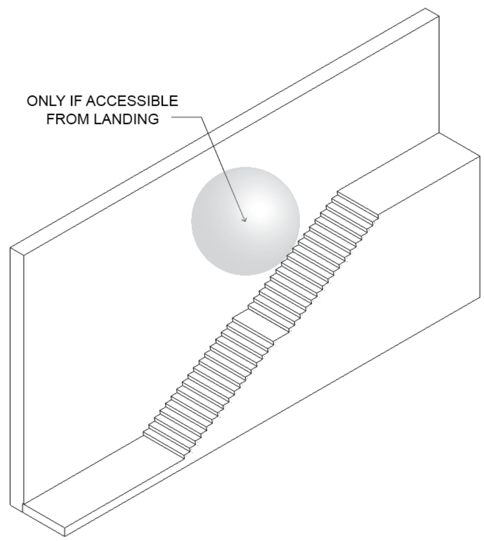
808.7.8 Certification Management (Not Used)

808.8 APPENDICES

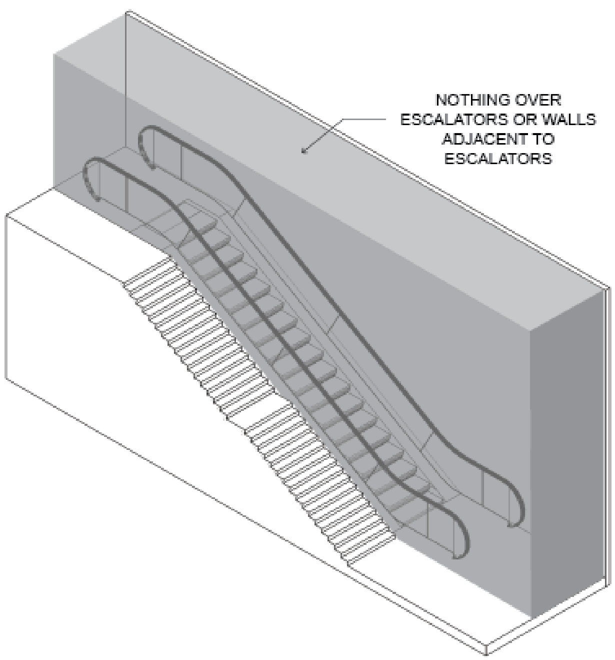
808.8.1 Typical Light Rail Station Vertical Circulation Artwork Site Restrictions



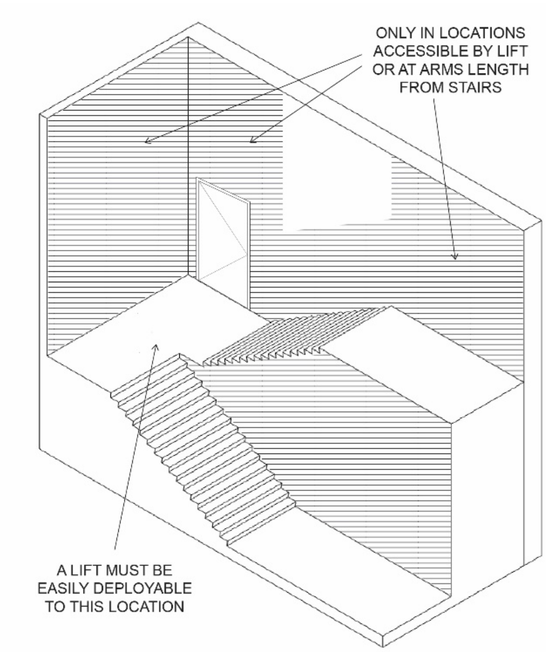
STAIRCASE WALLS



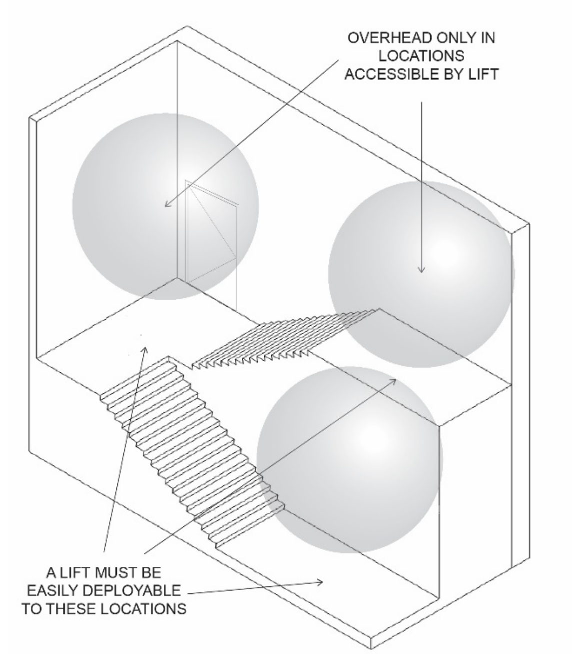
OVER STAIRCASES



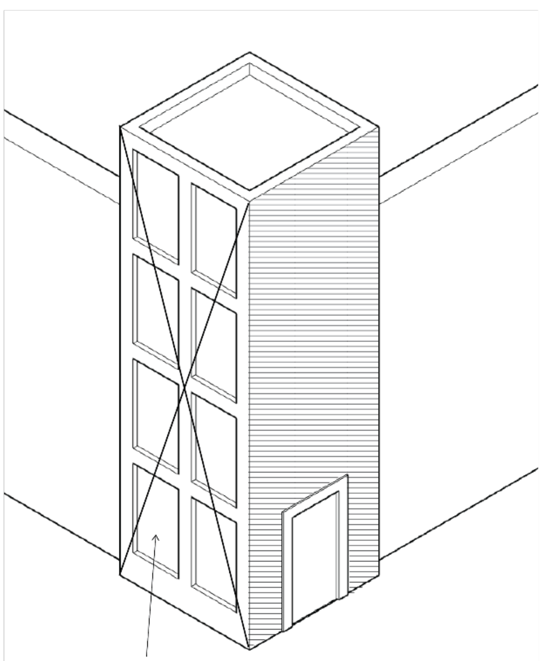
OVER ESCALATORS



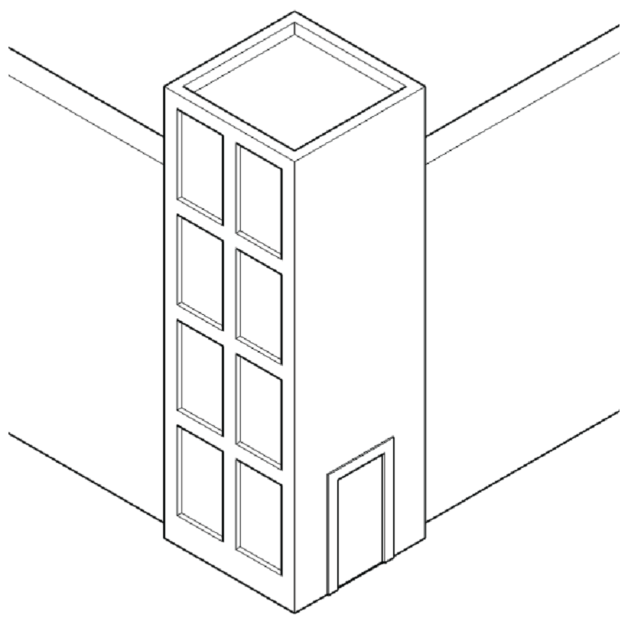
STAIRS WITH LANDING



STAIRS WITH LANDING

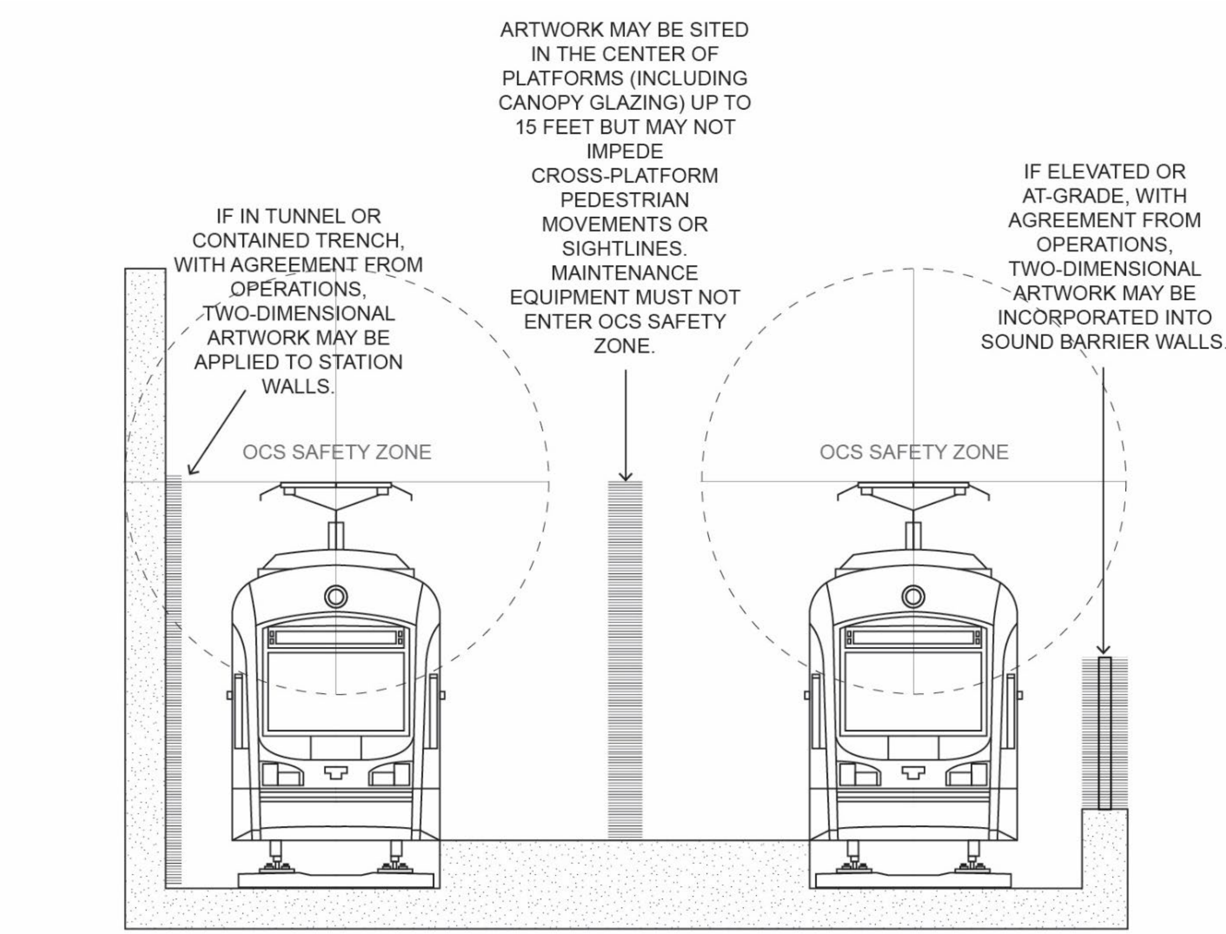


NO ARTWORK IN ELEVATOR
HOISTWAY GLAZING



ARTWORK MAY BE SITED IN
STAIRCASE TOWER

808.8.2 Typical Light Rail Station Platform Artwork Opportunity Locations



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815 TELECOMMUNICATIONS SPACES

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SET - 815 TELECOMMUNICATIONS SPACES

815.1 INTRODUCTION

815.1.1 Document Scope

815.1.1.1 This document provides definition for telecommunications spaces standards and requirements for the design of safe, secure, and reliable spaces intended for housing systems and telecommunications equipment inside Sound Transit facilities. When these standards are implemented properly and requirements met, systems and telecommunications equipment will be hosted in dependable, protected, and reliable areas intended for the equipment operation and maintenance.

815.1.1.2 Sound Transit requires the equipment hosted in its facilities to be provided with an environment that guarantees their operation during normal and abnormal conditions. The telecommunications spaces must be designed for expansion in the foreseeable future. The final goal is designing telecommunications spaces that may host the equipment for the useful life of the facility. Since the equipment lifecycle is much shorter than the facilities, the designer must provide enough expansion capabilities for the systems to accommodate future transit system's requirements.

815.1.2 Regulations, Codes, Standards, and Guidelines

815.1.2.1 International Regulations, Codes, Standards, and Guidelines

815.1.2.1.1 International Fire Code (IFC)/Seattle Fire Code (SFC) Section 510-2018 or later.

815.1.2.1.2 Client Assistance Memo (CAM) 5123.

815.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

815.1.2.2.1 NFPA 70 National Electrical Code.

815.1.2.2.2 NFPA 72 National Fire Alarm and Signaling Code.

815.1.2.2.3 NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems.

815.1.2.2.4 NFPA 1221Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems.

815.1.2.2.5 NFPA 1225 Standard for Emergency Services Communications.

815.1.2.2.6 Underwriters Laboratories.

815.1.2.2.6.1 UL 444, UL Standard for Safety Communications Cables.

815.1.2.2.6.2 UL 444 BULLETIN, UL Standard for Safety Communications Cables.

815.1.2.2.6.3 UL 2524 Standard for In-Building 2-Way Emergency Radio Communications Enhancement Systems.

815.1.2.2.6.4 UL Lightning Protection Marking and Application Guide

815.1.2.2.7 Building Industry Consulting Service International (BICSI).

815.1.2.2.7.1 BICSI 002, Data Center Design and Implementation Best Practices.

815.1.2.2.7.2 BICSI ITSIMM, Information Technology Systems Installation Methods Manual.

815.1.2.2.7.3 BICSI OSPDRM, Outside Plant Design Reference Manual.

815.1.2.2.7.4 BICSI TDMM, Telecommunications Distribution Methods Manual.

815.1.2.2.7.5 BICSI/NECA 568, Standard for Installing Commercial Building Telecommunications Cabling.

815.1.2.2.7.6 BICSI/NECA 607 Standard for Telecommunications Bonding and Grounding Planning and Installation Methods for Commercial Buildings 2011.

815.1.2.2.8 Institute of Electrical and Electronics Engineers.

815.1.2.2.8.1 IEEE SA 1588 IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems (version 2 or later).

815.1.2.2.9 American Society of Heating, Refrigerating and Air-Conditioning Engineers

815.1.2.2.9.1 ASHRAE TC9.9 Data Center Power Equipment Thermal Guidelines and Best Practices

815.1.2.2.10 Telecommunications Industry Association.

815.1.2.2.10.1 TIA-758-B “Customer-Owned Outside Plant Telecommunications Infrastructure Standard.

815.1.2.2.10.2 TIA-606-B, Administration Standard for Commercial Telecommunications.

815.1.2.2.10.3 TIA-607-B, Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises.

815.1.2.2.10.4 TIA-758-B, Customer-Owned Outside Plant Telecommunications Infrastructure Standard.

815.1.2.2.10.5 TIA-942-A, Telecommunications Infrastructure Standard for Data Centers.

815.1.2.2.10.6 Fiber Optic Association (FOA) OSP Fiber Optics Civil Works Guide.

815.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

815.1.2.3.1 Washington State Department of Transportation.

815.1.2.3.1.1 WSDOT 2021 Standard Specification M 41-10.

815.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

815.1.2.4.1 Motorola Solutions Inc.

815.1.2.4.1.1 R56 Standards and Guidelines for Communication Sites (68P81089E50-B).

815.1.2.4.2 American Telegraph & Telephone

815.1.2.4.2.1 AT&T Outside Plant Engineering Handbook.

815.1.2.4.2.2 ATT-TP-76205 Electronic Equipment Enclosure / Cabinet (EEE/C) Standards Issue 5.

815.1.2.5 Sound Transit Regulations, Codes, Standards, and Guidelines

815.1.2.5.1 Standard Drawings (2019 or later).

815.1.3 Abbreviations and Acronyms (Not Used)

815.1.4 Definitions and Classifications

815.1.5 Definitions

Commentary: Telecommunications Spaces are closets, enclosures, rooms and datacenters. Note the following definitions may differ slightly from those in Telecommunications Distribution Methods Manual.

815.1.5.1 Active equipment: any equipment that requires to receive external energy to perform its intended functionality.

815.1.5.2 Non-active equipment: any equipment or material that does not require external power to perform its intended functionality, like cable terminations and cross-connect boards.

815.1.5.3 Telecommunications closets: A telecommunications closet is the architectural space intended to contain non-active equipment.

815.1.5.4 Telecommunications enclosures: A telecommunications enclosure is a closed metallic container intended to house non-active equipment. A telecommunications enclosure is intended to house only cable terminations and cross connect cabling.

Commentary: Outdoor telecommunications enclosures are not the preferred method for installing equipment, especially if it must contain active equipment. If used, they must be approved by ST and designed to meet TDMM environmental and access requirements.

815.1.5.5 Telecommunications Rooms: A Telecommunications Room is a secure architectural space intended to contain cables, cross-connects, connecting hardware and Telecommunications equipment.

815.1.5.6 Equipment Room: An Equipment Room is a secure architectural space intended to contain cables, cross connects, connecting hardware and active equipment.

Commentary: These are the rooms that do not have telecommunications equipment, but operationally meaningful equipment like: UPS Rooms, Electrical Rooms, Elevator Rooms, Mechanical Rooms, etc., where electronic equipment may be installed, and their environmental conditions must be properly addressed.

815.1.5.7 Entrance Facility: An Entrance Facility is the secure architectural space where external service providers have access to the facility.

Commentary: An Entrance Facility may share the space in a Telecommunications Room, but the room must be sized per TDMM requirements.

815.1.5.8 Datacenter: A Telecommunications Space that hosts 12 cabinets or more is defined as an Edge Datacenter, requiring the extra infrastructure to support a reliable operation of the equipment installed in it for extended periods of time.

Commentary: Datacenters are intended for maintenance facilities, if the threshold of 12 cabinets is reached in a station, the designer must get approval for a Datacenter design.

815.1.6 References (Not Used)

815.2 STAKEHOLDER NEEDS

815.2.1 Passenger Experience (Not Used)

815.2.2 Operational Needs (Not Used)

815.2.3 Maintenance Needs (Not Used)

815.2.4 Safety Needs (Not Used)

815.2.5 Security Needs (Not Used)

815.2.6 Reliability, Availability, and Maintainability Needs

815.2.6.1 The designers must use the following table to guide their design:

Table 815-1: Design Service Life

Telecommunication Space/Component	Design Service Life
Mechanical infrastructure: structural supports, maintenance holes, vaults, raceway, conduit, duct banks, pedestals, racks, and enclosures	50 years
Components and devices: doors, ventilation fans, HVAC, and AC power distribution	See Series 800 & 1000

815.2.7 Environmental and Sustainability Needs (Not Used)

815.3 SYSTEM REQUIREMENTS

815.3.1 General Requirements

815.3.1.1 Design telecommunications spaces to support maintenance activities performed at any time and allow personnel to access the equipment installed in the space.

815.3.1.2 Circulation diagrams must be developed to demonstrate the equipment can be installed, removed, or replaced at any time of the facility lifecycle without implying reworking the civil infrastructure.

815.3.1.3 Use the latest standards and recommendations in telecommunications spaces system. The infrastructure must be designed to meet the equipment requirements and ensure the equipment is properly hosted, powered, ventilated, and with enough space to be maintained.

815.3.1.4 Design telecommunications spaces to service the area taken from Architectural Code Information, Building Code Summary as (Total) Station Building Area.

815.3.1.5 Sound Transit operational needs require designs that meet current and future needs of the systems installed (or to be installed) at the facility. Use proactive thinking and avoid designing the telecommunication spaces just to meet the needs of the current equipment.

815.3.1.6 Cable pathways are an integral part of the telecommunications spaces.

815.3.1.6.1 Design cable pathways to meet the full capacity of the equipment intended to be installed in the telecommunications spaces.

815.3.1.6.2 Cable pathways must meet Set 1006 spare capacity in number of conduits and available filling capacity.

815.3.1.7 Accessibility: As defined in TDMM Latest Edition Chapter #4.

815.3.1.8 Acoustic noise levels: As defined in TDMM Latest Edition Chapter #4.

815.3.1.9 Administration: As defined in TDMM Latest Edition Chapter #4 and Chapter #10.

815.3.1.10 Cable separation: As defined in TDMM Latest Edition Chapter #4.

815.3.1.11 Ceilings: As defined in TDMM Latest Edition Chapter #4.

815.3.1.12 Clearances: As defined in TDMM Latest Edition Chapter #4.

815.3.1.13 Codes, standards, and regulations: Consistent with Set 001 and TDMM Latest Edition, Appendix A.

815.3.1.14 Conduits, trays, slots, sleeves, and ducts: As defined in TDMM Latest Edition Chapter #4.

815.3.1.15 Door dust and static electricity: As defined in TDMM Latest Edition Chapter #4.

815.3.1.16 Fire protection: As defined in Set 601 Fire-Life Safety and TDMM Latest Edition Chapter #7.

815.3.1.17 Flood prevention: As defined in TDMM Latest Edition Chapter #4.

815.3.1.18 Floor loading: As defined in TDMM Latest Edition Chapter #4.

815.3.1.19 Bonding and grounding (earthing): As defined in Set 1005, TDMM Latest Edition Chapter #9, TIA-607-B, NFPA 780 and R56 Recommendation for Type B1 sites.

815.3.1.20 Lighting: As defined in Set 1007 and TDMM Latest Edition Chapter #4.

815.3.1.21 Location: As defined in TDMM Latest Edition Chapter #4.

815.3.1.22 Safe and clean environment: As defined in TDMM Latest Edition Chapter #4.

815.3.1.23 Security: As defined in TDMM Latest Edition Chapter #4, BICSI-002 Section #12 and Series 1200.

815.3.1.24 Sensitive equipment and electromagnetic interference: As defined in TDMM Latest Edition Chapter #4.

815.3.1.25 Size guidelines: As defined in TDMM Latest Edition Chapter #4.

815.3.1.26 Unacceptable materials: As defined in TDMM Latest Edition Chapter #4.

815.3.1.27 Wall and rack, cabinet, or enclosure space for terminations: As defined in TDMM Latest Edition Chapter #4, and BICSI-002 Section #6.

815.3.1.28 Racks, cabinets, or enclosures: As defined in TDMM Latest Edition Chapter #4.

Commentary: Inside telecommunications spaces, Sound Transit only uses four-pole cabinets seismically rated meeting Set 701 Geotechnical. Two-pole cabinets are not acceptable.

815.3.1.29 Wall linings: As defined in TDMM Latest Edition Chapter #4.

815.3.1.30 Cabinet assignment: Sound Transit does not want shared use cabinets. Each cabinet must only host a defined system and should not be shared with any other. Similarly, spare space must be allocated by system, and not shared between systems.

815.3.1.31 Cabinet distribution: Cabinets must be installed following BICSI-002 Section #6 guidelines, making sure that hot and cold aisles are meticulously designed, and room cooling per -Set 1003 and following BICSI-002 Section #10.

Commentary: Sound Transit facilities may have external antennas, so they must be designed as a Type B site per R56

815.3.1.32 Twisted pair wiring: Twisted pair wiring design must use UL-444 and BICSI/NECA 568,

815.3.2 Functional Requirements

815.3.2.1 General Requirements

815.3.2.1.1 Earthquake, disaster, and vibration requirements: Facilities must meet requirements in Set 701 Geotechnical. Equipment installed inside those facilities must be secured to survive an earthquake.

815.3.2.1.2 Electrical power: As defined in Set 1006 Electrical Raceway and TDMM Latest Edition Chapter #10.

Commentary: Provide a minimum design load of 5 kilowatts per communications cabinet. Provide enough spare capacity for such loads in the electrical design and distribution panels. Coordinate with Series 1005 for any additional power load.

815.3.2.1.3 Environmental control: As defined in Set 1003 and ASHRAE TC9.9 Data Center Power Equipment Thermal Guidelines and Best Practices to size the HVAC requirements for telecommunications spaces and meet Set 1003 Mechanical-HVAC.

Commentary: Telecommunications spaces must have all material inside hosted in seismically secured structures and meet requirements in Set 701 Geotechnical. Wall and pole mounting are not acceptable means to install equipment in the Telecommunications Spaces, even if the manufacturer offers it as an installation option.

815.3.2.1.3.1 Telecommunications space size: Telecommunications Spaces must be sized to meet TDMM Table 4.1 based on the area to be serviced defined in 815.3.1.4.

815.3.2.2 Specific Requirements

815.3.2.2.1 Telecommunications Closets

815.3.2.2.1.1 Active equipment: Telecommunications closets are not meant to contain or directly provide any power beyond the auxiliary outlets to temporarily power testing equipment.

Commentary: Installing any equipment that requires external power in a telecommunications closet makes it a Telecommunications Room as defined in 815.1.5.3.

815.3.2.2.1.2 Energy Storage: Telecommunications closets must not house any type of energy storage devices.

815.3.2.2.2 Telecommunications Enclosures

815.3.2.2.2.1 Minimum rating: Telecommunications enclosures must meet NEMA 4X specification, and/or IP66 rated, intended to house non-active equipment.

815.3.2.2.2.2 Materials: Telecommunications enclosures must be built of stainless steel. Composite or synthetic materials like polycarbonate or acrylics are not acceptable.

815.3.2.2.2.3 HVAC requirements: Telecommunications enclosures must not require heating or cooling to allow the wiring installed in it to perform its normal function.

Commentary: Enclosures are not intended to house any active device.

815.3.2.2.2.4 Fire code compliance: Materials housed inside a telecommunications enclosure must meet NFPA 1221 section 9.6 requirements for survivability and have all its components properly secured inside.

Commentary: Parts hanging from the cables in the enclosure are not acceptable. All components must be properly tied and secured inside. Glued components are not acceptable.

815.3.2.2.2.5 Energy storage: Telecommunications enclosures must not house any type of batteries, especially those that require special ventilation to avoid noxious or explosive gas concentration.

815.3.2.2.2.6 Door locking: Telecommunications enclosures must be locked using keyed 2-point locks. The keys must be mastered.

Commentary: Note that if the design uses a Telecommunications Closet or Enclosure to house active equipment, Sound Transit considers it as a Telecommunication Room, and therefore must meet the requirements listed in 815.1.5.4.

815.3.2.2.3 Telecommunications Rooms

815.3.2.2.3.1 Minimum area: A telecommunications room is intended to serve a single floor or small building and must be sized to match the area to be served, as defined in 815.3.1.4.

Commentary: The area to be served must include the platform and the garage parking areas, even if they are not intended to be permanently occupied.

815.3.2.2.3.2 Space distribution: A telecommunications room must have at least 40% of its area dedicated to the facility backbone cable distribution. The designer must provide at least 30% space, power (mains & backup) and HVAC equipped for expansion.

815.3.2.2.3.3 Energy storage: Any energy storage device that produces corrosive or noxious fumes must not be installed in a telecommunications room.

Commentary: Any energy storage device that produces fumes must be stored in a separate room with adequate ventilation as required in the fire code.

815.3.2.2.3.4 Unacceptable locations: As defined in TDMM Chapter #4

Commentary: if it is not possible to avoid having pipes in the Telecommunications Room walls, the designers must provide mitigations to a possible water spill affecting the room.

815.3.2.2.4 Equipment Rooms

815.3.2.2.4.1 Room area: An equipment room must be sized to meet the equipment requirements in it. See Series 1000 for guidance.

815.3.2.2.4.2 Power requirements: An equipment room must have main and backup power, have a properly sized HVAC, grounding and rack space equipped for at least 30% expansion.

815.3.2.2.5 Entrance Facilities

815.3.2.2.5.1 Every facility must be designed with an entrance facility for external services access.

815.3.2.2.5.2 Colocation: Only an equipment room may contain a properly sized entrance facility in it.

815.3.2.2.5.3 Area: An entrance facility must be sized to meet the service provider requirements and provide enough space for maintenance of the services in it as described in TDMM Chapter 3.

815.3.2.2.5.4 Redundancy: Sound Transit entrance facilities must be designed to adhere to the minimum required redundancy when designing an entrance facility in a single room. Refer to Set 301 for details.

815.3.2.2.6 Edge Datacenters

815.3.2.2.6.1 Power density: Edge datacenters must be designed to meet a minimum power density of 60W/ft2, as defined in BICSI-002.

815.3.2.2.6.2 Operational level: Minimum operational level must be 3, as defined in BICSI-002

815.3.2.2.6.3 Downtime impact: Edge datacenters must be designed to meet a downtime Severe impact, as defined in BISCI-002

815.3.2.2.6.4 Availability class: Edge datacenter must be designed for an Availability Class F2 as defined by BICSI-002.

815.3.2.2.6.5 The design of any datacenter space must meet ANSI/TIA-942 and BICSI-002.

815.3.2.2.6.6 Out of a station location: When the room is located outside of a station, like in a maintenance facility, it must be designed as a datacenter sized to support direct fiber optic interconnectivity with other Sound Transit datacenters.

815.3.2.2.6.7 Inter-datacenter fiber optic interconnection: all Sound Transit datacenters must be interconnected with an uninterrupted, direct redundant fiber optic cable with a minimum of 144 strands of single mode fiber, solely dedicated to inter-datacenter interconnection.

815.3.2.2.6.8 Datacenter cabinet distribution: Datacenter rooms must provide:

815.3.2.2.6.8.1 Fiber optic termination cabinets: must be configured to host a minimum of two cabinets dedicated to incoming fiber optic terminations.

815.3.2.2.6.8.2 Core network cabinets: Two cabinets dedicated to core network switches, wired with redundant power circuits to support not less than 15 KW each.

815.3.2.2.6.8.3 General computing cabinets: All other cabinets must be wired with redundant power circuits to support not less than 5 KW each cabinet.

815.3.2.2.6.8.4 Power circuit terminations: Each cabinet must have each circuit terminated in a Managed Power Strip (PDU).

815.3.2.2.6.8.5 All Datacenter AC/DC Power Distribution and HVAC equipment must be installed in dedicated adjacent spaces designed to support the required infrastructure and its expansion. Ancillary equipment must not be installed inside the equipment datacenter area.

815.3.2.2.7 Outside Plant

815.3.2.2.7.1 Outside plant facilities must be designed following WSDOT 2021 Standard Specification M 41-10 (or later), AT&T Outside Plant Engineering Handbook, BICSI Outside Plant Design Reference Manual (OSPDRM), and ATT-TP-76205 Electronic Equipment Enclosure / Cabinet (EEE/C) Standards Issue 5 or later.

815.3.2.2.7.2 Standard components: Only standard components must be used following the guidelines of TIA-758 standard.

815.3.2.2.7.3 Fiber optic type: All fiber optic cables must use single mode fiber optic meeting Series 300 Operational Communications.

815.3.2.2.7.4 Pathways: Any design of fiber optic pathways must meet Series 300 Operational Communications.

815.3.2.2.7.5 Terminations: All fiber strands in any outside plant fiber optic cables must be terminated in fiber optic distribution panels.

Commentary: Designers must use FOA Fiber Optics Civil Works Guide is added as a field installation reference.

815.3.2.2.7.6 Backbone Distribution Systems

815.3.2.2.8 In-facility backbone distribution: in-facility backbone distribution must be designed meeting TDMM Latest Edition Chapter #5 Backbone Distribution Systems.

815.3.2.2.9 Horizontal Distribution Systems

815.3.2.2.9.1 Horizontal wiring design in all Sound Transit facilities must meet Series 300 Operational Communications and TDMM Latest Edition Chapter #6.

815.3.2.2.9.2 Cables and Connecting Hardware

815.3.2.2.9.3 Cable systems design must meet Series 300 Operational Communications and TDMM Latest Edition Chapter #7.

815.3.2.2.9.4 Global Time Synchronization

815.3.2.2.9.5 Each datacenter must be provided with a GPS-disciplined, Grandmaster-capable, IEEE 1588 (v2 or later) compliant clock interconnected via the fiber optic network to similar clocks located at other datacenters to provide a meshed Stratum 1 time base available to all devices in Sound Transit network.

815.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

815.4.1 System Breakdown Structure

815.4.2 System Sites and Locations

815.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 815-2: Interface Between Communication Spaces and Other Disciplines

SET SERIES	SET NAME	SET 815 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	
300	Operational Communications	X
400	Vehicle	
500	Track	X
600	Fire-Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

815.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

815.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

815.7.1 Requirements Management

815.7.2 Interface and Integration Management

815.7.3 Design Management

815.7.4 Manufacturing and Construction Management

815.7.5 Installation Management

815.7.6 Inspection and Testing Management

815.7.7 Training, Pre-Revenue Operations

815.7.8 Certification Management

815.8 APPENDICES (NOT USED)

END SET - 815

820 FACILITY AREA PLANNING

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SET - 820 TABLE OF CONTENTS

TABLES

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SET - 820 FACILITY AREA PLANNING

820.1 INTRODUCTION

820.1.1 Document Scope

820.1.1.1 This set establishes the design criteria for areas surrounding Sound Transit facilities, such as plazas. Elements discussed in this set include the general guidelines for use in the design of bus access, pick-up and drop-off areas, bicycle access, pedestrian access and circulation, and park-and-ride facilities.

820.1.1.2 The urban design surrounding Sound Transit facilities must be a cohesive part of the overall transit system and an integrated element of the neighborhoods and community of which it is a part.

820.1.1.3 The urban design must provide an appropriate solution for the program needs, site conditions, and location, incorporating best practices and creating a sense of place.

820.1.1.4 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 820 owner to determine the technical source for the design criteria.

820.1.2 Regulations, Codes, Standards, and Guidelines (Not Used)

820.1.2.1 International Regulations, Codes, Standards, and Guidelines

820.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

820.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

820.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

820.1.2.5 Other Jurisdictions (Not Used)

820.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

820.1.2.6.1 Station Experience Design Guidelines.

820.1.3 Abbreviations and Acronyms (Not Used)

820.1.4 Definitions and Classifications (Not Used)

820.1.5 References (Not Used)

820.2 STAKEHOLDER NEEDS

820.2.1 Passenger Experience

820.2.1.1 Coordinate requirements with passenger experience as described in the Sound Transit Station Experience Design Guidelines.

820.2.1.2 Provide clear sightlines between facilities.

820.2.1.3 Provide tactile wayfinding path at modal transfers to stations, including paratransit.

820.2.1.4 Expand paratransit criteria to include location and accommodation of paratransit vehicle types.

820.2.2 Operational Needs (Not Used)

820.2.3 Maintenance Needs

820.2.3.1 Provide durable materials at vehicular traffic areas.

820.2.4 Safety Needs

820.2.4.1 Minimize street crossings needed to access stations.

820.2.5 Security Needs (Not Used)

820.2.6 Reliability, Availability and Maintainability Needs (Not Used)

820.2.7 Environmental and Sustainability Needs (Not Used)

820.3 SYSTEM REQUIREMENTS

820.3.1 General Requirements

820.3.1.1 Refer to the Station Experience Design Guidelines for passenger experience expectations, station environment typologies for access, and transit-oriented development guidance.

820.3.2 Pedestrian Circulation

820.3.2.1 The criteria listed below are minimum requirements relevant to pedestrian circulation and must not supplant the logic of a better functional solution. Certain circulation elements can handle a finite number of people conveniently in a given period of time.

820.3.2.2 There are five distinct groups that must be considered in the design of pedestrian circulation: regular passengers, occasional passengers, first-time passengers, passengers with belongings such as bicycles, luggage, or strollers, and passengers with disabilities using mobility devices. The five groups move through the system in different ways:

i. Regular passengers move quickly with a minimal guidance.
ii. Occasional passengers and first-time passengers may move easily with great reliance on signs for guidance.
iii. Passengers with bicycles, luggage, or strollers may need more maneuvering room.
iv. Passengers with disabilities move slowly with guidance required depending on the frequency of use and the degree of the disability.

Commentary: Not all disabilities are visible, and care must be taken to consider passengers with visual or hearing impairments or those with cognitive disabilities.

820.3.2.3 The following general principles must be employed to accommodate these varying demands:

i. Right-hand flows are the norm and therefore desirable.
ii. Pedestrian flow will take the path-of-least-resistance. Stations and station areas must be designed to accommodate anticipated pedestrian movement directly and safely.
iii. Grade changes are to be minimized, refer to Set 904 Grading and applicable facility layout sets in the 800 Series. Grades must conform to slope criteria for individuals with disabilities.
iv. Circulation elements must provide a clear and easily understood path of travel for the passenger.
v. Circulation must be designed to accommodate hesitation or slow passage so that the individual with a disability, the infrequent user, or the waiting passenger can pause adjacent to, but out of, the main pedestrian flow.
vi. Surge and queuing spaces must be provided ahead of every barrier, change in circulation direction or mode, and in front of ticket vending machines.
vii. Obstructions within the main pedestrian flow are prohibited.
viii. Enclosed shelter areas and circulation elements must have sufficient transparency to permit adequate visual surveillance of these spaces and to discourage illicit behavior.
ix. Pedestrian access from bus stops, pick-up and drop-off areas, park-and-ride lots, and neighborhood sidewalks must be direct, easily understood, and allow sightlines for security and wayfinding.
x. Separate bicycle movement and pedestrian flows on plazas, sidewalks, and non-motorized paths.

820.3.3 General Configuration

820.3.3.1 In public areas, eliminate exposed horizontal surfaces that are difficult to access for regular maintenance.

Commentary: Exposed horizontal surfaces in public areas that are difficult to access by Facilities personnel are susceptible to an accumulation of trash and must be avoided. Examples of elimination include access prevention or sloping the surface at a minimum 45-degree angle to promote trash movement.

820.3.4 Site Requirements

820.3.4.1 Travel Modes

820.3.4.1.1 Refer to the Sound Transit Station Experience Design Guidelines for types of station access that describe the modes of travel.

820.3.4.1.2 Pedestrian Access

820.3.4.1.2.1 Pedestrian circulation routes must provide direct, safe, and convenient access to station entrances from off the site, park-and-ride lots and bus loading zones, and from nearby existing and new development. Routes must minimize the distance pedestrians have to travel and must minimize conflict with other forms of travel, such as bicycles, vehicles, buses, or rail. Major pedestrian movements must be separated from bicycle and vehicle circulation.

820.3.4.1.2.2 Ensure the travel distance in pedestrian connections is minimized. Minimize the distance between Link station entry and the off-street bus transfer facility. At least 75 percent of the bus stops within the bus transfer facility must be within 500 feet of a station entry.

820.3.4.1.2.3 Pedestrian safety must be supported through minimizing conflict with other forms of travel. Minimize the number of bus and general traffic lanes a pedestrian must cross between the off-street active bus bays and the station entry. Eliminate or reduce potential pedestrian conflicts occurring with bus turning movements. Reduce pedestrian desire lines between the off-street active bus bays and the station entry that would increase the likelihood of jaywalking.

820.3.4.1.2.4 Provide traffic calming measures such as speed bumps or rumble strips at major pedestrian crossings where vehicle speed is a concern.

820.3.4.1.2.5 Provide clear pedestrian sightlines to station plaza and/or entry from the off-street active bus bays to support ease of transfer between modes. Minimize the need for signage and wayfinding to direct passengers from bus active bays to station entry and vice versa. Provide minimal grade changes or little to no reliance on equipment that would be required to support an ADA compliant path when transferring between buses and the station entry.

820.3.4.1.2.6 The requirements of this section may be prioritized as determined by Sound Transit when station areas include four or more Sound Transit modes (e.g., Sounder, Link, Tacoma Link, Sound Transit Express, and/or Stride BRT), and the station area is in a dense urban environment or where Sound Transit has limited control of neighboring properties. See the Station Experience Design Guidelines for additional requirements.

820.3.4.1.2.7 Driving aisles in park-and-ride areas must be oriented to prioritize pedestrian needs and safety as well as lot capacity. Pedestrian movements within park-and-ride lots will normally occur within the driving aisles. Pedestrian walkways may be necessary to minimize vehicular interference, to reduce the number of points where pedestrians cross aisles, or to shorten irregular routes through successive aisles. Designate crosswalks within the parking areas for major pedestrian circulation routes.

820.3.4.1.2.8 Adhere to the following design guidelines:

i. Avoid steps or abrupt changes in level in walkways. Layout of walkways must provide maximum visibility of and by oncoming rail and vehicular traffic.
ii. Vertical changes of less than three steps (18 inches) must use ramps or sloping walks in lieu of steps. Diminishing steps are not allowed. All steps must end in a full tread and riser.
iii. The width of pedestrian walkways must be as indicated in Table 820-1.
iv. Comply with Chapter 4 of the Station Experience Design Guidelines for right-of-way dimensions.

Table 820-1: Walkway Guidelines

Walkways	Preferred	Minimum
Walkways approaching station entries	12 to15 ft.	8 ft.
Crosswalks over at-grade tracks	15 ft.	10 ft.
Waiting areas at edge of tracks	8 to 10 ft. (depth) by crosswalk width	5 ft. - 6 in. (depth) by crosswalk width
Walkways through bus stop areas	12 ft.	7 ft. – 2 in.
Walkways adjacent to long-term parallel parking	8 ft.	6 ft.
Walkways adjacent to short-term parallel parking	10 ft.	7 ft. – 2 in.
Crosswalks	12 ft.	10 ft.

820.3.4.1.2.9 Provide safe pedestrian pathways to crosswalks in the most direct path possible. Crosswalks must be marked and be clearly visible to motorists. Warning signs or signals must be provided at crossings of light rail tracks and railroad tracks, as well as adjacent roadways in accordance with Set 120 At-Grade Crossing.

820.3.4.1.2.10 Station crosswalk materials must be noticeably different color or texture to clearly indicate crosswalk location.

820.3.4.1.2.11 Pedestrian walkways must be adequately lighted for safety. See Set 1007 Electrical Lighting.

820.3.4.1.2.12 In locations where no other physical barrier, curb, or landscaping is provided between pedestrian circulation and vehicle circulation, detectable warnings complying with ADA section 705 are required.

820.3.4.1.3 Track Crosswalks

820.3.4.1.3.1 Provide track crosswalks at areas where pedestrians cross tracks. Crosswalks must be located on tangent track, if possible, and away from special trackwork areas.

820.3.4.1.3.2 Track crosswalks must be level with the top of rail except for a maximum 2.5-inch gap on the inner edge of each rail to permit passage of wheel flanges.

820.3.4.1.3.3 Track crosswalks must be made of materials sufficiently durable for pedestrian traffic and, if located directly adjacent to a street crossing, for vehicular traffic. Ensure a safe and slip resistant walking surface.

820.3.4.1.3.4 Track crosswalks must comply with the requirements of ADA standards.

820.3.4.1.4 Paratransit Facilities

820.3.4.1.4.1 Provide a minimum of one paratransit stop with an off-street loading area or an on-street loading area out of traffic at stations. Additional paratransit stops may be provided in coordination with projected paratransit use. This location may not be shared with a bus only zone. See Set 830 Parking Facilities Layout for additional information.

Commentary: The paratransit stop with a loading area provides short-term parking for vans to load and unload safely out of traffic.

820.3.4.1.4.2 Locate the paratransit stop a maximum of 60 feet from a station entry.

Commentary: It is preferred the paratransit stop is located within 30 feet of a station entry.

820.3.4.1.4.3 Vehicle, bus, and track crossings between the paratransit stop and the station entry are prohibited.

820.3.4.1.4.4 Provide unobstructed sightline from the paratransit stop to the station entrance.

820.3.4.1.4.5 The paratransit stop must have a continuous accessible path to the ticket vending machines and the platform through this station entry.

820.3.4.1.4.6 Private or public shuttle services may serve stations. Accommodate the variety of physical requirements for these shuttles, typically large vans or small buses, including rear-loading vans. A curb ramp must be within 50 feet of the front or back of a paratransit stop.

Commentary: A nearby curb ramp serving a public crosswalk is an acceptable solution.

820.3.4.1.4.7 Paratransit services must load from the side of the vehicle onto the sidewalk area. Provide space for the lift to operate and land in the sidewalk area with room for a wheelchair to load and unload. Paratransit stop sidewalk area must be level for the length of the vehicle.

820.3.4.1.4.8 A shelter or windscreen and overhead weather protection must be provided adjacent to the paratransit stop to shelter passengers waiting for paratransit service. Include a bench with armrests in a portion of the covered area. Allow space for two wheelchair users.

820.3.4.1.4.9 Provide space for one three-foot bench and space for a wheelchair within the shelter for protection from weather.

820.3.4.1.4.10 Provide unobstructed sightline between paratransit stop and ADA drop-off.

Commentary: This is to reduce potential confusion between pick-up locations and allow operators to see if a passenger is awaiting pick-up nearby.

820.3.4.1.4.11 Provide 8 feet of clear space from face of curb at paratransit stop.

Commentary: This is to provide clearance for the use of a side lift. Bollards at paratransit spaces are also not allowed in this zone.

820.3.4.1.4.12 Design paratransit stops to not require shuttles to back up in order to unload.

Commentary: These vehicles are often not permitted to back up for safety reasons.

820.3.4.1.4.13 Consider potential vehicular intrusion from the paratransit stop into other site areas and protect with bollards.

820.3.4.1.4.14 Paratransit stops are not permitted in bus loops.

820.3.4.1.5 Bicycle Facilities

820.3.4.1.5.1 Provide bicycle storage facilities in compliance with Set 807 Bike Program.

820.3.4.1.6 Bus Service

Commentary: Some stations will include bus service access.

820.3.4.1.6.1 The layout of bus facilities must be coordinated with the transit companies (private and public) that will service these stations and must use Sound Transit criteria. Where other AHJ criteria conflicts with Sound Transit criteria, Sound Transit must seek concurrence with the other AHJs for any modifications to the design criteria. This concurrence may result in cost sharing agreements.

820.3.4.1.6.2 The design of station sites must address the potential for relocating bus zones, rerouting bus lines, and establishing new bus lines, and layover and turnback facilities. Analyze and evaluate on-street bus layover options in public right of way and off-street layover accommodations away from the station before committing to off-street layover on Sound Transit station property. Design teams must coordinate comfort stations or other operator facilities as required.

820.3.4.1.6.3 Bus stops must be placed to minimize passenger travel time (bus and walk time). Street curb bus service is preferred over on-site access for all types of buses and especially for "through" buses to limit property needs and to provide efficient service.

820.3.4.1.6.4 Walk distance must be minimized between the train entry/platform and buses. Where buses must circulate within the site, curb radii, and other turning movement geometry must conform to the bus operators design criteria.

820.3.4.1.6.5 Prioritize the efficiency of pedestrian travel times between transit-to-transit connections over the efficiency of bus operational movements.

820.3.4.1.6.6 To efficiently manage long-term bus operational costs, the maximum travel time for a bus traveling from the station's bus layover area to the active bus bays must be a maximum of three minutes, as measured during the PM peak period.

820.3.4.1.6.7 Curbs within bus circulation routes must not sustain significant damage or displacement from repeat vehicle impacts.

820.3.4.1.6.8 Weather protection in the form of canopies and windscreens must be provided at bus stops adjacent to or within Link station facilities. Canopy coverage must be at least three feet back from the edge of the street curb. Type and size of weather protection must be determined in conjunction with the bus service provider and maintenance agreements. Where other agencies are maintaining the facility, their standards must be met. Where Sound Transit is maintaining the facility, Sound Transit standards for materials must be met.

820.3.4.1.6.9 Schedule and route information must be prominently displayed. Bus information at bus stops must be in accordance with Sound Transit Customer Signage Design Manual.

820.3.4.1.6.10 Bus Loading Area

820.3.4.1.6.10.1 At all Sound Transit facilities with off-street bus loading areas, provide truncated dome detectable pavers at bus boarding edges immediately behind the six-inch concrete curb. Refer to Set 801 Architectural Materials, Elements, And Furnishings for detectable warning edge paver material. The truncated dome surface must extend the full length of public boarding areas and must be 24 inches wide. Truncated dome surface must be continuous between adjacent bus bays.

820.3.4.1.6.10.2 At all Sound Transit facilities with off street bus loading areas, provide a tactile boarding pad adjacent to each bus stop pole, or leading edge of the bus zone, directly behind the truncated dome pavers. Tactile pad to be 6 feet x 6 feet. Pavers with raised ribs oriented parallel to the platform edge must be used. Refer to Set 801 Architectural Materials, Elements, And Furnishings for waiting pad material.

820.3.4.1.7 Passenger Pick-up and Drop-Off and Taxi Area

820.3.4.1.7.1 Size of passenger loading area and quantity of short-term parking must be determined by Sound Transit during station site development. Refer to the curb space demand estimation methodology by the Access, Integration, and Station Area Planning Program for additional requirements.

820.3.4.1.7.2 Provide on-street passenger loading zones in locations as determined by Sound Transit in conjunction with the AHJ.

820.3.4.1.7.3 Locate passenger loading zones or taxi drop-off on the same side of the street as the station and within view of the platform(s) or station entrance.

820.3.4.1.7.4 Pick-up and drop-off zones for commercial vehicles (e.g., taxis, transportation network companies, private or employer transit) locations are preferred on adjacent public streets over off-street on Sound Transit property.

820.3.4.1.7.5 Short-term parking locations must not contribute to traffic congestion around the station.

820.3.4.1.7.6 Where possible, provide convenient pick-up and drop-off vehicle recirculation at short-term parking.

Commentary: This is helpful if short-term parking spaces become filled.

820.3.4.1.7.7 See Set 830 Parking Facilities Layout for specific layout requirements.

820.3.4.1.8 Vehicular Access to Station Sites

820.3.4.1.8.1 The design of entrances for motor vehicles at station sites with bus interface, parking, and pick-up and drop-off facilities must take into consideration both existing and planned adjacent land uses and avoid large unplanted and paved areas that are out of scale with those uses.

820.3.4.1.8.2 Driveway access must be minimized while fulfilling the following requirements:

i. Direct access for service must be from streets designated as arterials and from minor commercial streets.
ii. Direct access from quiet residential streets must be minimized.
iii. Entrance roadways to station sites must be designed to contain sufficient traffic storage capacity to meet expected transit patronage at peak times and to prevent traffic backing up into public streets.
iv. Entrance and exit points for public transit buses must be separated from other vehicular traffic wherever possible to improve the speed, reliability, and safety of bus operations.
v. Conflicts must be avoided between entrance roadways, bicycle access, and pedestrian access points.
vi. Access by motor vehicles into a station site with more than 1,000 parking spaces must be from more than one street. For such large station sites, more than one station site exit to the local street system must be considered to reduce traffic delays.

820.3.4.1.8.3 Access roadways to parking stalls, bus zones, park-and-ride, and pick-up and drop-off facilities must comply with Set 906 Roadways and Non-Motorized Facilities. Refer to Set 601 Fire/Life Safety for fire apparatus access road requirements.

820.3.4.1.8.4 Roadway design must accommodate the loading and turning radii requirements for transit fleet vehicles while considering accommodations for pedestrian safety.

820.3.4.1.8.5 One-way traffic operation on access roadways is preferred.

820.3.4.1.8.6 Provisions for passing a stalled vehicle must be provided.

820.3.4.1.8.7 Separate site access for car and buses must be provided, if possible.

820.3.4.1.9 Micromobility

820.3.4.1.9.1 Sound Transit may consider micromobility accommodations at off-street station areas. Contact Sound Transit for pre-approval.

820.3.4.1.10 Service and Transit Security Vehicle Parking

820.3.4.1.10.1 Provide service vehicle and transit security parking at stations.

820.3.4.1.10.2 Provide space for two service vehicles at multi-level stations such as elevated, tunnel, or retained cut stations. Designated street parking may be used to meet this requirement. Provide at least one of the service vehicle parking spaces within 100 feet of station, whenever possible.

820.3.4.1.10.3 Provide space for two security vehicles at multi-level stations if no passenger drop-off areas are provided. Where stations have passenger drop off areas for at least two vehicles, or short-term parking, no additional security vehicle parking is needed, except at terminus stations. Designated street parking may be used to meet this requirement.

820.3.4.1.10.4 Where multi-level stations do not provide parking or passenger drop-off areas, service and security parking can use pedestrian areas for temporary parking if the area does not inhibit pedestrian and bicycle circulation flow. These parking areas can be located on pedestrian plazas out of the way of general pedestrian flow and shared with emergency vehicle response locations. Coordinate with drainage for areas of pollution generating pavement.

820.3.4.1.10.5 Provide space for three security vehicles and three service vehicles at terminus stations.

820.3.4.1.10.6 Determine parking requirements for special service vehicles based on equipment location and operational needs. TPSS, signals, and communications equipment will require adjacent parking access. When these elements are located at the stations, coordinate vehicle access and parking requirements. Refer to Set 220 Traction Power for additional requirements at TPSS locations.

820.3.4.1.11 Food Service Vending Trucks

820.3.4.1.11.1 At Sound Transit direction, designate parking areas for food service trucks that comply with the following:

i. Areas must be visible and open to passengers.
ii. Must be at least fifty feet away from the guideway.
iii. Must not be directly beneath the guideway.
iv. Must not allow entrainment of cooking smoke to facilities.
v. Food service trucks and related signage, advertising, and adjacent surge spaces must not obstruct required site and station circulation, maintenance paths, or facility emergency exits.

820.3.4.1.11.2 Provide utility services as required by code at food service truck locations.

820.3.4.1.11.3 Utilities used for non-transit activities by vendors connected to Sound Transit's utilities must be separately metered for billing purposes.

820.3.4.1.11.4 Food service truck locations must have access to separate power connections.

820.3.4.1.11.5 Water must be available nearby via hose bibb in a universal key lock box.

820.3.4.1.12 Vehicle Barriers

820.3.4.1.12.1 Station entrances must be designed with physical barriers to deter vehicular intrusion. Comply with Set 801 Architectural Materials, Elements, and Furnishings for requirements.

820.3.4.1.12.2 Vehicle barriers at bus loops must be set back from the curb such that buses will not hit the barrier while maneuvering.

820.3.4.1.13 Seating

820.3.4.1.13.1 On-site bus stops must be provided with a minimum of three lineal feet of seating per bus stall. Seating and shelter for bus stops on public streets will typically be provided by the local transit company(s).

820.3.4.1.13.2 Comply with additional requirements as described in Set 801 Architectural Materials, Elements, And Furnishings.

820.3.4.1.14 Trash and Recycling Receptacles

820.3.4.1.14.1 Provide one trash receptacle and one recycle near each other at plazas and bus/shuttle areas.

820.3.4.1.14.2 Receptacles for the general site, park and ride, or short-term parking and drop-off areas must be determined on a site-specific basis.

820.3.4.1.14.3 Standard trash and recycling receptacles must be used. Refer to Set 801 Architectural Materials, Elements, And Furnishings.

820.3.4.1.14.4 Comply with Set 801 Architectural Materials, Elements, And Furnishings for additional receptacle requirements.

820.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

820.4.1 System Breakdown Structure

820.4.1.1 Facility area planning must include the following elements:

i. Pedestrian circulation
ii. Bus loading area
  a. Boarding edge
  b. Tactile waiting pad
  c. Geometry
  d. Material
iii. Travel modes
iv. Pedestrian access
v. Track crosswalk
  a. Warning sign/signal
  b. Material
  c. Lighting
vi. Paratransit facility
  a. Quantity
  b. Loading
  c. Location
  d. Tactile path
  e. Curb ramp
  f. Shelter
  g. Seating
vii. Bicycle facility
  a. Access
  b. Storage
viii. Bus stop/service
  a. Layout
  b. Travel time
  c. Weather protection
  d. Schedule and route information
  e. Shelter
  f. Passenger information
  g. Seating
ix. Passenger pick-up and drop-off and tax area
  a. Location
  b. Size
  c. Quantity
  d. Traffic circulation
x. Right-of-way
  a. Vehicle access
  b. Entrance roadway
  c. Entry/exit point for buses
  d. Multi-modal interface
  e. Access to large station sites
  f. Access roadway
  g. Traffic flow

xi. Service and transit security vehicle parking
  a. Quantity
  b. Location
xii. Food service vending trucks
  a. Location
  b. Infrastructure
  c. Space
  d. Sub-metering
xiii. Vehicle barriers
xiv. Seating
  a. Quantity
  b. Location
xv. Trash and recycling receptacles
  a. Location

820.4.2 System Sites and Locations

820.4.2.1 Facility area planning is applied to:
i. Park-and-ride
ii. Walkway
iii. Crosswalk
iv. Paratransit facility
v. Off- street bus stop and loading area
vi. Passenger loading zones and taxi area
vii. Right-of-way
viii. Vehicle parking
  a. Service
  b. Transit security
ix. At-grade
  a. Track crosswalk
x. Vertical transportation
  a. Ramp
  b. Sloped walk

820.5 SYSTEM INTERFACE REQUIREMENTS

Table 820-2 lists requirement sets that are typically coordinated, and may have dependencies, with this set.

Table 820-2: Interface Between Architecture and Other Disciplines

SET SERIES	SERIES NAME	SET 820 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	
300	Operational Communications	
400	Vehicle	
500	Track	
600	Fire/Life Safety	X
700	Structures	
800	Architecture	X
900	Civil	X
1000	Mechanical / Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

820.5.1 Civil

820.5.1.1 Coordinate grading requirements.

820.5.1.2 Coordinate at-grade track crosswalk requirements.

820.5.1.3 Coordinate roadway and driveway requirements.

820.5.1.4 Coordinate drainage and utility requirements.

820.5.1.5 Coordinate egressing requirements.

820.5.2 Mechanical / Electrical and Building Systems

820.5.2.1 Coordinate walkway lighting requirements.

820.5.2.2 Coordinate electrical and plumbing requirements for food vending trucks.

820.5.3 Communications

820.5.3.1 Coordinate real time information requirements.

820.5.3.2 Coordinate CCTV requirements.

820.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

820.7 ENGINEERING MANAGEMENT REQUIREMENTS

820.7.1 Interface and Integration Management

820.7.1.1 The design must consider and account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructable documentation and functional designs.

820.7.2 Design Management

820.7.3 Manufacturing and Construction Management

820.7.4 Installation Management

820.7.5 Inspection and Testing Management

820.7.5.1 The design must adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

820.7.6 Training, Pre-Revenue Operations

820.7.7 Certification Management

820.8 APPENDICES (NOT USED)

END SET - 820

821 STATION LAYOUT - COMMUTER RAIL

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SET - 821 TABLE OF CONTENTS

TABLES

FIGURES

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SET - 821 STATION LAYOUT - COMMUTER RAIL

821.1 INTRODUCTION

821.1.1 Document Scope

821.1.1.1 This set covers the Sounder station platform layout and its architectural elements, including the platform design, amenities, and pedestrian crossings. The standards and requirements for station elements provides consistency and ensures quality design for all Sounder stations. Refer to Set 822 Station Layout – Light Rail for Link station requirements.

821.1.1.2 Each station's design must be a cohesive part of the overall transit system, as well as integrate elements of the unique neighborhoods and community of which it is a part. Within this framework, the use of standardized elements for stations, the station design concept, and the architectural materials, create a common design language, which can then be adapted to a specific station site to best serve the passenger experience and achieve design excellence. This set provides requirements for new stations and improvements at existing stations as Sounder projects anticipate future ridership needs.

821.1.1.3 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 821 owner to determine the technical source for the design criteria.

821.1.1.4 Regulations, Codes, Standards, and Guidelines

821.1.1.5 International Regulations, Codes, Standards, and Guidelines

821.1.1.5.1 International Building Code (IBC) with local amendments.

821.1.1.5.2 International Fire Code (IFC) with local amendments.

821.1.1.6 Federal and National Regulations, Codes, Standards, and Guidelines

821.1.1.6.1 ADA Standards for Transportation Facilities (DOT) (ADA Standards) Washington State Accessibility Standards.

821.1.1.6.2 American Association of State Highway and Transportation Officials (AASHTO). Policy on Geometric Design of Highways and Streets.

821.1.1.6.3 American National Standards Institute, Inc. (ANSI) A117.1 Accessible and Usable Buildings and Facilities.

821.1.1.6.4 Crime Prevention Through Environmental Design (CPTED).

821.1.1.6.5 National Fire Protection Association (NFPA) Standard for Fixed Guideway Transit and Passenger Rail Systems (NFPA 130).

821.1.1.6.6 Occupational Safety and Health Administration (OSHA).

821.1.1.7 State and Local Regulations, Codes, Standards, and Guidelines

821.1.1.7.1 Washington Administrative Code (WAC).

821.1.1.7.2 Washington State Department of Safety and Health (DOSH).

821.1.1.8 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

821.1.1.9 Other Jurisdictions (Not Used)

821.1.1.10 Sound Transit Regulations, Codes, Standards, and Guidelines

821.1.1.10.1 Sound Transit Customer Signage Design Manual.

821.1.1.10.2 Sound Transit Equipment and Facilities Numbering Standard.

821.1.2 Abbreviations and Acronyms

821.1.2.1 AHJ–authority having jurisdiction

821.1.2.2 APTA–American Public Transportation Association

821.1.2.3 CES–customer emergency station

821.1.2.4 CPTED–Crime Prevention Through Environmental Design

821.1.2.5 DWS–detectable warning surface

821.1.2.6 NFPA–National Fire Protection Association

821.1.2.7 PET– passenger emergency telephone

821.1.2.8 PTZ–pan-tilt-zoom

821.1.2.9 SCR–Sounder commuter rail

821.1.2.10 TVM–ticket vending machine

821.1.3 Definitions and Classifications (Not Used)

821.1.4 References (Not Used)

821.2 STAKEHOLDER NEEDS

821.2.1 Passenger Experience

821.2.1.1 Refer to the Station Experience Design Guidelines for passenger experience expectations.

821.2.2 Operational Needs (Not Used)

821.2.3 Maintenance Needs

821.2.3.1 Refer to Section 821.3.24 Maintenance Access for maintenance requirements.

821.2.4 Safety Needs

821.2.4.1 Refer to Section 821.3.2 AHJ Criteria for the requirements of the AHJ.

821.2.5 Security Needs (Not Used)

821.2.6 Reliability, Availability and Maintainability Needs (Not Used)

821.2.7 Environmental and Sustainability Needs (Not Used)

821.3 SYSTEM REQUIREMENTS

821.3.1 Station Concept and Planning

821.3.1.1 The design of the Sounder station must adhere to all applicable government codes, regulations, and standards at time of design, except as modified by agreement or other documentation (e.g., development agreements). The track corridor does not require local AHJ permits.

821.3.1.2 Stations must be designed to facilitate the movement of passengers in an efficient, accessible, safe, and secure manner, which includes creating the most direct route from one point to another, keeping pathways unobstructed, and maintaining visibility and sightlines.

821.3.1.3 Station design must incorporate CPTED principles appropriate to a transit station.

821.3.2 AHJ Criteria

821.3.2.1 Identify the AHJ at every level of governance at each station site and locate jurisdictional boundaries relevant to the station design and development.

821.3.2.2 Apply the urban design guidelines and policies of each AHJ, including the planning framework, zoning regulations, and supporting codes.

821.3.2.3 Review adopted municipal codes, AHJ master plans, and relevant studies.

821.3.2.4 Where there are conflicts with requirements, whether reference or by the AHJ, the more stringent requirements govern.

821.3.2.5 Where other AHJ criteria conflicts with Sound Transit criteria, Sound Transit must seek concurrence with the other AHJs for any modifications to the design criteria. This concurrence may result in cost sharing agreements.

821.3.2.6 The designer of record must update their code analysis at every milestone.

Commentary: AHJ's often update their codes. It is important the architect of record/engineer of record verifies throughout all design phases and milestones that there have not been code revisions or new codes introduced.

821.3.3 Code Considerations

821.3.3.1 For architectural and structural material code requirements see Set 801 Architectural Materials, Elements, and Furnishings, Set 720 Building Structures, and Set 601 Fire/Life Safety.

821.3.3.2 The station design team must work with each AHJ to determine the appropriate codes that apply to the Sounder station area, which includes the platforms, any adjacent plazas, Sound Transit surface parking, and circulation elements on Sound Transit property.

821.3.3.3 The IBC applies to all areas of the station that are not within the right-of-way. When the platform and station elements are within the BNSF or SCR right-of-way, then the owner of the right-of-way dictates the applicable codes.

Commentary: Right-of-way occupies a significant portion of a Sounder station's square footage. SCR and BNSF Railway Company (BNSF) interstate freight commerce share right-of-way and BNSF owns the majority of the right-of-way where Sounder trains are operated within. Commuter rail right-of-way extends approximately 10 feet perpendicularly to the centerline of each track. At SCR stations, this right-of-way passes through the station and constitutes a significant portion of the station square footage.

821.3.3.4 Sounder stations are not subject to National Fire Protection (NFPA) 130 regulation. However, Sound Transit requires NFPA 130 compliance in specific applications, including:

i. Means of Egress Amendments – Washington State IBC Chapter 10 and NFPA 130.
ii. Means of Egress [5.3] – NFPA 130. See Set 601 Fire–Life Safety for more information.

821.3.4 Exiting Requirements

821.3.4.1 The minimum exit provisions must meet the IBC and NFPA 130. Confirm requirements with local AHJ requirements. See Set 601 Fire–Life Safety for additional requirements.

821.3.4.2 When applying NFPA 130 for platform egress, see the vehicle technical specifications for the full load of the consist to calculate for exiting.

821.3.4.3 For platform expansion projects, the exiting capacity for the station must be designed to account for the changes in consist size. Refer to the vehicle technical specifications to obtain the full load.

Commentary: As of 2021, Sounder South consists include one locomotive and seven passenger cars with plans to provide ten-car consists to accommodate projected future ridership.

821.3.4.4 Current Sounder peak headways are 20 minutes but could be compressed to 15 minutes in the future to allow for more trains and projected future ridership. Confirm with Sound Transit Operations before completing analysis.

821.3.5 Facility Naming and Numbering Convention

821.3.5.1 All facility naming and numbering must follow the current edition of the Sound Transit Equipment and Facilities Numbering Standard.

821.3.6 Fire Department Access Routes

821.3.6.1 Coordinate and incorporate fire department requirements into the station layout, such as fire fighter access, location of fire lanes, fire hose reach, locations of standpipes and fire hydrants, fire separation walls, and code requirements. See Set 601 Fire/Life Safety for specific requirements.

821.3.7 Construction Types

821.3.7.1 Stations must be of non-combustible construction (Type I or II) as defined by the IBC, Chapter 6. Combustible materials per IBC 603 are allowed.

821.3.7.2 Station Configuration

821.3.7.3 The station layout must minimize the number of decisions a passenger makes at any one point and is organized in a clear, logical, and sequential manner that reinforces and assists the smooth and accessible flow of passengers.

Commentary: Station layout concepts can be tested with passenger experience workshops to determine if decision points, accessibility, passenger movements, sight line obstructions and other requirements are being met.

821.3.7.4 Station platforms can either be of center or side platform type depending on station functional requirements, site constraints, or traffic conditions; however, BNSF discourages center platforms.

821.3.7.5 The station platform layout must be efficient and fit within the constraints of the site.

821.3.7.6 The station layout must avoid "mixing zones" between pedestrians and bicycle paths, to prevent collisions along paths of travel.

821.3.7.7 The station layout must utilize architectural elements to guide passengers and not rely on signage.

821.3.7.8 Freestanding columns within 10 feet of a platform edge must be located so as not to coincide with the location of vehicle doors during station stops to minimize congestion. Columns beyond 10 feet have no restrictions in their placement.

821.3.7.9 Non-public spaces must be arranged and sized such that equipment is sensibly located, coordinated, easily operable, and accessible providing a clear path, so equipment can be maintained and replaced. See Section 821.3.55 Ancillary Spaces for specific requirements.

821.3.7.10 Obstructions of passengers and CCTV camera sight lines must be minimized. See Set 1202 CCTV - TIDS for specific requirements.

821.3.8 Views and System Identity

821.3.8.1 Sounder stations must be recognizable through Sound Transit branding per Sound Transit communications guidelines.

821.3.8.2 Sounder stations must incorporate Sound Transit signage guidelines, see Sound Transit Customer Signage Design Manual and Set 806 Signage.

821.3.9 Wayfinding and Decision Points (Orientation)

821.3.9.1 Passengers must have a simple, seamless, and intuitive way to navigate the station.

821.3.9.2 Critical decision points must be identified to ensure passengers have points of reference, such as other built elements or wayfinding markers, to orient themselves within the station without relying on maps.

821.3.9.3 The station layout must provide cues for wayfinding to exits with views from one decision point to another.

821.3.9.4 The designer must provide inflow/outflow diagrams highlighting decision points starting at conceptual design.

821.3.9.5 Decision points must have a minimum of 10 feet from one point to the other (not overlap), so they are easy to identify and navigate.

821.3.9.6 Decision points must be clear of obstructions by fixed platform elements (e.g., furniture, plantings, advertising, retail kiosks).

821.3.9.7 For guidance placing signage at key decision points see the Sound Transit Customer Signage Design Manual.

821.3.9.8 Signage used to support wayfinding, must be legible and follow the Sound Transit Customer Signage Design Manual.

821.3.9.9 Provide fencing to support wayfinding and control access to keep passengers safe. See Fencing for requirements.

821.3.10 Sight Lines

821.3.10.1 Sight lines must be unobstructed from one decision point to the next and comply with security and CPTED principles.

821.3.10.2 Sight lines must be maintained by minimizing obstructed views of static and VMS signage. See Set 1202 CCTV - TIDS and the Sound Transit Customer Signage Design Manual for additional requirements.

821.3.10.3 Provide clear sight lines to station plaza and/or entry from bus active bays to support ease of transfer between modes.

821.3.11 Transparency

821.3.11.1 Transparency must be provided between the street and the station to aid in wayfinding.

821.3.11.2 Enclosed shelter areas and circulation elements must have sufficient transparency to permit adequate visual surveillance of these spaces and to discourage vandalism.

821.3.11.3 See Set 805 Vertical Transportation for elevator transparency requirements.

821.3.11.4 Pedestrian bridges must be transparent to permit visual surveillance and support security. If not fully enclosed with glazing, metal mesh must be used to prevent people from throwing objects onto BNSF tracks or elsewhere.

821.3.11.5 Glazing must be accessible and designed for ease of maintenance. Glazing must be rectilinear for ease of cleaning. See Set 801 Architectural Materials, Elements, And Furnishings for acceptable glazing sizes and material requirements.

821.3.12 Bus Loading and Layover Areas

821.3.12.1 Bus loading areas must be determined in coordination with the appropriate transit agency having jurisdiction. See Set 906 Roadway and Non-Motorized Facilities for additional requirements.

821.3.12.2 Provide curb cuts and ramps from bus loops for the most direct and safest access to the platform from the bus drop off area.

Commentary: The goal of this requirement is to shorten the distance travelled and improve accessibility. It came from the Sound Transit Alternate ADA Elevator Solutions from April 2021 and was accepted by Sound Transit Accessibility Services.

821.3.12.3 Bus drop-off areas must be placed, so they're visible from the station and identifiable with elements, such as a bus shelter and signage following Sound Transit Customer Signage Design Manual and requirements by code.

821.3.12.4 At off-street bus loading areas, provide a gray DWS of truncated dome pavers at bus boarding edges immediately behind the 6-inch concrete curb. The DWS must extend the full length of public boarding areas and be 24-inches wide. The DWS must be continuous between adjacent bus bays. See Set 801 Architectural Materials, Elements, And Furnishings for DWS material descriptions and details.

Commentary: The 24-inch width of the DWS complies with Chapter 7 Section 705 of the ADA Standards for Transportation Facilities for detectable warnings where they are provided. This requirement is an addition to the 2021 requirements that improves safety and access at bus bays and is accepted by Sound Transit Accessibility Services.

821.3.12.5 Provide a tactile boarding pad adjacent to each bus stop pole, or leading edge of the bus zone, directly behind the DWS of truncated dome pavers. Tactile pad must be 6 feet by 6 feet. Pavers with raised ribs oriented parallel to the platform edge must be used. See Set 801 Architectural Materials, Elements, And Furnishings for DWS materials.

821.3.12.6 Coordinate bus charging at layover areas where required.

821.3.12.7 Detectable warning strips must be placed to indicate locations of ramps. Visual cues that reinforce the accessible path of travel, such as crosswalk paint, must be maintained to preserve high visibility.

821.3.12.8 Where a boarding edge area is at-grade with traffic (i.e., at bus loops) and abuts a pedestrian street crossing, add an additional visual cue at the crosswalk portion of the curb edge to guide passengers to the appropriate crossing location and discourage jaywalking, such as a deeper detectable warning strip, landscaping, or varying the color at the crossing portion of the curb.

Commentary: Accessible paths of travel can either be defined by using the tactile wayfinding strip or where feasible, landscaping can be used. For instance, if the paved pathway has a grass border, then the border can be used for wayfinding.

821.3.12.9 Provide a DWS of truncated detectible dome pavers at all curb ramps and when the curb is flush with the street.

821.3.13 Architectural Design: Existing Stations

821.3.13.1 The designs of the existing stations are typically site-specific with each station having a unique character reflecting the surrounding community. As platform extensions occur and stations areas expand, the design must integrate with the existing architectural language at each unique station to complement the character while also providing a more streamlined modern interpretation. See the Section 821.3.26 Station Architectural Elements for specific requirements.

Commentary: Stations built prior to 2021 are all unique in style. Sound Transit's preference is that stations designed and built after the year 2021 provide consistency across multiple stations with a similar design language.

821.3.14 Architectural Design: Future Stations

821.3.14.1 Overall architecture design at future stations must reflect a universal approach that is straightforward, timeless, and expresses Pacific Northwest modernism. The design must avoid historic references, such as ornate details and hip roof forms. The functionality of the stations must be practical and consistent.

Commentary: Below are examples of Sounder station shelters at Everett and Puyallup. Everett station demonstrates a simplified and functional modern design approach while Puyallup utilizes traditional design elements. For future stations, Sound Transit prefers a streamlined modern approach as demonstrated at Everett and described in the requirements above.

Figure 821-1: Everett and Puyallup Sounder Station Shelters

821.3.14.2 Station public areas must reflect quality design and construction with efficient layouts, materials that elevate spaces with texture and color, landscaping to create visual interest, connections to the station platform both physically and visually, and seamless architectural details where materials meet.

821.3.14.3 Forms must repeat along the length of the platform creating consistency and rhythm while complementing the surrounding area, the train, and other station infrastructure.

821.3.14.4 The station design must prioritize lower operating costs with an efficient well-integrated layout that supports maintenance as a function.

821.3.14.5 Architecture must avoid diagonals unless functionally necessary to support passenger flow.

821.3.15 Community Integration

821.3.15.1 Coordinate and develop the station design with the surrounding community, adjacent property owners, and other public agencies.

821.3.15.2 Station design must connect to the neighborhood context and incorporate visual guidance informed from Sound Transit community design workshops.

821.3.16 General Configuration

821.3.16.1 Eliminate alcoves in public areas.

Commentary: Alcoves create partially or fully concealed areas that cause safety, security, and maintenance issues and must be avoided.

821.3.16.2 In public areas, eliminate exposed horizontal surfaces that are difficult to access for regular maintenance.

Commentary: Exposed horizontal surfaces in public areas that are difficult to access by Facilities personnel are susceptible to an accumulation of trash and must be avoided. Examples of elimination include access prevention or sloping the surface at a minimum 45-degree angle to promote trash movement.

821.3.17 Materials and Details

821.3.17.1 The station design must use durable materials appropriate for their location and high-traffic public outdoor spaces. See Set 801 Architectural Materials, Elements, and Furnishings for specific requirements.

821.3.17.2 Architectural details must be well integrated, functional, and elevate the station design and minimize maintenance.

821.3.17.3 Include materials with sound absorbing properties and details to reduce unwanted acoustic reflection.

821.3.18 Color and Texture

821.3.18.1 Color must be integrated and complimentary to the station material palette and combine with materials, textures, lighting, and artwork for a distinctive feel and aesthetic for each station.

821.3.18.2 Use accent walls and art to draw eyes to key decision points to support wayfinding and to enhance the passenger experience.

821.3.18.3 Station colors must compliment Sound Transit system-wide identity colors and brand. See Sound Transit brand guidelines https://www.soundtransit.org/sites/default/files/documents/web-st-brand-guidelines.pdf for information regarding system-wide identity colors. Refer to Set 801 Architectural Materials, Elements, and Furnishings for acceptable field-applied metal paint colors.

821.3.18.4 For specific materials with color requirements see Set 801 Architectural Materials, Elements, And Furnishings.

821.3.18.5 Provide color contrast between surfaces to assist people who are visually impaired.

821.3.18.6 Utilize light colors to improve lighting efficiency.

821.3.18.7 Use colors that enhance a sense of safety and security.

821.3.19 Standardized Structural Grid

821.3.19.1 Use of a basic grid of 4 feet accommodates standardized glazing. Spacing of 16 feet will accommodate the standard platform edge light for Sounder stations. See Set 801 Architectural Materials, Elements, and Furnishings.

821.3.20 Accessibility and Tactile Wayfinding

821.3.20.1 Implement a universal design approach and ensure the station area design is barrier free.

821.3.20.2 Redundant accessible paths must be provided at every platform where there is a pedestrian bridge with either two elevators serving each platform, a ramp and an elevator, or an elevator and another alternative route. The alternative route must be less than 600 feet travel distance from one side of the pedestrian bridge to the other side of the platforms closest point of entry/exit.

Commentary: The goal of providing redundant accessible paths is to provide an equitable experience to all passengers in the event an elevator is out of service and to limit inconvenience. If a ramp or another route is chosen over an elevator, they must provide a similar experience, such as keeping the travel time comparable to someone using stairs and providing weather protection, lighting, and security.

821.3.20.3 The designer must use the accessibility design review checklist to evaluate the project for accessibility and ensure compliance with the ADA and related standards. The checklist must be consulted and checked throughout the design process to avoid major revisions during project close out.

Commentary: The accessibility design review checklist process is described in EP-03 and requires submittals at 60 percent and 90 percent design milestones for Sound Transit review. Final site verification to be conducted by a site representative and sent to the FTA as a record.

821.3.20.4 Refer to the Sound Transit Customer Signage Design Manual and Set 806 Signage for criteria regarding accessibility signage. Signage must be coordinated with station elements and architecture.

821.3.20.5 Tactile wayfinding provisions must be provided to assist people with disabilities, who are blind, or have vision impairments. See Set 801 Architectural Materials, Elements, and Furnishings.

821.3.20.6 Tactile wayfinding provisions must be provided along all major recommended transit pathways throughout the entire station area on Sound Transit property, including:

i. Multi-modal connections at Sounder stations such as to Link, bus loading, transit centers, parking garages, paratransit, or car-share waiting areas.
ii. Along the platform
iii. Accessible boarding waiting areas and mini-high platforms.
iv. Information areas.
v. Ticket vending machines and card readers.
vi. Pedestrian bridges and elevators.
vii. Shelters.
viii. Thresholds of vertical circulation elements.

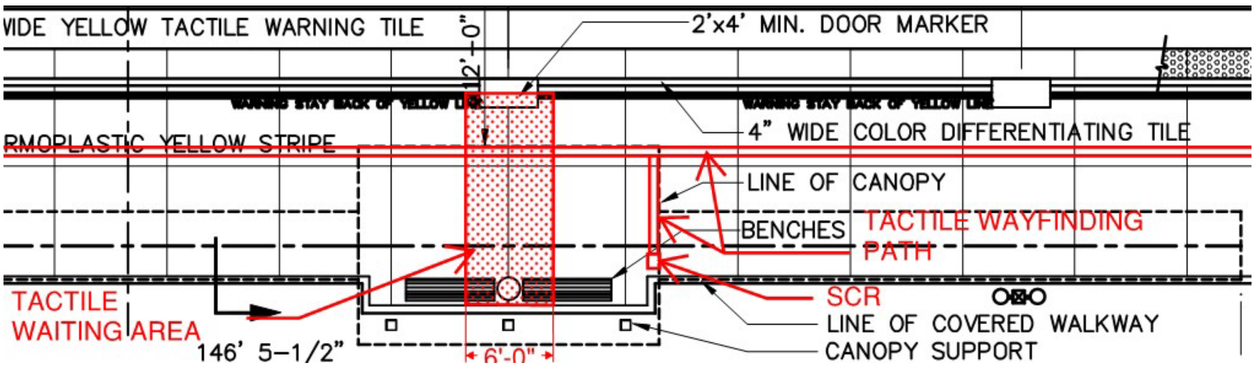
Commentary: This is a new requirement in 2021 identified by Sound Transit Accessibility Services, addressing the need for a more extensive network of tactile wayfinding provisions. This need came out of passenger feedback at South Tacoma Station and is also being addressed with project improvements, as well as requirements for new stations and station improvements.

821.3.20.7 . From the perpendicular start paver, the path must extend to the fare vending/information areas and TVM and onto the platform or to the thresholds of vertical circulation areas. See Set 801 Architectural Materials, Elements, and Furnishings.

821.3.20.8 The tactile path must be located 4 feet back from the platform edge detectable warning surface. Where the tactile path intersects with the center of the mini-high, it can continue on the other side. See Figure 821-2 below.

Commentary: Sounder platforms are a minimum of 16 feet wide and mini-high platforms are 5 feet 6 inches wide. The location of the tactile path is set off the non-trackside edge of the platform to provide as much space as possible when passing a mini-high accessible platform. While being able to provide 4 feet on both sides of the tactile path is ideal, it is only necessary to have access from one side.

Figure 821-2: Tactile Wayfinding Path at Mini-high Platform



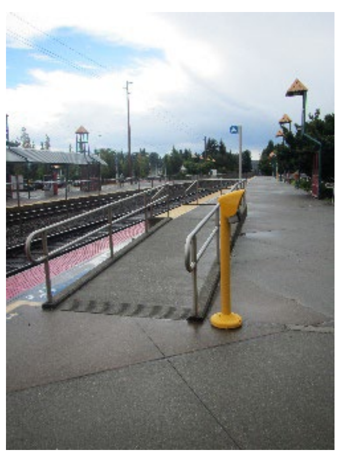
821.3.20.8.1 The design of the tactile path must avoid turns and provide the most direct path.

821.3.20.8.2 The tactile path of "corduroy" (three-striped pattern) pavers must be oriented parallel to the platform edge. See Set 801 Architectural Materials, Elements, and Furnishings.

821.3.20.9 A platform edge DWS is required to meet ADA standards. Provide a 24-inch wide strip of tactile warning tiles, located along the track-side edge of the platform for the full length of the public use area. See Set 801 Architectural Materials, Elements, And Furnishings.

821.3.20.10 A DWS must be located at the base and top of the mini-high ramp. See Figure 821-3 as an example and the Sounder standard drawings for more detail.

Figure 821-3: Typical Sounder Mini-high Platform, Sumner Station



821.3.20.11 Tactile waiting pads must be provided in front of the elevators. Align the pad with the doors at 3 feet wide by 2 feet deep minimum. See Set 801 Architectural Materials, Elements, and Furnishings for paver material.

821.3.20.12 DWS must visually contrast with adjacent surfaces, either light-on-dark or dark-on-light.

821.3.20.13 Wherever there are accessible stalls at surface parking lots, a marked crosswalk and curb cut must be provided adjacent.

821.3.20.14 Curb cuts required at vehicle drop off areas must comply with ICC-A117.1 Section 406.

821.3.20.15 At crossings, provide contrasting paint at curbs to provide more visibility. Comply with Manual on Uniform Traffic Control Devices.

Commentary: This requirement came from the Sound Transit Alternate ADA Elevator Solutions from April 2021 and was accepted by Sound Transit Accessibility Services.

821.3.20.16 Avoid placing vertical posts for guardrails going up ramps as they cause obstructions for non-visual wayfinding.

821.3.20.17 Provide tactile warning strips at crosswalks.

821.3.21 Tactile Train Waiting Area

821.3.21.1 A tactile train waiting area must be located at the door closest to the mini-high platform.

Figure 821-4: Example from Caltrain Station Tactile Train Waiting Area Adjacent to Mini-high Platform

821.3.21.2 The waiting area must be 6 feet wide and extend the full depth of the platform, except where the platform edge detectable warning tile and the tactile wayfinding path are located. See Figure 821-2.

821.3.21.3 The designated waiting area must be adjacent to a canopy to provide weather protection for waiting passengers. At stations where TVMs and SCRs are located on the platform, the waiting area must be located at the same canopy. See Sounder standard drawings.

Commentary: The tactile train waiting area location must provide the most convenience for waiting passengers, including weather protection and proximity to TVMs and SCRs when located on the platform. This is a new requirement as of 2021 and is intended to indicate a waiting area close to a train door and provide weather protection while passengers wait.

821.3.21.4 For the tactile train waiting area paver requirements see Set 801 Architectural Materials, Elements, and Furnishings.

821.3.22 Tactile Bus Waiting Area

821.3.22.1 Provide a 2-foot-wide detectable warning strip at bus waiting areas.

821.3.22.2 At bus stops, indicate the location of the front door of the bus with 6 feet by 6 feet of corduroy pavers.

821.3.23 Surge Spaces

821.3.23.1 Platforms must be designed to accommodate all surge expectations. Allow for 7 square feet per occupant when determining platform size and overflow spaces, such as plazas. Request the current and twenty-year future ridership demand from Sound Transit Planning to determine number of expected passengers.

Commentary: The intent of this requirement is to ensure there is space enough for passengers waiting for and exiting the train during peak periods to avoid overcrowding and create safe access.

821.3.23.2 Provide surge and queuing spaces ahead of every barrier, point of change in circulation direction or mode, and in front of TVMs.

821.3.23.3 Stair and elevator surge zones must be free of obstructions.

821.3.23.3.1 Provide an elevator surge zone of 10 feet by 10 feet area in front of the elevator door.

821.3.23.3.2 Provide a stair surge zone of 15 feet long (measured from end of handrail) and, where conditions permit, 5 feet wider in each direction that the stair's width. Floor materials in surge zones must be highly slip- and wear-resistant. See Set 801 Architectural Materials, Elements, and Furnishings.

821.3.24 Maintenance Access

821.3.24.1 Access to all station elements and equipment must be safe for maintenance workers and inspectors.

821.3.24.2 Provide adequate access for equipment maintenance envelopes and replacement paths. Clearances must be demonstrated early in the design process. Refer to Project Implementation and Integration Plan for equipment clearance diagram deliverables.

821.3.24.3 The station design must minimize safety hazards and the number of architectural elements to maintain.

821.3.24.4 Access spaces must provide enough headspace, hand space, and foot space for ease of maintenance.

821.3.24.5 Must design for appropriate ladder reach, use, and footprint.

821.3.24.6 Avoid requiring shared right-of-way and shared property for access.

821.3.24.7 Locate station elements 9 feet minimum above public pathways that could be vandalized, such as light fixtures, speakers, and cameras.

821.3.24.8 For specific criteria regarding locations and maintenance access for lighting, see Set 1007 Electrical Lighting.

821.3.24.9 Window washing and fall protection must be provided at the station and throughout the area, including at shelters, pedestrian bridges, rooftops, or other structures and architectural elements. See Set 804 Fall Protection for requirements.

821.3.25 Site Circulation

821.3.25.1 Various transportation modes exist at the station including pedestrian, bicycles, scooters, cars, buses, and trains, each with a unique circulation path that must be identified and coordinated to avoid points of congestion.

821.3.26 Passenger Flow

821.3.26.1 Minimize impediments to passenger flow, such as level changes, physical barriers, circulation conflicts, directional disorientation, and crowding.

821.3.26.2 Fare collection must be visible from the station entry with an unobstructed path.

821.3.26.3 On paths of travel, avoid objects that obstruct the pathway or interfere with accessibility. Fire hydrants and other support equipment must be coordinated to keep pathways free of obstructions.

821.3.27 Pedestrian Access and Circulation

821.3.27.1 Provide accessible stations with safe, direct, convenient, and obstacle-free paths for all passengers including passengers with disabilities and the general public.

821.3.27.2 Pedestrian circulation must connect to station entrances from off the site, park-and-ride lots, parking garages, and bus loading zones and from nearby existing and new development. Routes must minimize the distance pedestrians have to travel and must minimize conflict with other forms of travel, such as bicycles, vehicles, buses, or rail. Major pedestrian movements must be separated from bicycle and vehicle circulation.

821.3.27.3 Protect or close any unintended pedestrian routes into the station and/or platform.

821.3.27.4 Provide at least one accessible route to a station entrance from the street, sidewalk, parking area, drop-off areas, and adjacent development.

821.3.27.5 Minimize the path of travel from accessible station access locations (ADA parking, paratransit drop-offs) to accessible path of travel nodes (elevators, raised boarding areas).

821.3.27.6 Comply with Set 820 Facility Area Planning for pedestrian circulation requirements.

821.3.27.7 Pedestrian safety must be supported through minimizing conflict with other forms of travel. Minimize the number of bus and general traffic lanes a pedestrian must cross between the bus active bays and the station entry. Eliminate or reduce potential pedestrian conflicts occurring with bus turning movements. Reduce pedestrian desire lines between the bus active bays and the station entry that would increase likelihood of jaywalking.

821.3.27.8 Provide minimal grade changes or little to no reliance on equipment that would be required to support an ADA compliant path when transferring between buses and the station entry.

821.3.27.9 Driving aisles in park-and-ride areas must be oriented to prioritize pedestrian needs, safety, and parking lot capacity. Pedestrian movements within park-and-ride lots will normally occur within the driving aisles. Pedestrian walkways may be necessary to minimize vehicular interference, to reduce the number of points where pedestrians cross aisles, or to shorten irregular routes through successive aisles. Designate crosswalks within the parking areas for major pedestrian circulation routes.

821.3.27.10 Two-way communications systems must follow the IBC, placing CES at the platform and elevators. See Set 601 Fire–Life Safety and Set 302 Telephony.

Commentary: Those unable to self-rescue may indicate their location using CES equipped with blue light stations and passenger assistance intercoms.

821.3.27.11 Stairs, escalators, ramps, and accessible walkways must be oriented in the same direction (be parallel) so that passenger movement is simple, logical, and reinforces the direct travel path from entry to platform. See Set 805 Vertical Transportation.

821.3.27.12 Provide platform access via ramped walkways not to exceed 5% running slope and 1.5% cross slope. See Set 906 Roadways and Non-Motorized Facilities for cross slopes of non-superelevated pavement areas.

821.3.28 Station Architectural Elements

821.3.28.1 The various elements, such as canopies, platform furniture, lighting, and other amenities must present a cohesive design with a shared architectural vision.

821.3.28.2 Repetitive station elements must be standardized across the platforms and station area to create continuity and efficiency in manufacturing and maintenance.

821.3.28.3 For platform extensions, below is a list of elements and methods that complement an existing design element:

i. Light posts: match color and general shape with simplified forms. See Set 1007 Electrical Lighting for additional requirements including height.

ii. Site furniture: Follow furniture requirements. See Set 801 Architectural Materials, Elements, And Furnishings.

iii. Paving patterns: Match existing materials (poured concrete vs. pavers) and patterns where appropriate. New materials must complement existing.

iv. Canopies: Follow the general shape, angles, proportions, materials, and colors of existing canopies. Where appropriate, simplify details and follow the requirements outlined in this set. New canopies must incorporate all relevant requirements, such as bird deterrent, maintenance access, and hiding conduit.

821.3.28.4 Infrastructure for signage must be provided and coordinated throughout the station. See Set 720 Building Structures for details.

821.3.28.5 Station elements must be oriented orthogonally unless diagonals are functionally necessary to support passenger flow.

821.3.29 Station Entrances & Exits

821.3.29.1 A minimum of two exits from the platform must be provided and all exiting requirements per code must be met. See Set 601 Fire–Life Safety.

821.3.29.2 Entrances/exits must be determined by ridership and sized accordingly.

821.3.29.3 Emphasize entrances by incorporating architectural and landscape features and integrating signage and art as appropriate. Entrances must be recognizable.

821.3.29.4 The design of the entrances and exits must support activities, such as trip planning, waiting for pickup, and wayfinding by being sized to accommodate passengers that are not only moving through the space, but also being stationary while reading posted information and interpreting wayfinding markers.

821.3.30 Platform Length

821.3.30.1 Sounder N Line train platform lengths vary based on site constraints, new stations, and expansions to existing stations and must be determined by Sound Transit Planning and Operations.

Commentary: Two two-car sets and two three-car sets are typically operated on Sounder N Line platforms. Operating longer sets would require coordinating across stations to accommodate longer platforms, relocating mini-highs, working with positive train control requirements, and coordination with BNSF. Operations has never anticipated operating more than six-car train sets on the Sounder north lines.

821.3.30.2 For Sounder S Line trains, the platform length available for boarding and alighting must be 855 feet minimum to accommodate a ten-car train set.

Commentary: Cars are typically 85 feet in length and the platforms are typically 650 feet long. Extending the platform by three car lengths would extend all platforms by 255 feet to accommodate up to a ten-car set, with the following exceptions: King Street Station and Tacoma Dome north currently have capacity for a ten-car set, and the eastside Auburn platform, where the platform extension is assumed to only extend 85 feet to accommodate an eight-car set.

821.3.31 Platform Width

821.3.31.1 Platform widths vary based on the number of passengers, wayfinding provisions, the configuration of vertical circulation elements, center vs. side platform configuration, and station site considerations.

821.3.31.2 Side platforms must be 16 feet wide minimum from the edge of the platform to the face of the station wall or parapet railing.

821.3.31.3 Center platforms must be 30 feet wide minimum.

821.3.32 Platform Edge conditions

821.3.32.1 Along the track side of the platforms, provide a two-foot wide DWS edge paver condition with domes placed in an orthogonal pattern. See Sounder standard drawings and for specific materials and details see Set 801 Architectural Materials, Elements, and Furnishings.

821.3.32.2 The platform surface material must be slip resistant to provide for passenger safety. Material choice must also be durable and economical to construct and maintain. See Set 801 Architectural Materials, Elements, and Furnishings.

821.3.32.3 All platforms must provide tactile wayfinding. See Section 821.3.18 Accessibility and Tactile Wayfinding in this set.

821.3.32.4 The granite 2 feet by 3 feet "Welcome Mats" serve as train door markers on the Sounder station platforms. The art tile must be installed flush with the platform and be spaced according to the Sounder standard drawings, except where there is a tactile train waiting area provided. For tile information see Set 801 Architectural Materials, Elements, and Furnishings and see Sounder standard drawings for locations.

Commentary: The Sounder "Welcome Mats" were inspired by an 1800s quilt pattern called "Railroad Quilt" and were designed by artist Jerry Mayer in 2000. This project is part of the art programs initiative to provide a "look and feel" unique to each of Sound Transit's modes. Sound Transit owns the right to reproduce the mats.

Figure 821-5: Jerry Mayer, "Welcome Mats," at all Sounder Stations

821.3.33 Platform Slope and Adjacent Trackway

821.3.33.1 Platforms must slope away from the tracks.

Commentary: By sloping away from the tracks, the slope reduces the risk of rolling effects for wheelchairs towards the tracks.

821.3.33.2 The cross slope and the longitudinal slope must not be less than 1.3 percent. This condition applies regardless of surface material or location. See Set 904 Grading for cross slopes of non-superelevated pavement areas.

Commentary: The slope is set at 1.3 percent to address construction tolerances and ensure meeting accessibility requirements. Sound Transit Operations has also found ponding occurs at 1 percent slopes. DCM Rev. 5 NTD TU-1007 Grading of Accessible Routes provides further background and justification for slope requirements.

821.3.33.3 For center platforms, an under drain must be provided at the center of the platform width.

821.3.34 Vertical Clearances

821.3.34.1 For platform clearances, surface/edge features, and geometrics see Sounder standard drawings.

821.3.34.2 Comply with BNSF Railway Company, Union Pacific Railroad Company, Washington Utilities and Transportation Commission, and Sound Transit clearance requirements. See Set 520 Vehicle Clearance and Track Spacing.

821.3.34.3 Follow BNSF standards unless otherwise directed by Sound Transit's project manager. The designer must confer with Sound Transit capital projects staff to review relevant standards identified with BNSF.

821.3.34.4 BNSF requires a dynamic envelope or zone of clear passage that must be clear of all posts, canopies, signs, handrails, and other physical obstacles.

821.3.34.5 Curved tracks at station platforms are not allowed. See Set 520 Vehicle Clearance and Track Spacing or Set 521 Track Geometry.

821.3.34.6 The designer must calculate the clearance based on the curvature and super elevation of the track if any.

821.3.34.7 For platform elevations and edge conditions see Set 520 Vehicle Clearance and Track Spacing.

821.3.34.8 All platforms must be built 8 inches from top of rail. Sounder car floors are 21 inches above top of rail.

Commentary: BNSF requires that platforms are 8 inches from top of rail to accommodate clearances for freight trains. In 2012, the ADA began requiring level boarding at commuter train stations. Traditionally, stations on the east coast separate commuter rail from freight rail; however, on the west coast, the tracks are often shared. The freight train requirements create a unique challenge for Sounder station platforms as they cannot provide level boarding. Currently Sounder stations provide mini-high platforms for accessibility. Amtrak car floors are 15 inches above top of rail.

821.3.34.9 Sufficient handrail clearances must be provided in the station design. See Sounder standard drawings.

821.3.35 Mini-High Accessibility Platforms

821.3.35.1 Mini-high accessibility platforms must be provided at each station to allow ramp access to Sounder cars.

821.3.35.2 Mini-high accessibility platforms must align and provide level boarding with car number 2 and must be consistent across all stations.

821.3.35.3 Each mini-high platform has at least one ADA-compliant ramp to access the remainder of the platform.

821.3.35.4 For mini-high platform slope, dimensions, and details, refer to Sounder standard drawings.

821.3.35.5 The mini-platform edge is 7 feet 11 inches from the track centerline and 2 feet 7 inches farther back from the rest of the platform, to provide the BNSF-required horizontal clearance.

Commentary: Passengers with mobility-impairments access the train using an aluminum bridge plate placed manually across the gap to the threshold by the train conductor.

821.3.35.6 Provide 2-foot wide DWS at top of mini-high platform parallel to the track. See Sounder standard drawings.

821.3.35.7 Provide weather protection and lighting over the mini-high platform, the location must not impede on the clearance envelope for the track. See Set 520 Vehicle Clearance and Track Spacing for requirements regarding the clearance envelope.

Commentary: Providing weather protection for passengers waiting on the mini-high platforms is a new requirement in 2021.

821.3.36 Canopies

821.3.36.1 Platform canopies must provide weather protection. In general, canopy and rain screen design must assume that rain is falling at a 15-degree angle from vertical. However, the orientation of a station's platform areas will influence the effectiveness of canopies in providing shade and rain protection. Station orientation must be considered in developing canopy and wind/rain screen designs on a station-specific basis.

821.3.36.2 Drip lines must not be placed over travel pathways or platform edges. At Sounder stations, canopies must be designed in a manner that prevents water from draining onto tracks.

821.3.36.3 Avoid creating bird perching or nesting areas.

821.3.36.4 Canopies must be cantilevered, avoiding posts that will block sight lines.

821.3.36.5 Canopies must be 10 feet from the platform slab to the underside of the canopy. See Sounder standard drawings.

821.3.36.6 Canopies must be transparent or translucent to allow for natural light to reach platform. See Set 801 Architectural Materials, Elements, and Furnishings.

821.3.36.7 Canopies must be designed so they can be accessed for regular maintenance.

821.3.36.8 Total canopy area to be 5 square feet per passenger for a single passenger train maximum anticipated entraining load.

821.3.36.9 Provide weather protection at public stairs and approaches to same within 5 feet of termination of handrails.

821.3.36.10 Provide weather protection at fare vending equipment including, at a minimum, a 4-foot by 4-foot area in front of the equipment.

821.3.36.11 Provide weather protection at passenger facilities, such as system map viewing areas, public and emergency telephones.

821.3.37 Windscreens

821.3.37.1 To protect passengers from strong wind-blown rain, transparent windscreens must be provided on the platforms for a minimum of one-third of canopy coverage.

821.3.37.2 At stand-alone windscreens, the design must provide a minimum 6-inch gap at the bottom of framing to top of slab for ease of cleaning.

821.3.37.3 Glazing must be rectilinear for ease of cleaning and maintenance. See Set 801 Architectural Materials, Elements, and Furnishings for standard glazing sizes.

821.3.37.4 Orient windscreens to protect from prevailing winds.

821.3.37.5 Provide windscreens around stair openings.

821.3.37.6 Must include gap next to the canopy to allow for smoke to escape in event of a fire.

821.3.37.7 Windscreens must be transparent to allow clear surveillance of station areas for passenger security and to discourage vandalism.

821.3.37.8 Lower portions of windscreens must be solid or semi-transparent to minimize damage to lower glazing due to kicking and to protect passengers from environments outside the platform, such as spray from vehicular traffic.

821.3.38 Seating

821.3.38.1 One bench must be located near each public entry point to the station and arranged so that it does not interfere with passenger circulation or emergency exiting.

821.3.38.2 At minimum, 30 percent of the platform seating must be designed with backs and full-length armrests to facilitate use by passengers with disabilities. The seating closest to the mini-high platform must be accessible.

821.3.38.3 At least two benches capable of seating four or more people must be provided at each canopy. The exception is the canopy located over the ticket vending machine.

821.3.38.4 Benches and/or seating units must have design features that prevents individuals from lying down. In addition, at least one leaning rail, protected by wind screens, must be provided for each bus boarding location. The bottom portion of the leaning rail must be 3 feet from the ground. The rail must be 1 foot in width. See Set 801 Architectural Materials, Elements, and Furnishings for material requirements.

821.3.38.5 The designer must choose from Sound Transit approved benches. See Set 801 Architectural Materials, Elements, and Furnishings.

821.3.38.6 Seats must not be adjacent to railings, stairways, or other openings which may present a fall hazard where the grade difference is more than 4 feet at the location of the seating.

821.3.38.7 On-site bus stops at stations must have a minimum of 3 lineal feet of seating per bus stall. Seating and shelter for bus stops on public streets will typically be provided by local transit companies.

821.3.39 Trash Receptacles

821.3.39.1 Trash receptacles must not be located on the platform.

821.3.39.2 Trash receptacles must be placed adjacent to stairs or ramps leading to/from the platform. This placement must be within the sight line of arriving/departing passengers, but not be placed within the egress/access path per industry recommendations, Trash and Recycling Receptacles for Transit Facilities, APTA SS-SIS-WP-014-13.

Commentary: This requirement was informed by the DSTT-TO8 – Trash Receptacle Security Risk Assessment February 02, 2020.

821.3.39.3 Trash receptacles must meet Sound Transit standards. See Set 801 Architectural Materials, Elements, and Furnishings for acceptable trash receptacle design.

821.3.39.4 Trash receptacle mounting hardware must be designed and installed to avoid trip hazards. See Set 801 Architectural Materials, Elements, and Furnishings for additional requirements.

821.3.39.5 Trash receptacles must be paired with recycling containers.

821.3.39.6 Place trash and recycling receptacles in the line of sight of surveillance cameras. See Set 1202 CCTV - TIDS for camera placement requirements at the station.

Commentary: This requirement was informed by the DSTT-TO8 – Trash Receptacle Security Risk Assessment February 02, 2020.

821.3.40 Bicycle Infrastructure

821.3.40.1 Bicycles must be directed to bicycle parking and platforms via signage, pavement markings, and other wayfinding cues. Bicycle parking must be provided with easy access from bicycle paths. Where bicyclists share space with pedestrian paths/trails, provide a minimum of 8 feet to ensure safety and comfort of pedestrians and bicyclists.

Commentary: The bicycle path width is based on the U.S. Department of Transportation Federal Highway Administration's Evaluation of Safety, Design, and Operation of Shared-Use Paths final report. The minimum is set at 8 feet, but Sound Transit recommends providing 10 feet or more where space will allow per this report's findings.

821.3.40.2 Bicycle storage and parking requirements must be provided at all facility locations, see Set 807 Bike Program for specific facilities requirements. Designers must reference current Sound Transit bicycle and access policies and refer to the System Access Implementation Plan to determine quantities of bicycle systems.

821.3.40.3 Provide bicycle storage facilities according to the Sound Transit bicycle parking estimation methodology and Set 807 Bike Program.

821.3.40.4 Bike parking must provide 75 percent of type Class I. See Set 807 Bike Program for acceptable bicycle rack styles.

821.3.40.5 Must coordinate bike parking requirements with AHJ.

821.3.40.6 Must provide bicycle rack clearances per Set 807 Bike Program.

821.3.40.7 "Smart" lockers hardwired for electrical power and data must be provided wherever site conditions allow. Identify conduit needs and see Set 1005 Electrical Power, Set 1006 Electrical Raceway, and Set 807 Bike Program.

Commentary: Sound Transit Facilities prefers hardwired lockers because batteries require more monitoring to ensure lockers are functioning.

821.3.40.8 Provide infrastructure, such as a concrete pad and power, per the manufacturer's requirements and coordinate with other disciplines.

821.3.40.9 Provide continuous bike runnels on both sides of public stairs flush with insider corner of tread and riser beneath handrails for the purpose of moving bikes up and down stairs. See typical detail in Sounder standard drawings.

821.3.41 Plazas

821.3.41.1 Locate station plazas to enhance connections to and from station access points.

821.3.41.2 Designers must collaborate with the local community so the plaza reflects the unique station area attributes.

821.3.41.3 Provide station plazas with amenities to enhance user comfort including seating, trash and recycling receptacles, pedestrian lighting, art, and bicycle racks.

821.3.41.4 Organize, furnish, and landscape station plazas to enhance visibility and facilitate pedestrian traffic to and from station entrances.

821.3.41.5 Station plazas and open spaces must be designed with high quality materials and low-maintenance native plantings and trees for weather protection. See Set 801 Architectural Materials, Elements, and Furnishings for material requirements and Set 802 Landscaping for planting requirements.

821.3.42 Public Art

821.3.42.1 Architectural Integration

821.3.42.1.1 Art must enhance stations for better passenger experience and place making.

821.3.42.1.2 Given the potential variety of character and size, art must be compatible with the volumes of the interior or exterior spaces in which they are located and must be compatible with the architectural expression of individual stations.

821.3.42.1.3 See Set 808 STart Program for specific requirements.

821.3.42.2 Location Criteria

821.3.42.2.1 The placement of art must recognize the primary importance of the functional clarity of stations.

821.3.42.2.2 Art must not impede passenger circulation, restrict clear sight lines, nor pose a safety hazard. See Set 601 Fire/Life Safety.

821.3.42.2.3 Art may compliment system signage but must not distract or block essential information and security features, such as station maps or CCTV cameras.

821.3.42.3 Maintenance and Performance Criteria

821.3.42.3.1 All materials used in the fabrication of artworks must support the concept developed for the station while recognizing the vital role of durability, vandal-resistance, and maintenance needs.

821.3.42.3.2 Artwork intended to be permanent must incorporate materials, fabrication methods, and installation methods which are appropriate for its expected life.

821.3.42.3.3 Art, art supports, and adjacent structure must be designed to meet structural requirements. See Set 720 Building Structures.

821.3.42.3.4 Maintenance and security needs of artwork must be consistent with the maintenance and security needs of the facility.

821.3.42.3.5 Artwork must not invite climbing or skateboarding unless specifically built for that purpose. There must be no sharp edges or potential trip hazards in the touch zone.

821.3.42.3.6 Artwork must work with the existing ambient lighting of the stations. Refer to Set 808 Start Program and Set 1007 Electrical Lighting for special lighting requirements.

821.3.42.3.7 Other special needs must be assessed on a station-specific basis and must be identified within station planning as early as possible.

821.3.42.3.8 The station designer must work with the STart program to incorporate into the station design those elements necessary to be provided by the station contractor to accommodate the artwork. The station designer must indicate in the contract documents the coordination required of the station contractor to accommodate the art program.

821.3.43 Advertising

821.3.43.1 Establish zones for advertising early in the design process (by 30 percent design). See Set 801 Architectural Materials, Elements, and Furnishings.

821.3.43.2 Advertising must not obscure or conflict with agency signage.

821.3.43.3 Advertising must be parallel to passenger travel paths (not perpendicular).

821.3.43.4 Coordinate mounting requirements with advertisers.

821.3.44 Vertical Circulation

821.3.44.1 The designer must provide vertical circulation that promotes safe, clear, and intuitive wayfinding.

821.3.44.2 All circulation elements must be coordinated along the main path of travel from the entry to the platform to support wayfinding with visible and direct access. The main path of travel must be fully accessible, including vertical circulation, such as elevators and ramps where necessary.

821.3.44.3 Vertical circulation elements must be located to be readily visible and identifiable as a means of access to the levels they are designated to interconnect.

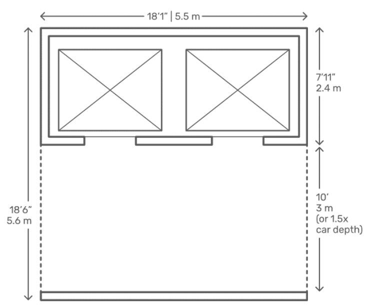
821.3.44.4 Where pedestrian bridges occur at stations, elevators must be provided on both sides of the bridge. See accessibility section to help determine required circulation elements.

821.3.44.5 If redundancy for accessible routes are not provided and the alternative route requires more than 600 feet, then an alternative approach, such as an On-Demand Rides program, shuttle, and/or express bus must be available to assist passengers who rely on elevators to access the station.

Commentary: Wait times must not exceed 15 minutes due to vertical conveyance being out of service.

821.3.44.6 Elevator landings must be located so that users waiting for elevators do not impede general circulation, have adequate space for queuing, and are open and visible. Provide a minimum of 10 feet clear depth in front of an elevator and incorporate elevator surge zone requirements. See Figure 821-6.

Figure 820-6: Elevator Landings



821.3.44.7 Comply with Set 1002 Mechanical – Plumbing for drainage requirements at elevator landings.

821.3.44.8 Elevators must be transparent on a minimum of two sides to support CPTED.

821.3.44.9 Provide passenger elevator cars and shaft walls with operable vision glass panels to assist surveillance and facilitate cleaning.

821.3.44.10 All elevator machine rooms and oil coolers must be equipped with an HVAC system. Refer to Set 805 Vertical Transportation for additional requirements in elevator machine rooms.

Commentary: These spaces easily overheat due to high traffic, and this will reduce overall elevator outages at the station.

821.3.44.11 Provide a GFCI electrical outlet and hose bibb at each elevator landing for maintenance in a recessed locking wall box for maintenance use to allow for cleaning the elevator and landing areas. See Set 1005 Electrical Power and Set 1002 Mechanical - Plumbing.

821.3.44.12 Platform lifts cannot serve as compliant back-ups for existing elevator service.

Commentary: As described by ADAS Section 206.7.5, platform lifts must be permitted where existing exterior site constraints make use of a ramp or elevator infeasible. None of the stations have site constraints that would prevent the use of ramps or elevators as feasible solutions to elevator outages on accessible *routes. Platforms lifts are not designed for transit use where there are high numbers of people potentially using this equipment and it would be challenging to maintain and keep in operating order. Lifts also require staff assistance.*

821.3.44.13 Where stairs are open to the public, the spaces created under stairs with a clearance height of less than 7 feet above the walking surface must be closed to prevent public access with a solid wall, screen, or other Sound Transit approved feature.

821.3.44.14 For stair materials see Set 801 Architectural Materials, Elements, and Furnishings.

821.3.44.15 Provide ramps per the most stringent standards and criteria of AHJ.

821.3.44.16 Ramps must meet all ADA criteria and A117.1 code requirements.

821.3.44.17 Provide ramps at-grade changes next to elevators to reduce travel time along accessible routes.

821.3.45 Horizontal Circulation

821.3.45.1 Public corridors must be sized to support passenger experience with enough space to meet exiting requirements per the IBC and NFPA 130.

821.3.45.2 Non-public passageways must be a minimum of 5 feet clear width.

821.3.45.3 Provide public pedestrian ways, overpasses, underpasses, and tunnels 16 feet minimum clear width and 10 feet minimum clear height unless indicated otherwise.

821.3.45.4 Textured paving along accessible paths cannot hinder travel along the accessible path.

821.3.45.5 Provide standard fixtures, furnishings, equipment, and other elements to make station spaces recognizable and familiar to infrequent users and passengers with special needs.

821.3.45.6 At pedestrian bridges provide lean rails. See Set 801 Architectural Materials, Elements, and Furnishings.

821.3.46 Lighting Design

821.3.46.1 Comply with Set 1007 Electrical Lighting for lighting requirements.

821.3.46.2 Comply with Set 803 Sustainability for light pollution prevention requirements.

821.3.47 Fare Collection / Ticket Vending Machines

821.3.47.1 Ticketing locations must be consistent across stations and accessible to all passengers along the main path of circulation.

821.3.47.2 TVMs must be at both platforms.

821.3.47.3 Locate the TVMs under a shelter at the platform, passengers and machines must be protected from the weather.

821.3.47.4 TVM concrete pad must be provided and coordinated for conduit infrastructure. Station layout must include location of pull boxes and coordinate with systems requirements.

821.3.47.5 Coordinate placement of TVMs with Sound Transit's manufacturer's requirements and the Transit Systems group. Provide all clearances per the TVM drawings.

821.3.47.6 TVMs must include Sound Transit signage per the Sound Transit Customer Signage Manual.

821.3.48 Smart Card Readers

821.3.48.1 The number of smart card readers must be determined by the size of the platform, provide one smart card reader for every 100 feet of platform at minimum. For example, a platform 650 feet long would have at minimum six smart card readers. Placement of smart card readers must follow the requirements in this section.

821.3.48.2 Where smart card readers are placed along the platform, they must be visible to passengers exiting the train.

821.3.48.3 Smart card readers must be within 5 feet of the station entries.

821.3.48.4 Smart card readers must be at the base of accessibility ramps leading to mini-high platforms. See Sounder standard drawings.

821.3.49 Signage and Graphics

821.3.49.1 Signage must provide safe, efficient, and effective communications and must be clear, direct, and coordinated to provide the best passenger wayfinding experience within the station area. See Set 720 Building Structures for signage support requirements.

821.3.49.2 Customer and operational signage must be coordinated and visible.

821.3.49.3 Static signage must be coordinated with video and/or audio surveillance. The signs inform passengers that they are under video and audio surveillance and that they may be recorded. See Set 806 Signage.

821.3.49.4 Location of VMS signage must follow the Sound Transit Customer Signage Design Manual. Coordinate with Set 1102 Passenger Information Management System (PIMS) and Set 1005 Electrical Power.

821.3.49.5 Coordinate and provide operational signage with Sound Transit Operations. See Set 010 Operations for specific requirements.

821.3.50 Electric Convenience Outlets

821.3.50.1 Must provide electric convenience outlets along the platform and at ancillary rooms and spaces. See Set 1005 Electrical Power.

821.3.50.2 At the platform and plaza, electrical convenience outlets must be placed, so all areas of the platform and plaza can be reached with a 100-foot cord.

821.3.50.3 Comply with Set 1006 Electrical Raceway for installation heights of electrical outlets.

821.3.50.4 Coordinate location of outlets with Sound Transit Facilities group.

821.3.51 Hose Bibbs and Hydrants

821.3.51.1 For all fire protection devices at the station, including hose bibbs and hydrants, see Set 1002 Mechanical - Plumbing and Set 601 Fire/Life Safety.

821.3.52 Fire Protection Support Systems

821.3.52.1 Coordinate fire protection systems, such as fire hydrants, standpipes, and Knox Boxes throughout the station area per code and Sound Transit Requirements. See Set 601 Fire/Life Safety.

821.3.52.2 Fire protection support systems must not be blocked from view.

821.3.53 Public Address System

821.3.53.1 Public address systems must be provided at Sounder Stations. The designer must provide sufficient conduit capacity to support a series of speakers located throughout public areas that can be recorded and real-time announcements produced on site at a central location.

821.3.53.2 Coordinate location of PA speakers throughout station area. For additional requirements see Set series 300 Operational Communications.

821.3.53.3 Coordinate PA system with emergency voice communication systems per code requirements. See Set 601 Fire/Life Safety.

821.3.54 CCTV

821.3.54.1 Provide CCTV cameras throughout the station area to ensure station surveillance.

821.3.54.2 CCTV cameras must be located a minimum of nine feet above the platform to avoid tampering.

821.3.55 CES

821.3.55.1 CESs are ADA-compliant call boxes and must be provided at each Sounder station.

821.3.55.2 A PTZ or fixed CCTV camera must be mounted near the CES. CESs must be located within the view of a PTZ or a fixed camera. See Set 1202 CCTV - TIDS for requirements. Coordinate with Sound Transit Communications and Security.

Commentary: Fixed CCTV cameras are preferred since PTZs often do not get returned to their intended view field.

821.3.56 Vehicle Barriers

821.3.56.1 Stations must have physical barriers to deter vehicle intrusion, which may consist of bollards, planters, grade changes, walls, curbs, and abutments.

821.3.56.2 Bollards must only be used when other architectural and landscaping elements are not possible.

821.3.56.3 Provide bollards or equal designed to meet applicable standards to protect station entrances from vehicles and to prevent exits from being obstructed.

821.3.57 Ancillary Spaces

821.3.57.1 The station layout must include ancillary spaces per the design requirements. Specific requirements for ancillary spaces must also be determined on a station-by-station basis with Sound Transit Operations and project teams. See Set 1003 Mechanical – HVAC and Set 601 Fire–Life Safety for specific ancillary space requirements.

821.3.57.2 Ancillary rooms and spaces must be integrated into an efficient station layout, including appropriate adjacencies, and be compatible with overall station architectural scheme while utilizing existing material palettes.

821.3.57.3 Where systems buildings are not enclosed within a station or facility and are visible to the public, provide an architecturally interesting and secure screen compatible with the neighborhood to enclose systems buildings

821.3.57.4 All non-public rooms must provide an accessible door, maneuvering clearances at the door, and latch clearances required per the ADA Standards Section 404. No permanent elements or equipment are allowed to block these clearances. Exceptions permitted for spaces with ladder access only, narrow access, or required change in elevation. Confirm all exceptions with Sound Transit.

821.3.57.5 All doors to ancillary spaces must have access control. See Set 801 Architectural Materials, Elements, and Furnishings and Set 1203 Access Control System for specific requirements.

821.3.57.6 Provide lites at interior doors at occupiable ancillary spaces, such as crew rooms or offices. Comply with Set 801 Architectural Materials, Elements, And Furnishings for material and finish requirements.

Commentary: Door lites allow visibility in back of house spaces for safety purposes.

821.3.57.7 Non-public (back of house) areas are not required to have as high level of finish as public spaces. Non-public spaces include areas only accessible by Sound Transit or authorized personnel. See

Set 801 Architectural Materials, Elements, and Furnishings for acceptable materials and finishes for non-public spaces.

821.3.57.8 Systems equipment, such as mechanical units, must be screened to conceal equipment otherwise visible to the public from the right-of-way, private property or stations, as well as views from adjacent buildings with higher vantage points requiring overhead screening. Provide screen walls of a height to conceal equipment. Do not rely on landscape screening. Screening must work with the surrounding context, utilizing architectural elements from the neighboring buildings and station elements.

821.3.57.9 All systems equipment must be secured by gates and have access points. Do not rely on landscape screening to screen equipment. See Set 802 Landscaping.

821.3.57.10 Access from ancillary rooms to a service vehicle parking stall must not exceed 300 feet.

821.3.57.11 Ancillary spaces including security offices, storage rooms, and janitor's closets may be located in a Sound Transit support facility, such as a Sounder garage, as long as the distance is within 600 feet of the Sounder station platform.

821.3.57.12 Provide adequate access for equipment maintenance envelopes and replacement paths per the manufacturer's requirements.

821.3.57.13 All overhead smoke/heat detectors, HVAC components, and access panels must be accessible and unobstructed in all ancillary rooms.

821.3.58 Security Office

821.3.58.1 The security office must accommodate the expected number of security personnel and equipment anticipated in the near- and long-term. Coordinate with Set series 1200 Security.

821.3.58.2 The security office must be between 80 to 100 square feet. Must provide desk surface for two computers/laptops, two network connections, phone connections, power receptacles, radio service, HVAC, and lighting. No clear glazing allowed to the exterior at eye level. If daylighting is provided, glazing must be above eye level or translucent. Room layout must provide ADA compliant turning space.

821.3.58.3 The security office must accommodate security equipment, including CCTV viewers and intercoms.

821.3.58.4 Locate security office within 50 feet of public restrooms if provided or elevators if public restrooms are not provided.

821.3.58.5 Where public restrooms are provided, the security office must be located such that the transaction window has an unobstructed sightline to the public restroom doors.

821.3.58.6 Provide 36inchby 36-inch minimum transaction window with SS frame around and clear, bullet resistant glazing material, which must be rated minimum Level 3 in compliance with UL 752. Additional accessories must include bullet-resistant speaking aperture for passive voice transmission, SS shelf and weather-protected deal tray. Transaction window and accessories must be ADA compliant. Framing for glazing must be detailed to maintain conformance to required glazing sizes and accommodate allowable tolerances for any supporting structure, such as steel. Where steel supporting members are provided in the same plane as the glazing and its framing, the designer must detail the condition to see maintain conformance to the glazing size requirements. See Set 801 Architectural Materials, Elements, and Furnishings for standardized glazing type and sizes.

821.3.58.7 All public-facing walls must be bullet-resistant and rated for minimum Level 3 in compliance with UL 752.

821.3.58.8 A PET must be provided directly outside the security office door. Where multiple doors exist, the PET must be located by the main door facing the public area.

821.3.58.9 CCTV coverage must be provided inside the security office.

821.3.58.10 The security office must be considered a high security area.

821.3.58.11 Provide privacy blinds on the interior side of the transaction window.

821.3.58.12 Two exits out of the security office is preferred.

821.3.58.13 An additional security office must be provided when a facility is identified as a major security hub. Coordination with Sound Transit Transportation and Security must be made in determining its need.

821.3.59 Communications, Electrical, and Mechanical Rooms

821.3.59.1 The Sounder station layout must provide designated space for system support elements, including the communication and signal equipment rooms/cabinets, electrical cabinets, electric power meters, water meters and valves, and irrigation valves and boxes on site specific cases.

821.3.59.2 The system support elements requirements must be coordinated with Sound Transit's Information Technology, Operations, Transportation Safety and Security, Sustainability, Transit Systems Operations, and Systems Engineering Groups.

821.3.59.3 Provide a table identifying all the system support elements and their space requirements to be incorporated into the Sounder station layout.

821.3.59.4 Identify and resolve requirements for communications to remote facilities by 60 percent design or equivalent.

821.3.59.5 The Sounder station must provide space for current and anticipated future equipment and integrate into the design, such as additional conduit infrastructure to support new technologies in communications and sustainability. Coordinate embedded conduit needs with raceway design. See 300 Series, 1100 Series, 1200 Series, and Set 1006 Electrical Raceway for requirements.

821.3.59.6 Provide additional conduits with inner duct, so cables can be pulled to accommodate for additional technologies related to passenger information, fare collection, safety and security, and sustainability. See 300 Series, 1100 Series, and 1200 Series for requirements.

821.3.59.7 Document all design requirements for future growth within the project specific requirements, such as providing for additional conduits, so they are not removed as part of a value engineering process. Refer to Set 1006 Electrical Raceway for empty conduit requirement.

821.3.59.8 Communications and electrical rooms must be provided at every station and be separated by a rated wall per code with separate entrances.

821.3.59.9 The size of the communications room/building must be sufficient to accommodate connections for passenger information, passenger convenience, safety, and security systems. See Set 815 Telecommunication Spaces. See system directive drawings for prototypical room layouts.

821.3.59.10 Follow the guidelines from the BICSI TDMM (Telecommunications Distributions Methods Manual) to determine the size, location, utility services, door, floor clearances, and lighting for the communications room.

821.3.59.11 The final size of the communications room must accommodate all the system support elements identified and provide space around equipment for maintenance personnel, as mandated by code, Set 815 Telecommunication Spaces, and approved by the Sound Transit Facilities group.

821.3.59.12 Locate the communications room off the platform, in an adjacent plaza or designated surface parking lot as the site constraints allow. If a parking garage is immediately adjacent to the station, the communication room may reside within the garage to eliminate duplication of UPSs, generators, and BMS. If cost sharing occurs with other agencies on the parking, separate or sub-metering is required.

821.3.59.13 Follow the BICSI TDMM for all door and clearance requirements.

821.3.59.14 All shelters and light standards must have conduit stub ups from the mainline duct bank for power and system communications. Coordinate with Set 1006 Electrical Raceway to identify size and determine data and power requirements.

821.3.59.15 As part of platform extensions for South Sounder stations, utilize the existing communications room and infrastructure to expand or provide an additional room for systems equipment based on project requirements.

821.3.59.16 Comply with Set series 1000 Mechanical-Electrical and Building (MEP) for MEP requirements.

821.3.60 Station Agent

821.3.60.1 At Sounder Stations the station agent must have a conditioned space separate from the communications and electrical rooms.

821.3.60.2 The station agent room must provide a designated sitting area, outlet for electronic devices, and a view towards the tracks.

821.3.61 Storage Room

821.3.61.1 A storage room must be provided at every Sounder station to accommodate severe weather equipment, such as ice melt or storage for lighting. This room can be combined with the station agent room if the room requirements for the station agent are provided. The storage room must be separate from the janitor's closet.

821.3.61.2 The storage room can be located in a Sound Transit parking garage within 600 feet of the station.

821.3.61.3 The storage space must be a minimum of 100 square feet with a minimum of 15 lineal feet of shelving for storage of materials and an open floor area to store cleaning equipment. Access door to be 40 inches wide minimum or a pair of 3-foot-wide doors.

821.3.61.4 Additional storage space is required for stations next to downtown areas with lots of pedestrian activity. Storage room size and layouts must be coordinated and approved by Sound Transit Operations.

821.3.62 Janitor's Closet

821.3.62.1 A janitor's closet must be located at the Sounder station. If a parking garage is within a quarter mile of the station platform, the janitor's closet may be provided there in support of the garage and the station.

821.3.62.2 The janitor's closet must be a minimum of 100 square feet and include a mop sink, emergency eye wash, 15 linear feet of wall-mounted shelving, and wall-mounted mop rack above the mop sink.

821.3.62.3 The janitor's closet door must either be a minimum of 40 inches wide or a pair of 36-inch-wide doors. Doors must be equipped with closers, lever locksets, and access card readers.

821.3.62.4 The janitor's closet must be located within 50 feet of public restrooms where provided and must accommodate open floor area to store cleaning equipment, including area directly beneath wall shelving.

821.3.62.5 All finishes and wall substrates must be moisture and impact resistant; floors must be sealed concrete. See Set 801 Architectural Materials, Elements, and Furnishings.

821.3.62.6 Must provide sealed concrete flooring.

821.3.62.7 Plumbing must include hot and cold potable water at mop sink. See Set 1002 Mechanical - Plumbing for potable water requirements.

821.3.62.8 HVAC must include a recessed or suspended electric unit heater for heating and louver for ventilation.

821.3.62.9 For janitor's closets in facilities seeking third party sustainability certification, additional provisions such as sealed ceilings and exhaust fans may be required. Coordinate specific sustainability requirements with project specific goals and Set 803 Sustainability.

821.3.63 Service Areas

821.3.63.1 Provide one trash enclosure for two four cubic yard dumpsters. Locate trash enclosure adjacent to truck access from local garbage hauler. Screen dumpsters from view or locate within a room. Provide a pair of three- foot-wide doors or gates. Lock separately from other trash enclosures on site. The trash enclosure must be within 100 feet of nearest trash receptacle. Preference is to have trash enclosure within 100 feet of nearest trash receptacle. If there is an adjacent Sound Transit garage, then the trash enclosure must be shared.

821.3.64 Generator

821.3.64.1 Provide an area to accommodate a temporary emergency generator unless a permanent generator is provided. Mobile generators must not be in an interior space nor in a parking garage. See Set 1005 Electrical Power for all generator requirements.

821.3.64.2 Generator must be screened from public view.

821.3.65 Staff Restroom

821.3.65.1 Every Sounder station must have one permanent staff restroom located out of public view.

821.3.65.2 Staff restrooms are unisex and equipped with a lavatory faucet, toilet, urinal, electric hand dryer, and mirror. Paper towel dispensers are not allowed. See Set 801 Architectural Materials, Elements, And Furnishings.

821.3.65.3 The location of the staff restroom must be out of public view, preferably not along the main pedestrian circulation paths and where possible, in non-public areas. Staff restroom location must be approved by Sound Transit.

821.3.65.4 Restrooms must comply with ADA standards.

821.3.65.5 All restroom hygiene products (e.g., lavatory faucets, urinals, toilets, hand dryers) must have "hands-free" operation. See Set 801 Architectural Materials, Elements, And Furnishings.

821.3.65.6 Provide a visual "Occupied" lock indicator separate from the keyed lock. See Set 801 Architectural Materials, Elements, And Furnishings for security parameters for openings.

821.3.65.7 Provide a viewing eye in the door to allow interior occupants to see outside prior to exiting the restroom as a safety measure.

821.3.65.8 Staff restrooms must have feminine hygiene dispensers that do not require coins to operate.

821.3.65.9 A staff restroom must be located within 500 feet of the Sounder station and may be located within a Sound Transit support facility.

821.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

821.4.1 System Breakdown Structure

821.4.2 System Sites and Locations

821.5 SYSTEM INTERFACE REQUIREMENTS

Table 821-1: lists requirement sets that are typically coordinated, and may have dependencies, with this set.

Table 821-1: Interface Between Architecture and Other Disciplines

SET SERIES	SERIES NAME	SET 821 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	
300	Operational Communications	X
400	Vehicle	
500	Track	X
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical/Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

821.5.1 Civil

821.5.1.1 Coordinate roadway requirements.

821.5.1.2 Coordinate walkway grading requirements.

821.5.2 Track

821.5.2.1 Coordinate BNSF, UP, WUTC, and Sound Transit clearance requirements at stations.

821.5.2.2 Coordinate clearance envelope requirements.

821.5.2.3 Coordinate track geometry at station platforms.

821.5.2.4 Coordinate platform elevation and edge conditions.

821.5.3 Fire/Life Safety

821.5.3.1 Coordinate means of egress requirements.

821.5.3.2 Coordinate fire department access routes, fire hose reach, standpipe and hydrant locations, fire separation walls and other requirements.

821.5.3.3 Coordinate two-communication system code requirements.

821.5.3.4 Coordinate fire protection pipe placement requirements.

821.5.3.5 Coordinate first responder access requirements.

821.5.4 Structures

821.5.4.1 Coordinate structural infrastructure for signage.

821.5.4.2 Coordinate structural infrastructure for artwork.

821.5.5 Mechanical/Electrical and Building Systems

821.5.5.1 Coordinate building clearances with equipment circulation diagrams.

821.5.5.2 Coordinate lighting requirements.

821.5.5.3 Coordinate illuminance levels throughout station areas and plazas.

821.5.5.4 Coordinate illuminance levels at devices and signage.

821.5.5.5 Coordinate bike locker power requirements.

821.5.5.6 Coordinate power and mechanical requirements for elevators.

821.5.5.7 Coordinate power requirements for digital signage.

821.5.5.8 Coordinate outlet locations.

821.5.5.9 Coordinate electrical provisions for future equipment and devices.

821.5.5.10 Coordinate power requirements for shelters.

821.5.5.11 Coordinate mop, sink, and potable water requirements.

821.5.5.12 Coordinate generator requirements.

821.5.6 Communications/Technology

821.5.6.1 Coordinate station communication rooms, closets, and infrastructure.

821.5.6.2 Coordinate communications infrastructure installed next to shelters and windscreens.

821.5.6.3 Coordinate network infrastructure.

821.5.6.4 Coordinate CCTV coverage and locations.

821.5.6.5 Coordinate VMS signage locations and data requirements.

821.5.6.6 Coordinate PET and CES requirements.

821.5.6.7 Coordinate access control requirements.

821.5.6.8 Coordinate quantities, spacing, locations, for fare vending such as TVMs and smart card readers.

821.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

821.7 ENGINEERING MANAGEMENT REQUIREMENTS

821.7.1 Interface and Integration Management

821.7.1.1 The design must consider and account for all interfaces. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructable documentation and functional designs.

821.7.2 Design Management

821.7.3 Manufacturing and Construction Management

821.7.4 Installation Management

821.7.5 Inspection and Testing Management

821.7.5.1 Design must adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

821.7.6 Training, Pre-Revenue Operations

821.7.7 Certification Management

821.8 APPENDICES (NOT USED)

END SET - 821

822 STATION LAYOUT - LIGHT RAIL

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SET - 822 STATION LAYOUT - LIGHT RAIL

822.1 INTRODUCTION

822.1.1 Document Scope

822.1.1.1 This set establishes the design criteria for Link stations. Elements discussed in this set include the design of platforms, platform access, amenities, vertical circulation, and bicycle parking. Refer to Set 821 Station Layout – Commuter Rail for Sounder station requirements.

822.1.1.2 Station design must be a cohesive part of the overall transit system and an integrated element of the neighborhoods and community of which it is a part. Within this framework, the use of a standardized family of materials for stations as outlined in this set will provide consistency for the system and accommodate the individual character of each neighborhood or community, while addressing the operations and maintenance requirements.

822.1.1.3 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 822 owner to determine the technical source for the design criteria.

822.1.2 Regulations, Codes, Standards, and Guidelines

822.1.2.1 International Regulations, Codes, Standards, and Guidelines

822.1.2.1.1 International Building Code (IBC) with local amendments.

822.1.2.1.2 International Code Council/American National Standards Institute (ICC/ANSI) A117.1 Accessible and Usable Buildings and Facilities.

822.1.2.1.3 International Fire Code (IFC) with local amendments.

822.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

822.1.2.2.1 ADA Standards for Transportation Facilities (DOT) (ADA Standards) Washington State Accessibility Standards.

822.1.2.2.2 American Association of State Highway and Transportation Officials (AASHTO). Policy on Geometric Design of Highways and Streets.

822.1.2.2.3 American National Standards Institute, Inc. (ANSI).

822.1.2.2.4 Crime Prevention Through Environmental Design (CPTED).

822.1.2.2.5 Federal Transit Administration (FTA) Regulation 49 CFR Part 37.

822.1.2.2.6 NACTO National Association of City Transportation Officials Transit Street Design Guide.

822.1.2.2.7 NACTO National Association of City Transportation Officials Urban Bikeway Design Guide.

822.1.2.2.8 NACTO National Association of City Transportation Officials Urban Street Design Guide.

822.1.2.2.9 National Fire Protection Association (NFPA) Standard for Fixed Guideway Transit and Passenger Rail Systems (NFPA 130).

822.1.2.2.10 NFPA 101 Life Safety Code.

822.1.2.2.11 Tile Council of North America (TCNA).

822.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

822.1.2.3.1 Washington Administrative Code (WAC).

822.1.2.3.2 Washington State Department of Safety and Health (DOSH).

822.1.2.4 Industry Regulations, Codes, Standards, and Guidelines.

822.1.2.5 Other Jurisdictions (Not Used)

822.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

822.1.2.6.1 Sound Transit Engineering Procedure 03 – Design Submittal and Review.

822.1.2.6.2 Sound Transit Access Control Lock and Key Policy.

822.1.2.6.3 Sound Transit Bicycle Program.

822.1.2.6.4 Sound Transit Customer Signage Design Manual.

822.1.2.6.5 Sound Transit Equipment and Facilities Numbering Standard.

822.1.2.6.6 Sound Transit Low Impact Development Stormwater Management (LID).

822.1.2.6.7 Station Experience Design Guidelines.

822.1.2.6.8 Sound Transit Bicycle Parking Estimation Methodology.

822.1.3 Abbreviations and Acronyms

822.1.3.1 ADA–Americans with Disabilities Act

822.1.3.2 AHJ– authority having jurisdiction

822.1.3.3 ATM–automated teller machine

822.1.3.4 CCTV–closed-circuit television

822.1.3.5 CES–customer emergency stations

822.1.3.6 CIP–cast-in-place

822.1.3.7 CPTED–Crime Prevention Through Environmental Design

822.1.3.8 EIF–exterior insulation and finish system

822.1.3.9 EP–engineering procedure

822.1.3.10 ESMS–environmental and sustainability management system

822.1.3.11 ERER–emergency responder equipment room

822.1.3.12 ETEL–emergency telephone system

822.1.3.13 FCC–fire command center

822.1.3.14 FCR–fire control room

822.1.3.15 FPZ–fare paid zone

822.1.3.16 HVAC–heating, ventilation, and air conditioning

822.1.3.16.1 LCC–Link control center

822.1.3.16.2 LEFE–low emission fuel efficient vehicle

822.1.3.16.3 LRV–light rail vehicle

822.1.3.16.4 MEP–mechanical, electrical, and plumbing

822.1.3.16.5 MSE–mechanically stabilized earth

822.1.3.16.6 OC –on center

822.1.3.16.7 OCS–overhead contact system

822.1.3.16.8 PA–public audio

822.1.3.16.9 PIMS–passenger information management system

822.1.3.16.10 PET– passenger emergency telephone

822.1.3.16.11 SCR–smart card reader

822.1.3.16.12 SF–square feet

822.1.3.16.13 SOC–Security Operations Center

822.1.3.16.14 STart–Sound Transit Art Program

822.1.3.16.15 TPSS–traction power substation

822.1.3.16.16 TSS–Transportation Safety & Security

822.1.3.16.17 TVM– ticket vending machine

822.1.3.16.18 VMS–variable message system

822.1.3.16.19 WSDOT– Washington State Department of Transportation

822.1.4 Definitions and Classifications

822.1.4.1 Non-Public: areas only accessible by Sound Transit or authorized personnel, also known as back of house.

822.1.5 References (Not Used)

822.2 STAKEHOLDER NEEDS

822.2.1 Passenger Experience

822.2.1.1 Stations must facilitate movement of passengers efficiently, economically, conveniently, reliably, and comfortably.

822.2.1.2 Refer to the Station Experience Design Guidelines for passenger experience expectations.

822.2.1.3 Amenities must not impede passenger flow.

822.2.1.4 Elevator landings must be located so that users waiting for elevators do not impede general circulation, have adequate space for queuing, and are open and visible.

822.2.2 Operational Needs (Not Used)

822.2.2.1 Stations must be designed for safe, convenient, economical, and efficient maintenance and operations.

822.2.3 Maintenance Needs (Not Used)

822.2.4 Safety Needs

822.2.4.1.1 Minimize confined spaces. Refer to Set 001 General for confined space requirements.

822.2.4.1.2 Avoid “mixing zones” between pedestrian and bicycle paths to prevent collisions along paths of travel.

822.2.5 Security Needs (Not Used)

822.2.6 Reliability, Availability and Maintainability Needs

822.2.6.1 To reduce inventory and maintenance costs, materials must be used that are readily available and can be easily repaired or replaced without undue cost or interference with the operation of the Link system. For example, hose bibbs, electrical outlets, lighting fixtures and lamps, glass, or plastic lights must be standardized on commonly available sizes and finishes to ease inventory stocking or direct purchase.

822.2.7 Environmental and Sustainability Needs (Not Used)

822.3 SYSTEM REQUIREMENTS

822.3.1 General Requirements

822.3.1.1 Stations must be designed to facilitate movement of passengers in an efficient, safe, and secure manner. This movement must be in conformance with all applicable codes and design criteria. Stations must aesthetically support the use of proven modern technology while providing for the traditional requirements of public transit systems such as identity as a location for public transit, shelter from severe weather, and cover and screening from average weather conditions.

822.3.1.2 Care must be taken in coordinating and developing the station design with the neighborhood and community, adjacent property owners, and other public agencies and community groups that may have interest in the station.

822.3.1.3 Stations must be designed to enhance both the actual and perceived security of the passenger and staff and to minimize property loss from damage or vandalism.

822.3.1.4 Comply with Set 820 Facility Area Planning for physical barriers outside stations to deter vehicular intrusion.

822.3.1.5 In designing stations, the anticipated growth and long-term life of the system must be considered for functional elements, operation, maintenance, materials, and visual quality. The quality of the designs must have timeless, lasting character and must use high quality, durable, and easily maintained materials.

822.3.1.6 All station public areas must be of high quality. Public areas include all areas used by, and visible to, the public including exterior plazas, general public areas of stations, trackways at stations, and emergency exit paths. Non-public areas are not required to have as high an aesthetic level of quality as public spaces.

822.3.1.7 Comply with Set 820 Facility Area Planning for pedestrian circulation requirements.

822.3.1.8 The design of stations must provide clear orientation and wayfinding for the passenger. To a large extent, this orientation can be accomplished by simplifying how passengers use the system, which can be measured in terms of the ease of passenger access to and dispersal from stations and trains. The ease of passenger access is best achieved by utilizing a common arrangement or organization of the functional spaces in stations. This level of commonality makes each station familiar to passengers and minimizes the need to learn the system on a station-by-station basis. Refer to Station Experience Design Guidelines and Sound Transit Directive Drawings for station layouts.

822.3.1.9 Station capacity must be designed to maintain Level of Service C as defined by the Transit Capacity and Quality of Service Manual. Refer to Station Experience Design Guidelines for calculation methodology and additional requirements.

822.3.1.10 Comply with the Station Experience Design Guidelines for the minimum number of station entrances.

822.3.1.11 All facility naming and numbering must follow the current edition of the Sound Transit Equipment and Facilities Numbering Standard.

822.3.2 Functional Requirements

822.3.2.1 Public access to the station must be restricted to designated public entrances only.

822.3.2.2 Public entrances must be open and direct passengers to the fare collection areas and circulation to the platform. Refer to Section 822.3.26 Fare Vending Area for FPZ requirements.

822.3.2.3 Locate fare collection areas prior to accessing the platform. Fare vending locations and designation of FPZs must be positioned in a similar manner in all stations.

822.3.2.4 The area of the FPZ must be clear and obvious and designated by signage and proximity of SCRs. The transition to FPZ boundary must be indicated by three elements: a tactile floor strip, SCRs, and overhead signage.

822.3.2.5 The FPZ area must provide at least 15 feet of clear space on either side to prevent long queuing of passenger movement near decision points or vertical transportation. This clear space must not overlap with other surge spaces related to vertical transportation elements. Refer to Set 805 Vertical Transportation for minimum dimensions of surge zones.

Commentary: SCRs placed within surge zones of escalators, stairs, or stairs can impede passenger flow through stations.

822.3.2.6 The connection of major spatial elements must minimize the number of decisions a passenger must make at any one point and must be organized in a clear, logical, and sequential manner that reinforces and assists the smooth flow of passengers.

822.3.2.7 Vertical circulation elements must be located to be readily visible and identifiable as a means of access to the levels they are designated to interconnect.

822.3.2.8 Vertical transportation elements must be located to provide equal access for passengers. Refer to the ADA standards for additional information.

822.3.2.9 Stairs and escalators must be located to reinforce the direct travel path from entry to platform.

822.3.2.10 Stairs and escalators must be oriented in the same direction (be parallel) so that passenger movement is simplified and logical, and to provide a readily accessed alternate route via stairs when escalators are not functioning.

822.3.2.11 Access to elevators serving the platform must be in fare paid areas.

822.3.2.12 Comply with Set 805 Vertical Transportation for surge zone requirements.

822.3.2.13 Non-public spaces must be arranged and sized such that equipment is sensibly and safely located, coordinated, easily operable, accessible for maintenance, and a clear path is available for replacement. Large equipment spaces such as TPSS must be located at or near grade for ease of ventilation and equipment maintenance and replacement.

822.3.2.14 Eliminate alcoves in public areas.

Commentary: Alcoves create partially or fully concealed areas that cause safety, security, and maintenance issues and must be avoided. For example, the interim alcove at a future joint development entrance at an existing station continues to generate safety, security, and/or maintenance work.

822.3.3 Material Selection

822.3.3.1 Sound Transit approved standard elements including site furnishings, customer signage systems, paving materials, glazing type and sizes, and light fixture types and lamps must be used to reduce inventory, maintenance efforts, and replacement costs. Refer to Set 801 Architectural Materials, Elements, And Furnishings and Set 1007 Electrical Lighting for requirements.

822.3.3.2 Materials must have the maintenance and performance characteristics to be durable and meet the vandal resistance and maintenance requirements of the station. Materials must be selected considering life cycle costs and total cost of ownership.

822.3.4 STart Program

822.3.4.1 The Sound Transit Art (STart) Program incorporates artwork in and adjacent to stations. Refer to Set 808 STart Program for artwork requirements.

822.3.4.2 The station must accommodate artwork at locations identified by Sound Transit.

822.3.4.3 Artwork locations must not impede passenger circulation, maintenance activities, restrict sightlines, nor pose safety hazards.

822.3.4.4 Artwork must comply with Set 601 Fire/Life Safety requirements.

822.3.4.5 Artwork must not compete with essential system signing, information, and security features, such as CCTV.

822.3.4.6 Maintenance and security requirements for the artwork must be consistent with the maintenance and security requirements of the facility in which it is located.

822.3.4.7 Artwork must work with general facility lighting. Refer to Set 808 STart Program and Set 1007 Electrical Lighting.

822.3.4.8 Artwork supports must be designed to comply with Set 720 Building Structures.

822.3.4.9 Provide artwork infrastructure in accordance with Set 808 STart Program.

822.3.5 Accessibility and Tactile Wayfinding Provisions

822.3.5.1 Provide a redundant accessible route for accessible routes. Travel distance from points of entry/exit must not exceed 600 feet.

Commentary: The goal of providing redundant accessible paths is to provide an equitable experience to all passengers in the event an elevator is out of service and to limit inconvenience. If a ramp or another route is chosen over an elevator, they must provide a similar experience, such as keeping the travel time comparable to someone using stairs and providing weather protection, lighting, and security.

822.3.5.2 Provide tactile wayfinding provisions to assist people with vision impairments.

822.3.5.3 Provide a tactile wayfinding path to guide passengers through the station. Refer to Sound Transit Standard Drawings for layouts/details and Set 801 Architectural Materials, Elements, and Furnishings for acceptable materials.

822.3.5.4 The tactile path must be direct while still considering the pedestrian flow through the station in both directions.

i. Minimize route legs between waypoints.
ii. Changes in direction must utilize 45-degree turns.

Commentary: Tactile paths at existing stations change direction at 90-degree angles; however, this does not accurately reflect the movement of tactile path users.

822.3.5.5 The tactile path must begin at each station entry with a detectable warning surface in a larger square configuration. From the start point, the path must extend to the following elements:

i. Customer information panel/kiosk
ii. Accessible TVM
iii. Card reader
iv. FPZ
v. Platform
vi. Threshold of elevators
vii. Handrail of stairs, escalators, and ramps
viii. Braille signage of restroom

822.3.5.6 Decision points must be indicated with a detectable warning surface in a larger square configuration.

Commentary: Decision points are where the tactile path tees off into more than one direction.

822.3.5.7 Where vertical circulation is collocated, direct the tactile path to the center of the arrangement.

822.3.5.8 At the platform level, the tactile path must extend from the station entries or threshold of public vertical circulation elements to the tactile train waiting/information areas at the center of the platform.

822.3.5.9 The tactile path must be located 4 feet back from the platform edge detectable warning surface. Where platforms wider than 30 feet are used, the path can be moved up to 6 feet back from the platform edge detectable warning surface if there is room for a minimum of 4 feet of circulation on both sides of the tactile path.

822.3.5.10 Comply with Sound Transit Directive Drawings for tactile path dimensions, pattern, and finish.

822.3.5.11 Materials used for the tactile path must be of a contrasting color to the adjacent floor material. Refer to Set 801 Architectural Materials, Elements, And Furnishings for material and Sound Transit Guidance Drawing for typical running pattern. Adjacent pavers or tiles must provide visual contrast for at least 80 percent of the tactile path. Visual contrast must comply with ADA standards.

822.3.6 Tactile Elevator Waiting Area

822.3.6.1 Provide a minimum 6-foot x 6-foot tactile waiting area directly in front of the elevator cab doors at each level. Refer to Set 801 Architectural Materials, Elements, And Furnishings for material. Coordinate drain locations with Set 1002 Mechanical – Plumbing.

822.3.7 Tactile Train Waiting Area

822.3.7.1 Tactile train waiting areas must identify the location of the two center-most sets of doors of a two-car train based on a center platform vehicle stopping location.

822.3.7.2 The tactile train waiting areas must be 6 feet wide and extend the full depth of platforms, except where the platform edge detectable warning tile and the tactile wayfinding path are located. Refer to Sound Transit Guidance Drawings.

822.3.7.3 Pavers with raised ribs oriented parallel to the platform edge must be used. Refer to Set 801 Architectural Materials, Elements, And Furnishings for material.

822.3.7.4 Pavers of the same materials and color as adjacent platform paving may be used.

822.3.7.5 Operational train stopping markers are required to allow vehicle operators to align vehicle doors with tactile train waiting areas. Refer to Set 806 Signage for requirements.

822.3.8 Tactile Platform Edge

822.3.8.1 A platform edge detectable warning surface is required to meet ADA Standards. Provide a 24-inch width of truncated dome pavers along the edge of the platform for the full length of the public use area. Refer to Sound Transit Standard Drawings.

822.3.9 Lighting

822.3.9.1 Refer to Set 1007 Electrical Lighting for requirements.

822.3.10 Emergency Access

822.3.10.1 Refer to Set 601 Fire/Life Safety for requirements.

822.3.11 General Configuration

822.3.11.1 In public areas, eliminate exposed horizontal surfaces that are difficult to access for regular maintenance.

Commentary: Exposed horizontal surfaces in public areas that are difficult to access by Facilities personnel are susceptible to an accumulation of trash and must be avoided. Examples of elimination include access prevention or sloping the surface at a minimum 45-degree angle to promote trash movement.

822.3.12 Platform Geometrics

822.3.12.1 Configuration and Access

822.3.12.2 Station platforms may be of center or side platform type depending on station functional requirements, site constraints, and traffic conditions. Center platform configurations are preferred. Side platforms may be considered if a center platform configuration is precluded by site constraints.

Commentary: Center platforms provide more flexibility for passengers, provide better pedestrian circulation if/when single track operation is required, and reduce the number of escalators and elevators when stations are elevated or below grade.

822.3.12.3 The design approach to the functional configuration of stations must consider patronage forecasts and system characteristics to achieve maximum system efficiency. As the capacity of the system increases, so does the importance of the interrelationship between stations. The objective is to achieve balanced vehicle loading by balancing platform access points within the whole system. Balanced vehicle loading also benefits passenger comfort.

822.3.12.4 Columns and walls are prohibited within 8 feet of a platform edge. Freestanding columns that are within 10 feet of a platform edge must be located so as not to coincide with the locations of vehicle doors during station stops to minimize congestion. Columns beyond 10 feet have no restrictions in their placement. Platform width design must take these column placement constraints into consideration to achieve clearances.

822.3.12.5 Minimize obstructions of passenger and CCTV camera sight lines. Avoid broken lines of sight and dark or obscured areas.

822.3.12.6 Door and gate maneuvering clearances must not encroach the light rail clearance envelope. Refer to Set 520 Vehicle Clearances and Track Spacing for light rail clearance envelope information.
822.3.12.7 Bracing for platform canopy structure must be coordinated with passenger flow, waiting areas, and vertical circulation to minimize interruptions to sight lines.

Commentary: Moment connections are preferred over bracing where possible. Bracing prevents visibility down the platform for passengers and CCTV, while also limiting usable space.

822.3.13 Platform Size

822.3.13.1 The dimensional requirements for station platforms are established by the vehicle length, exiting requirements identified in Set 601 Fire/Life Safety, wayfinding provisions, and the day-to-day passenger requirements as established in this section. Where calculations under the methods lead to different numbers, follow the more stringent.

822.3.13.2 The platform length available for boarding and alighting must be 380 feet to accommodate a four-car consist.

822.3.13.3 Platform widths will vary based on patronage, wayfinding provisions, the configuration of vertical circulation elements (for below-grade, retained cut, and elevated stations), and station site considerations. For initial planning purposes, the minimum platform widths outlined below must be used until patronage numbers are established to confirm or adjust required width of platforms.

i. At-grade, center platform: 20 feet minimum platform width.
ii. At-grade, side platform: 12 feet minimum platform width from edge of platform to the face of station wall, structural element, parapet, or railing.
iii. Elevated, retained cut, or tunnel, center, or side platform: 34 feet minimum platform width will be based on required clearances between the vertical circulation elements and the edge of platform.

822.3.13.4 Encroachment into the platform width by vertical circulation or other platform elements must not reduce the platform width at any given point to less than 8 feet between the edge of platform and the face of a wall, column, balustrade, railing, seating, or any other station furnishing. This dimension is based on the 24-inch platform edge detectable warning surface plus 4 feet (the minimum dimension to the tactile path/striped pattern), plus the 8-inch-wide tactile path/striped pattern, plus one travel lane (measured to the center line of the tactile path/striped pattern). Refer to the Sound Transit Guidance Drawings.

822.3.14 Platform Interface with LRV

822.3.14.1 The vertical distance between top of rail and finished platform floor and the horizontal distance between the centerline of track and platform edge are critical dimensions governed by the vehicle specifications. The allowed gap between the vehicle and the edge condition of the platform must meet ADA Standards. Refer to Sound Transit Standard Drawings and Set 421 Vehicles – Light Rail.

822.3.15 Platform Slope, Adjacent Trackway and Platform Edge Condition

822.3.15.1 The platform must have a cross slope of one percent to drain the platform towards the trackway.

822.3.15.2 The platform must be parallel to the vertical grade of the adjacent track alignment and maintain the prescribed distance from the edge of the platform to the top of rail for the full length of the platform. See Set 521 Track Geometry for maximum longitudinal slope of platform.

822.3.15.3 Comply with 520 Vehicle Clearances and Track Spacing for track clearances at platforms.

822.3.15.4 Platform edge condition must be as shown in Sound Transit Standard Drawings. Tolerances and clearances to track must be per Sound Transit Directive Drawings and Set 520 Vehicle Clearance and Track Spacing. Refer Set 801 Architectural Materials, Elements, And Furnishings for standard materials.

822.3.15.5 The platform edge angle must allow adjustability of up to 1/4 inch in both the horizontal and vertical direction to allow for adjustment during construction. This does not eliminate the need to meet the platform edge tolerances identified in Sound Transit Standard Drawings; it merely allows adjustability during construction to meet those tolerances more easily.

822.3.15.6 Provide between-car barriers at platform edge the three platform edge locations where LRV cars are connected to each other. Refer to the Sound Transit Customer Signage Design Manual for material requirements.

Commentary: Between-car barriers are an FTA requirement.

822.3.15.7 Refer to Set 721 Bridges and Elevated Structures for guardrail requirements at the edge of guideway.

822.3.15.8 Travel Lanes / Exit Provisions

822.3.15.9 The minimum exit provisions must be as required by IBC and NFPA 130, as modified by local jurisdictions. See Set 601 Fire/Life Safety for calculating exiting requirements.

822.3.15.10 Travel lanes must not occupy surge zone areas in front of elevator doors, TVMs, passenger assistance telephones, pay phones, SCRs, dynamic signs, and customer information/maps.

822.3.15.11 Vertical Clearances

822.3.15.11.1 Provide a minimum radial clearance of 10 feet from the OCS to other station elements.

822.3.15.11.2 Station elements that could be targeted for theft or vandalism must be located to provide a minimum of 9 feet clear above floor surface or as required by code.

Commentary: Examples of station elements include light fixtures, speakers, cameras, and signs.

822.3.15.11.3 Locate station furniture, such as seating and trash receptacles, in a manner that does not allow easier access to station elements that can be targeted for theft or vandalism.

Commentary: This prevents passengers from climbing on the furniture to access overhead station elements.

822.3.15.11.4 Horizontal elements, such as canopy framework or sign units that could be climbed upon, must also be located above 9 feet.

822.3.15.11.5 Vertical elements must be designed to minimize the ability to climb them.

822.3.15.11.6 Elements along walls, such as suspended signs, may be located a minimum of 8 feet above the platform if needed to achieve visibility.

822.3.15.11.7 Locate equipment and light fixtures between 9 feet and 16 feet above the floor or other flat surface for access. Where equipment, lighting, or other elements are above 16 feet high, such as tunnel stations, roofs, canopies, and window walls, fall protection must be provided for maintenance crews to safely access these areas. Refer to Set 804 Fall Protection for requirements.

822.3.15.11.8 For stations with systems or elements with no ability to be serviced by a 12-foot ladder or other protected system, provide storage for a scissor lift, storage for the lift, clear access paths, and elevator capacity.

822.3.15.11.9 The platform end landing edge adjacent to track access stairs must be protected with a 4-inch toeboard.

Commentary: This is to stop tools and other objects from rolling off the platform to the track below or between the guideway.

822.3.16 Elements of Vertical Transportation

822.3.16.1 Quantities and types of vertical transportation at stations must be determined according to the methodology described in Set 805 Vertical Transportation.

822.3.16.2 Comply with requirements, including configuration, geometry, and accessories, described in Set 805 Vertical Transportation for:

i. Stairs
ii. Ramps
iii. Sloping walks
iv. Elevators
v. Escalators

822.3.16.3 Refer to Set 801 Architectural Materials, Elements, And Furnishings for vertical transportation material requirements.

822.3.17 Station Entries and Weather Protection

822.3.17.1 Station Entries

822.3.17.2 Station entries must be transparent and unobstructed to allow clear surveillance and the ability for passengers to see all areas quickly and to be seen. Entries must direct the passenger through the entry sequence of FPZ and circulation to the platform in a seamless manner.

822.3.17.3 Weather protection must be provided over the entry of the station through the fare vending area.

822.3.17.4 Stations, other than at-grade stations adjacent to or open to public streets, must have the ability to be secured during non-revenue hours.

Commentary: It is preferable to have the security closure in-line with or in front of the FPZ.

822.3.17.5 Security closures must be overhead vertical lift gates that are connected to the LCC for off-site operation. Vertical lift gates must be a stacking style with number and size of panels based on available clearances.

Commentary: Wide security closures such as vertical lift gates facilitate ease of pedestrian flow.

822.3.17.6 A secondary ADA compliant man door exit with egress hardware, or as otherwise required to meet code requirements, must be provided within 10 feet of the area that is being secured.

822.3.17.7 Station entry signs, hours of operation signs, and VMS must be visible to the public when the security closure is down.

822.3.17.8 Weather Protection

822.3.17.9 Though the Pacific Northwest climate allows for open stations, passenger protection from the sun, rain, wind, accumulated snow, and ice warrant special consideration. Weather protection from precipitation must be provided for the following:

i. All public access points to the station.
ii. Public stairs and adjacent surge zones.
iii. Escalators and elevators and adjacent surge zones.
iv. Fare vending equipment and adjacent surge zones.
v. System map viewing areas and other passenger facilities, such as dynamic signs and emergency telephones.
vi. Platform areas in accordance with Section 822.3.11 Platform Geometrics.

822.3.17.10 In general, canopy and wind screen design must assume that rain is falling at a 15-degree angle from vertical; however, the orientation of a station platform will impact the effectiveness of canopies in providing shade and rain protection. Station orientation must be considered in developing canopy and wind screen concepts on a station-specific basis. Canopy drainage must not discharge onto the platform, sidewalks, or other pedestrian routes.

822.3.18 Platform Canopy

822.3.18.1 Canopy Coverage

822.3.18.1.1 Provide the following canopy coverage according to the station type.

i. At-grade stations: Minimum of 30 percent of the platform area.
ii. Elevated stations: Minimum of 65 percent of the platform area.

Commentary: Platform area includes the detectable warning surface at the platform edge, stairs, escalators, elevators, surge zones, and central boarding areas.

822.3.18.1.2 Canopy must extend over the platform area and as close to the platform edge as permitted by the vehicle and overhead catenary clearance envelope.

822.3.18.1.3 Canopy must cover the central boarding area including the tactile train waiting/information areas.

822.3.18.1.4 Canopy must be continuous from elevators to the central boarding area of the platform.

822.3.18.1.5 Canopy must be provided for public stairs, escalators, and all surge zones.

822.3.18.1.6 Canopy must be provided over all windscreens. Where the path between the elevators and the tactile train waiting areas is in front of windscreens, provide a 3-foot minimum canopy coverage plus coverage as needed due to fifteen degree rain angle.

822.3.18.1.7 The combined coverage of canopies and windscreens must maintain an open station classification.

Commentary: AHJs may interpret extensive canopies combined with windscreens as enclosed stations. Refer to Set 601 Fire/Life Safety for additional information.

822.3.18.2 Canopy Structure

822.3.18.2.1 A basic design module of 4 feet OC must be employed in the design of canopies and related structures to permit the consistent accommodation of signage, standardized glazing, and station furnishings.

822.3.18.2.2 Platform canopies must be supported by groups of columns centered on the platform for center platform stations or supported at the platform edge opposite the trackway for side platform stations.

822.3.18.2.3 Canopies must be designed to support maintenance crews for cleaning of glazing and gutters. Canopy structures and related connection points must have adequate structural capacities to safely support fall protection system loads including maintenance crews and equipment loadings. Refer to Set 804 Fall Protection for requirements.

822.3.18.2.4 Canopy structures must be designed to accommodate signage. Refer to SET 1102 Passenger Information Management System (PIMS).

822.3.18.3 Canopy Clearances

822.3.18.3.1 Canopy designs must accommodate clearances required for the LRV and the OCS.

822.3.18.3.2 Canopies and their structures must provide clear floor space conforming to ADA standards.

822.3.18.3.3 The minimum vertical clearance under the canopy, or any equipment attached to same, must be 9 feet.

822.3.18.4 Canopy Drainage

822.3.18.4.1 Canopies must slope away from the platform edge with drainage collection near the center of a center platform station or near the back of a side platform station.

Commentary: Sloping the canopy away allows for gutter cleaning with lesser impact to train service.

822.3.18.4.2 Minimum slope of canopies is 1.5 percent.

822.3.18.4.3 Canopies that are directly adjacent to walls or other vertical surfaces must provide protection to prevent water dripping between the surface and the canopy.

Commentary: Small gaps between a canopy and adjacent surface are difficult to maintain, create moisture issues, and cause uneven weathering on the surface materials.

822.3.18.5 Canopy Materials

822.3.18.5.1 Canopies must be composed of materials that are durable and economical to repair or replace. Refer to Set 801 Architectural Materials, Elements, And Furnishings for requirements.

822.3.19 Windscreens

822.3.19.1 Windscreen Coverage

822.3.19.1.1 To protect passengers from wind and wind-blown rain, transparent windscreens must be provided on the platform. Windscreens must be covered by platform canopies and oriented to protect passengers against prevailing winds. Windscreens must include side panels to allow protection from weather in multiple directions.

822.3.19.2 Windscreen Location

822.3.19.2.1 Provide windscreens at the perimeter of the openings for stairs, escalators, and elevators. At these locations, provide canopy coverage for a minimum depth of 3 feet plus coverage as needed to account for the 15-degree rain angle. Windscreen side panels are not required in these locations because they would intrude on the 8-foot clearance from the platform edge.

822.3.19.2.2 Provide areas protected by windscreens on three sides where platform geometry allows this. Provide a minimum area of 500 square feet with windscreen protection on three sides for elevated platforms.

822.3.19.2.3 At side platform stations, each platform must be provided with at least half of the canopy length of windscreen. Where side platform stations are directly adjacent to streets, provide windscreen for at least 80 percent of the length of the canopy.

822.3.19.3 Windscreen Layout

822.3.19.3.1 A basic planning module of four feet OC must be used. Refer to Set 801 Architectural Materials, Elements, And Furnishings for material and size requirements.

822.3.19.3.2 Provide a gap measuring between 4 inches and 6 inches at the bottom of windscreen framing for ease of cleaning and visibility except where windscreen is adjacent to a street, parking, or landscape areas where no gap is required to prevent splash from vehicle traffic or planting areas.
822.3.19.3.3 Provide closure trim between adjacent surfaces if windscreen creates an accessible gap of 1 inch to 6 inches.

Commentary: The intent of this is to minimize debris collection in inaccessible areas behind windscreens that are difficult to clean.

822.3.19.4 Windscreen Material

822.3.19.4.1 Windscreens must be transparent to allow clear surveillance of station areas for passenger security and to discourage vandalism. Lower portions of windscreens may be solid or semi-transparent to minimize damage to lower glazing due to kicking and to protect passengers from environments outside the platform, such as spray from vehicular traffic.

822.3.19.4.2 Glazing and other infill material sizes must be standardized to allow ease of replacement. Refer to Set 801 Architectural Materials, Elements, And Furnishings for requirements.

822.3.19.4.3 Windscreens must extend to the underside of the canopy. The canopy edges must extend past the windscreens to maximize protection from inclement weather. Gaps between the windscreen and canopy are permitted where necessary to meet the definition of open station.

822.3.19.4.4 Provide lean rails for a minimum of one third of the linear length of the windscreens.

822.3.20 Station Furniture

822.3.20.1 Seating

822.3.20.1.1 The minimum seating provided at platform level must be 30 seats at a center platform and 20 seats for each side platform.

822.3.20.1.2 The seating must be uniformly distributed to three or more locations along platform areas, with one required location near a train door.

Commentary: Providing seats near a train door allows passengers who need or want to rest without having to rush when a train arrives or leaves.

822.3.20.1.3 At least 60 percent of the seating must be protected within areas covered by canopy.

822.3.20.1.4 Additional seating must be located near each public entry point (fare vending areas) to the station and arranged so that they do not interfere with passenger circulation or emergency exiting.

822.3.20.1.5 Platform seating must be designed with backs and full-length armrests to facilitate use by individuals with disabilities. Backs are not required if seating is accessible from both sides. Seating areas must be placed to allow space for a wheelchair user to be located next to a bench.

822.3.20.1.6 Standard seating must be used. Refer to Set 801 Architectural Materials, Elements, And Furnishings for standard seating and other requirements.

822.3.20.1.7 Refer to Set 820 Facility Area Planning for seating at areas surrounding stations.

822.3.21 Ancillary Spaces

822.3.21.1 Ancillary spaces such as electrical rooms, elevator machine rooms, train control and communications rooms, and janitor closets, as well as traction power rooms or buildings, may be required at stations. Specific requirements, such as quantities, must be determined on a station-by-station basis in the station program during initial station layout.

822.3.21.2 In addition to systems requirements, stations with more than one level and containing vertical transportation must include, at minimum:

i. Janitor's Closet
   a. Quantity: One.
   b. Size: 100 square feet; must accommodate open floor area to store cleaning equipment, including area directly beneath wall shelving.
   c. Location: Must be within the station boundary and easily accessible by maintenance staff. When public restrooms are provided, must be within 50 feet of public restrooms.
   d. MEP: Emergency eye wash, mop sink, hot and cold potable water at mop sink. Refer to Set 1002 Mechanical – Plumbing for potable water requirements. Include a recessed or suspended electric unit heater for heating and louver for ventilation. Refer to Set 1003 Mechanical – HVAC for ventilation requirements. Refer to Set 1007 Electrical Lighting for lighting requirements.
   e. Openings: Minimum 40-inch-wide door or a pair of 36-inch-wide doors.
   f. Door hardware: Closers. Refer to Set 801 Architectural Materials, Elements, And Furnishings for additional requirements.
   g. Furnishings: 15 linear feet of wall-mounted metal shelving, and wall-mounted mop rack above the mop sink.
   h. Materials: Finishes and wall substrates must be moisture and impact resistant. Provide stainless steel wall guard(s) at the mop sink to contain splashes. Provide sealed concrete flooring.

ii. Storage Room
   a. Quantity: One.
   b. Size: 100 square feet, must accommodate open floor area to store cleaning equipment
   c. Location: At grade.
   d. MEP: Refer to Set 1007 Electrical Lighting for lighting requirements.
   e. Openings: Access door to be 40-inch-wide minimum or a pair of three-foot-wide doors.
   f. Storage room to be separate from janitor's closet.
   g. Furnishings: Minimum 15 lineal feet of metal shelving.

iii. Storage Closet
   a. Quantity: One.
   b. Size: Must accommodate storage for signage and barricades per the following:
      i. Short-term outage signs: One sign per vertical conveyance per level it serves.
      ii. Platform outage signs: One sign per station entrance, one sign per station concourse/mezzanine, and one sign per out-of-service platform.
      iii. Inaccessible station signs: one sign per station entrance, one sign per concourse/mezzanine, and one sign per platform.
      iv. Barricades to cover approximately 20 percent of outages at any given time
   c. Location: Accessible to authorized personnel including Facilities and station agents.
   d. Storage closet to be separate from janitor's closet and main storage room

iv. Emergency Responder Equipment Room
  a. Quantity: One.
  b. Size: Comply with Set 601 Fire/Life Safety for size requirements.
  c. MEP: Refer to Set 1007 Electrical Lighting for lighting requirements.

v. Unisex Staff Restroom. See below for restroom requirements.
  a. Quantity: One.

vi. Trash Enclosure
  a. Quantity: One.
  b. Size: Accommodate two four cubic yard dumpsters.
  c. Location: Adjacent to truck access from local garbage hauler.
  d. Openings: Provide a pair of 3-foot-wide doors or gates.
  e. Door Hardware: Lock separately from other trash enclosures on site.
  f. Enclosure: Screen dumpsters from view or locate within a room. Trash enclosure must be roofless.

vii. Security Office
  a. Quantity: One
  b. Size: 80 square feet. Room layout must accommodate ADA compliant turning space.
  c. Location: Near public restrooms when provided and near elevators if no public restrooms are provided. Where public restrooms are provided, the security office must be located such that the transaction window has an unobstructed sightline to the public restroom doors.
  d. MEP/Communication: Provide power receptacles and HVAC, radio service, PET directly outside the Security office door. Where multiple doors exist, the PET must be located by the main door facing the public area. CCTV coverage must be provided inside the Security Office. Refer to Set 1007 Electrical Lighting for lighting requirements.
  e. Openings: Two exits out of the security office are preferred with relites in doors for visibility
  f. Furnishings: Desk surface for two computers/laptops, two network connections, and phone connections. Provide 36-inch x 36-inch minimum transaction window with SS frame surround and clear, bullet-resistant glazing material. Refer to Set 801 Architectural Materials, Elements, And Furnishings for glazing requirements. Additional accessories must include bullet-resistant speaking aperture for passive voice transmission or a bullet-resistant window with separate intercom device, SS shelf, and weather-protected deal tray. Transaction window and accessories must be ADA compliant. Provide privacy blinds on the interior side of the transaction window.
  g. Bullet-Resistance: Public-facing walls, windows, and doors must be bullet-resistant and rated for minimum Level 3 in compliance with UL 752. Refer to Set 801 Architectural Materials, Elements, And Furnishings.
  h. The security office is considered a High Security Area.
  i. An additional security office must be provided when a facility is identified as a major security hub. Coordination with Sound Transit Security must be made in determining its need.

822.3.21.3 At-grade stations do not require rooms other than for systems requirements.

822.3.21.4 Terminus stations must include rooms noted for grade-separated stations. Additional required rooms include:

i. Unisex Staff Restroom
  a. Quantity: Two.
  b. Location: As recorded in executed agreement with Link operator partner and adjacent to crew room. One restroom must be for exclusive use of Link operators and must be signed as such. The other restroom will be shared by staff. See Section 822.3.21 Restrooms for requirements.

c. MEP: Provide power receptacles per Set 1005 Electrical Power and lighting per Set 1007 Electrical Lighting.

ii. One Supervisor's office

a. Quantity: One.
b. Size: 100 square feet.
c. Furnishings: One workstation
d. MEP/Communication: HVAC, power receptacles, network connection, and phone. Provide lighting per Set 1007 Electrical Lighting.
e. Enclosure: Provide daylighting where possible with relites in doors with access to circulation areas.

iii. One Crew Room

a. Quantity: One.
b. Size: Accommodate amenities and associated maneuvering clearances
c. Furnishings: ADA-compliant appliances and accessories, including microwave, undercounter refrigerator, compost and waste receptacles, paper towel holder, four-foot minimum counter area, table, and chairs to accommodate four personnel, space for two vending machines.
d. MEP/Communication: Provide HVAC, power receptacles, sink with chilled and filtered water, and phone jack. Provide lighting per Set 1007 Electrical Lighting.
e. Enclosure: Provide daylighting where possible.

822.3.21.5 Provide adequate access for equipment maintenance envelopes and replacement paths. Clearances must be demonstrated early in the design process. Refer to Project Implementation and Integration Plan for equipment clearance diagram deliverables. Rooms containing large equipment such as the TPSS transformers must be located at or near grade and must have an equipment replacement path defined. Special considerations must also be made for removal and replacement of tunnel and smoke emergency ventilation equipment including providing removal paths.

822.3.21.6 All overhead smoke/heat detectors, HVAC components, access panels, etc. must be accessible and unobstructed in all ancillary spaces. Refer to Set 1003 Mechanical – HVAC and Set 601 Fire/Life Safety for additional requirements.

822.3.21.7 Where systems equipment would be visible to the public from public rights-of-way, private property or stations, provide screen walls of a height to conceal equipment. Gates and access points must be coordinated with screening to provide a secure area for the systems equipment. Do not rely on landscape screening to screen equipment. See Set 802 Landscaping for requirements of off-site landscape areas and landscape screens.

822.3.21.8 Provide maximum travel distance of 300 feet between ancillary spaces and a service vehicle parking stall.

822.3.21.9 Design of ancillary spaces must be compatible with the station architectural scheme.

822.3.21.10 Where systems buildings are not enclosed within a station or facility and are visible to the public, provide an architecturally interesting and secure screen compatible with the neighborhood to enclose systems buildings. Comply with local code for additional screening requirements.

822.3.21.11 Non-public rooms must provide an accessible door and maneuvering clearances as required by ADA Standards. Permanent elements or equipment must not block these clearances.

Commentary: Exceptions may be permitted for spaces with ladder access only, narrow access, or required change in elevation. Confirm all exceptions with Sound Transit Accessibility Services and Employee & Construction Safety.

822.3.21.12 Provide lites at interior doors at occupiable ancillary spaces, such as crew rooms or offices. Comply with Set 801 Architectural Materials, Elements, And Furnishings for material and finish requirements.

Commentary: Door lites allow visibility in back of house spaces for safety purposes. Consider different glazing types where necessary for security.

822.3.21.13 Comply with Set 601 Fire/Life Safety, Set 1003 Mechanical – HVAC, Set 1005 Electrical Power, and Set 815 Telecommunication Spaces for space needs associated with fire protection, MEP, and communication requirements of ancillary spaces.

822.3.21.14 Provide fare ambassador hubs at the following locations:
- Alaska Junction Station (West Seattle Extension)
- SODO Station (West Seattle Extension)
- Ballard Station (Ballard Extension)
- Everett Station (Everett Extension)
- Tacoma Dome Station (Tacoma Dome Extension)
- Central Issaquah Station (South Kirkland Issaquah Extension)
- South Kirkland Station (South Kirkland Issaquah Extension)
- Tacoma Community College Station (TCC Extension)

822.3.21.14.1 For each fare ambassador hub, provide:
- Two supervisor offices with desks. These are in addition to the already required supervisor offices.
- Break room (combined with required crew rooms at Link terminus stations) must be large enough to accommodate all employees who will be using it at the same time, which is approximately six fare ambassadors maximum, in addition to any other users.
    - o <u>Quantity:</u> One
    - o <u>Size</u>: Accommodate amenities and associated maneuvering clearances
    - o <u>Furnishings:</u>
        - ▪ Garbage, recycling, and compost bins
        - ▪ Microwave
        - ▪ Mini fridge
        - ▪ One shelf 30 by 12 inches deep for print material
        - ▪ Wall-mounted time clock terminal for check-in/out
        - ▪ First aid supplies
        - ▪ 12 half- or full-size lockers for storing weather gear
        - ▪ 10 cages 24 inches wide by 42 inches deep and 78 inches tall to hold and charge Phones and printers
        - ▪ Table and chairs to accommodate 15 staff (including fare ambassadors, security, etc.).
          Note: Break room seating may be reduced to 10 staff at Alaska Junction and SODO stations.
    - o <u>MEP/Communication</u>: Provide HVAC, power receptacles, sink with chilled and filtered water, and phone jack. Provide lighting per Set 1007 Electrical Lighting, and a sink with running water and soap for employees to wash their hands. Potable water sources must allow for refilling of company-issued 11-inch-tall water bottles (water bottle fillers preferred).
- Restrooms available to the fare ambassadors. Number of restrooms provided shall at a minimum support the Break Room occupancy.

822.3.22 Restrooms

822.3.22.1 Comply with Set 801 Architectural Materials, Elements, And Furnishings for restroom requirements.

822.3.22.2 Staff Restrooms

822.3.22.2.1 Staff restrooms must be provided at locations as determined by the Sound Transit.

822.3.22.2.2 At staff restrooms are designated for use by Link operators. Provide special access control provisions compliant with the executed agreement with the Link operator partner.

822.3.22.3 Public Restrooms

822.3.22.3.1 Public restrooms must be provided at stations when all the following criteria are met:

i. A station averages 10,000 or more boardings per day.
ii. A station where the nearest public restroom is farther than a 20-minute ride.
iii. Five or more transit routes converge at a location.

Commentary: Where code requires public restrooms at stations not meeting the criteria, Sound Transit and the designer of record will investigate if AHJ will consider waiving this code requirement in order to meet Sound Transit Board Policy.

822.3.22.3.2 Provide public restrooms at the following locations when Sound Transit deems them to be required:

i. At stations that are inaccessible during non-revenue hours: public restrooms must be located within the FPZ.
ii. At stations that are accessible during non-revenue hours: public restrooms must be located within the station area, visible from pedestrian traffic flows, and have restroom doors secured behind a dedicated gate or grille during non-revenue service.

822.3.22.4 Comply with Set 1203 Access Control for concept of operations for public restroom access.

822.3.22.5 Comply with other sections in this set and Set 801 Architectural Materials, Elements, And Furnishings for materials requirements in public restrooms.

822.3.23 Advertising

822.3.23.1 Refer to Set 801 – Architectural Materials, Elements, And Furnishings for system-wide advertising review, approval, placement, and other requirements.

822.3.23.2 See Set 801 – Architectural Materials, Elements, And Furnishings for additional advertising requirements.

822.3.24 Trash and Recycle Receptacles

822.3.24.1 Trash and recycle receptacles are prohibited on platforms at tunnel or elevated stations.

822.3.24.2 Trash and recycle receptacles at at-grade stations must be placed in clear areas away from canopies and windscreens.

822.3.24.3 A minimum of one trash receptacle and one recycle receptacle near each other per fare vending area must be provided.

822.3.24.4 Refer to Set 820 Facility Area Planning for receptacle requirements in areas surrounding stations.

822.3.24.5 Standard trash and recycle receptacles must be used. Refer To Set 801 Architectural Materials, Elements, And Furnishings.

822.3.24.6 Comply with Set 801 Architectural Materials, Elements, And Furnishings for additional receptacle requirements.

822.3.25 Plumbing Requirements

822.3.25.1 Comply with Set 1002 MEP – Plumbing for hose bibb and drainage requirements.

822.3.25.2 Piping must be run in an organized manner and be incorporated within chases to reduce visual clutter and deter bird roosting. Where piping must be exposed to view in public areas, lines, hangers, and related appurtenances must be configured and installed in an organized manner, tight to adjacent surfaces, and painted to match those surfaces. Where piping is exposed in public or non-public areas outside of closed rooms, provide bird deterrent devices.

822.3.26 Electrical Conduit and Receptacles

822.3.26.1 Electrical conduits, junction boxes, and appurtenances required to support the electrical system at stations must be hidden from public view by locating them in an organized manner within raceways, cable trays, or chases. Design raceways and chases to deter bird roosting. Conduit exposed to view in public areas of the stations is prohibited. Where conduits must be exposed to public view to connect to equipment or fixtures, the conduit and any junction boxes must be in an organized manner, tight to adjacent surfaces and painted to match those surfaces. Where horizontal conduits are exposed in public or non-public areas outside of closed rooms, provide bird deterrent devices. Refer to Set 1005 Electrical Power for electrical requirements.

822.3.26.2 Raceways from public areas which service the platform or guideway must be protected from vehicular traffic, climbing, and access via bollards, curbs, and/or fencing.

Commentary: Vehicles can hit vertical raceways servicing the guideway. Additionally, the support structures for the conduit commonly create ladders for climbing.

822.3.26.3 Receptacles and outlet boxes in public spaces must be flush mounted or recessed.

Commentary: These are frequent targets of vandalism.

822.3.27 Fare Vending Area

822.3.27.1 These areas must include:

i. Customer information panels, as described in the Sound Transit Customer Signage Design Manual.
ii. TVMs. See Set 1103 Fare Vending for quantity calculation methodology.
iii. SCRs. See Set 1103 Fare Vending For quantity calculation methodology.
iv. Bench.
v. Location and conduits for future dynamic rider information sign (previously Trip Planner).
vi. PET.

822.3.27.2 Fare vending areas must be located prior to entering the FPZ and platform. See Sound Transit Guidance Drawings for general layout. Allow a 30-inch by 48-inch surge zone in front of each TVM.

822.3.27.3 Fare vending equipment, information displays, and adequate queue space must be located to ensure required travel lanes are not obstructed.

822.3.27.4 All elements located within the fare vending areas must be weather protected and rated as exterior grade.

822.3.27.5 TVMs must be protected from rain above and on all sides. Assume rain at a 15-degree angle from vertical.

822.3.27.6 Protect TVM screens from sun and glare. Canopies must be large enough to prohibit sun from reaching the TVM screens in all seasons. Where this is not practical, orient TVMs to reduce glare and sun exposure, or provide screening or landscape to shade TVMs.

822.3.27.7 Where TVM orientation is limited and glare or sun exposure is likely, consult with Sound Transit to determine if special TVM screens may be warranted.

822.3.27.8 Include space for one future Dynamic Passenger Information Sign (previously Trip Planner) at each TVM area. Provide a 30-inch-deep x 36-inch-wide surge space at the dynamic sign location outside required circulation space.

822.3.27.9 Locate SCR adjacent to passenger circulation after the TVMs but before the platform area. Align with “Fare Paid Zone” customer signs. See Sound Transit Customer Signage Design Manual.

822.3.27.10 Refer to Set 1103 Fare Vending for information on quantity, spacing, location, and other data on ticket vending machines, SCRs, and related facilities.

822.3.28 Fare Paid Zone

822.3.28.1 The transition to the FPZ boundary must be indicated by three elements: a tactile floor strip, SCRs, and overhead signage.

822.3.28.2 The FPZ boundary must be located between the TVM area and the entry to the platform.

822.3.28.3 In grade-separated stations, the FPZ boundary must be located so that the vertical circulation elements (ramps, stairs, escalators, and elevators) are within the FPZ.

822.3.28.4 At stairs and escalators, the FPZ boundary must be located at least 10 feet outside of the stair and escalator surge zones.

Commentary: Exceptions may be allowed with Sound Transit approval at existing stations and at stations where space is constrained, and pedestrian flow will not be impeded.

822.3.28.5 Elevators serving the platform must be behind the FPZ boundary.

Commentary: At elevators for existing stations, the tactile pavers which are required per the DCM will serve as the tactile cue for the FPZ.

822.3.28.6 FPZ signage must be continuous above the tactile floor strip and must follow the same path. Signage must be aligned with the tactile floor strip and approximately the same length.

822.3.28.7 Signage above the tactile floor strip is based upon current standard signage. This signage weighs 32 pounds per lineal foot. Pendant mounts are preferred. The minimum required height from finish floor to bottom of signage is 9 feet. If there is directional signage mounted below the FPZ signage, then the lowest sign must be a minimum of 9 feet above finish floor.

Commentary: It is preferred to mount the signage at 9 feet above finish floor for optimal passenger sightlines.

822.3.28.8 The FPZ tactile floor strip must be 24 inches. Comply with Set 801 Architectural Materials, Elements, And Finishes for FPZ flooring requirements.

822.3.28.9 A 15-foot by 15-foot surge zone must be provided on either side of the FPZ boundary. This surge zone must not overlap any other surge zones.

Commentary: This surge zone is to provide space for queueing at SCRs.

822.3.29 Signage

822.3.29.1 Architectural elements, landscaping, and other design features must identify destination points such as entrances, exits, and traffic routes without the need for signage to identify the function.

822.3.29.2 Comply with signage requirements described in Sound Transit Standard Specification 10 14 00, Set 806 Signage, and the Sound Transit Customer Signage Design Manual for:

i. Station signage
ii. Regulatory and room signage
iii. Operational train stopping markers
iv. Signage at terminus stations
v. Public audio and variable message signs (PA/VMS)
vi. Equipment and room numbering
vii. Digital signage
viii. Customer signage

822.3.30 Telephones

822.3.30.1 Public Telephone

822.3.30.1.1 Public telephones are prohibited at Sound Transit facilities.

822.3.30.2 PET

822.3.30.2.1 PETs are required at stations. The station designer must accommodate these devices and incorporate them into the station design. PETs must be located as identified in Set 302 Telephony. See Sound Transit Customer Signage Design Manual for applicable customer signage.

Commentary: PETs may serve as two-way communication for areas of refuge and elevator lobby systems were required. Refer to Set 601 Fire/Life Safety for additional information.

822.3.30.3 ETEL

822.3.30.3.1 ETEL are required at stations. The station designer must accommodate these devices and incorporate them into the station design. ETEL must be back-up communications for the Fire Department and other emergency personnel. Reference Set 302 Telephony for requirements.

822.3.31 CCTVs

822.3.31.1 The station designer must accommodate and incorporate CCTV into the station design. Refer to Set 1202 CCTV for requirements and locations.

822.3.32 Fire and Emergency Responder

822.3.32.1 FCC and FCR

822.3.32.1.1 FCC or FCR must be adequately sized based on input from electrical, mechanical and systems designers and the local AHJ. Refer to Set 601 Fire/Life Safety and Sound Transit Systems Guidance Drawings for additional requirements.

822.3.32.2 ERER

822.3.32.2.1 ERER must be adequately sized based on Sound Transit emergency response equipment as coordinated with AHJ. Refer to Set 601 Fire/Life Safety and Sound Transit Systems Guidance Drawings for additional requirements.

822.3.32.3 Emergency Responder Equipment Cabinet

822.3.32.3.1 Where required by AHJ, provide a lockable, metal Emergency Responder Equipment Cabinet on the platform to contain four emergency “grab-and-go” backpacks. Refer to Sound Transit Guidance Drawings.

Commentary: Emergency Responder Equipment Cabinets are an alternative solution to ERER only, not in addition to.

822.3.33 Bird Control

822.3.33.1 Design facilities to prevent the creation of bird roosts, perches, or nesting areas. Refer to Set 801 Architectural Materials, Elements, And Furnishings for bird control requirements.

822.3.33.2 Where horizontal surfaces and pendant lights cannot be avoided, include bird deterrent as part of the project. Refer to Set 801 Architectural Materials, Elements, And Furnishings for bird control requirements.

822.3.34 Window Washing System

822.3.34.1 Comply with Set 804 Fall Protection for window washing system requirements.

822.3.35 Fall Protection

822.3.35.1 Stations must include structural features to allow general maintenance to occur. Refer to Set 804 Fall Protection for means of access and fall protection requirements.

822.3.36 Lighting

822.3.36.1 Lighting design must facilitate passenger movement and assist in providing site security.

822.3.36.2 Comply with Set 1007 Electrical Lighting for illumination requirements.

822.3.37 Vending Machines and Concessions

822.3.37.1 Refer To Sound Transit Board Motions M98-58 and M98-66 for additional requirements on ATMs, passenger amenities, and concessions.

822.3.37.2 Vending Machines

822.3.37.2.1 At Sound Transit direction, allocate space and provide power for vending machines which may include beverage or snack vending, ATMs, or other types of passenger conveniences.

822.3.37.2.2 Vending machines are prohibited on the platform.

822.3.37.2.3 Vending equipment and adjacent surge space must not obstruct required site and station circulation.

822.3.37.2.4 Vending machines must have weather protection.

822.3.37.3 Food Service Vending Trucks

822.3.37.3.1 Comply with Set 820 Facility Area Planning for food service vending truck requirements.

822.3.37.4 Built-in Concessions / Retail Spaces

822.3.37.4.1 At Sound Transit direction, provide built-in concessions and/or retail spaces within the station facility. Sound Transit shall determine, based on market analysis, whether conditions allow for positive net revenue and rents sufficient to recover capital costs and annual maintenance for required mechanical, electrical, restroom facilities, and other facilities required to support these spaces.

822.3.37.4.2 Requirements of built-in facilities must be determined based upon the market analysis conditions.

822.3.37.4.3 Determine services required by code for retail and/or food service. Sound Transit to direct what facilities to be built initially. Utilities used for non-transit activities by tenants connected to Sound Transit's utilities must be separately metered for billing purposes.

822.3.37.4.4 If concessions or retail spaces are included with the project, consider provisions for delivery parking and garbage/recycle collection. These provisions must be separate and in addition to the station requirements.

822.3.38 Rooftop Structures

Commentary: Rooftop structures can present readily available points of access to a facility accessible to the public.

822.3.38.1 Infrequently used access points, such as openings in elevator penthouses, rooftop hatchways, and trap doors must be secured using the following requirements.

822.3.38.2 Rooftop access points must be secured with approved high security tamper proof padlocks, locks, and/or security bars.

822.3.38.3 Roof areas with HVAC equipment must be treated like mechanical areas. Fencing or other barriers must restrict access from adjacent roofs. Barriers must be at least 8 feet high.

822.3.38.4 Access to roofs must be strictly controlled through keyed locks or other methods.

822.3.38.5 CCTV coverage for rooftop access points must be reviewed by Sound Transit TSS. Refer to Set 1220 CCTV for requirements.

822.3.38.6 Maximize roof area available for photovoltaic panels by consolidating rooftop equipment and penetrations. Refer to Set 803 Sustainability for additional placement requirements.

822.3.39 Bicycle Facility

822.3.39.1 Provide bicycle storage facilities according to the Sound Transit Bicycle Parking Estimation Methodology.

822.3.39.2 Provide infrastructure for bicycle storage facilities in compliance with Set 807 Bike Program.

822.3.40 Material and Finish Requirements

822.3.40.1 Comply with Set 801 Architectural Materials, Elements, And Furnishings for material and finish requirements.

822.3.40.2 Safety

822.3.40.2.1 Refer to Set 801 Architectural Materials, Elements, And Furnishings for safety requirements.

822.3.40.3 Ease of Maintenance

822.3.40.3.1 Refer to Set 801 Architectural Materials, Elements, And Furnishings for cleaning, maintenance, and material requirements.

822.3.40.3.2 Refer to Set 804 Fall Protection for access to equipment requirements.

822.3.40.4 Resistance to Vandalism

822.3.40.4.1 Refer to Set 801 Architectural Materials, Elements, And Furnishings for vandal resistance requirements.

822.3.40.5 Security

822.3.40.5.1 Refer to Set 1203 Access Control System and Set 801 Architectural Materials, Elements, And Furnishings for security parameters and access control.

822.3.40.5.2 Refer to Set 801 Architectural Materials, Elements, And Furnishings for first responder access requirements.

822.3.40.6 Standardized Structural Grid

822.3.40.6.1 Use a basic 4 feet grid to accommodate standardized glazing.

Commentary: Spacing of 16 feet will accommodate the standard platform edge light for at-grade and elevated stations.

822.3.40.7 Standard Floor Finishes

822.3.40.7.1 Main Floor Area

822.3.40.7.2 Refer to Set 801 Architectural Materials, Elements, And Furnishings for main floor area material requirements.

822.3.40.7.3 Tactile Wayfinding

822.3.40.7.4 Sound Transit utilizes several tactile floor materials to improve wayfinding in stations. Refer to Set 801 Architectural Materials, Elements, And Furnishings for material requirements and Sound Transit Standard and Directive Drawings for details.

822.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

822.4.1 System Breakdown Structure

822.4.1.1 Station layout must include the following elements:

- i. Station program
- ii. Arrangement and sizing of spaces
- iii. Aesthetic
- iv. Material
- v. Travel lane
- vi. Station entrance
  - a. Physical barrier
  - b. Visibility
  - c. Weather protection
  - d. Security closure
  - e. Fare vending area
    - i. FPZ
- vii. Vertical transportation
- viii. Artwork
- ix. Platform
  - a. Type
  - b. Clearance
  - c. Surge zone
  - d. Size
  - e. Length
  - f. Width
  - g. Cross slope
  - h. Geometry
  - i. Platform edge
    - i. Material
    - ii. Assembly
  - j. Between-car barrier
  - k. Guardrail at edge of guideway
  - l. Canopy
    - i. Coverage
    - ii. Module
    - iii. Clearance
    - iv. Structure
    - v. Performance
    - vi. Material
    - vii. Slope
  - m. Windscreen
    - i. Weather protection
    - ii. Location
    - iii. Module
    - iv. Material
    - v. Lean rail
  - n. Furnishing
    - i. Seating
  - o. Windscreen
    - i. Weather protection

- ii. Location
- iii. Module
- iv. Material
- v. Lean rail

p. Operation train stopping marker
- i. Location
- ii. Design

q. Information kiosk

r. Boarding area

s. Tactile train waiting area
- i. Location
- ii. Layout

t. Topping slab
- i. Material
- ii. Assembly

u. Interface with track and LRV
- i. Vertical distance
- ii. Horizontal gap

x. Ancillary space or building

a. Equipment area or room

b. Janitor’s closet
- i. Furnishings
- ii. Size
- iii. Door hardware
- iv. Location
- v. Plumbing
- vi. HVAC

c. Storage Room
- i. Furnishings
- ii. Size
- iii. Location
- iv. Door hardware

d. Emergency responder equipment room

e. Staff restroom
- i. Quantity
- ii. Location

f. Trash enclosure
- i. Quantity
- ii. Size
- iii. Location
- iv. Door hardware
- v. Screening

g. Security office
- i. Quantity
- ii. Size
- iii. Location
- iv. Electrical
- v. HVAC
- vi. Communication
- vii. Bullet resistance
- viii. PET

ix. CCTV
x. Exiting
xi. Programmatic adjacency
xii. Glazing
xiii. Transaction window
xiv. Furnishing

h. Emergency responder equipment cabinet
i. Location
ii. Quantity
iii. Size

i. FCC and FCR
i. Size

xi. Track crosswalk
a. Location
b. Vertical alignment
c. Material

xii. Bike facility
a. Locker
b. Rack

xiii. Fare vending area
a. Equipment
i. TVM
ii. SCR

b. FPZ
i. Boundary
ii. Sign
1. Location
2. Height
3. Weight
4. Attachment

iii. Flooring

c. Location
d. Weather protection

xiv. Retail space and built-in concession
a. Location
b. MEP infrastructure
c. Space
d. Restroom
e. Sub-metering

xv. Terminus station
a. Programmatic adjacency
b. Supervisor's Office
i. Components
ii. Size
iii. HVAC
iv. Communication

c. Crew room
i. HVAC
ii. Communication

d. Maintenance access
e. Screening

822.4.2 System Sites and Locations

822.4.2.1 Station layout is applied to:

i. At-grade
ii. Elevated
iii. Tunnel

822.4.2.2 Components are further broken down into:

i. Station entrance
   a. Fare vending area
      i. FPZ
ii. Retail
   a. Space for lease
   b. Built-in-concession
   c. Food truck
iii. Bike parking facility
   a. Rack
   b. Locker
iv. Vertical transportation
   a. Elevator
   b. Escalator
   c. Stair
      i. Public
      ii. Exit
      iii. Maintenance
   d. Ramp
   e. Sloped walk
v. Restroom
   a. Public
   b. Staff
vi. Platform
   a. Tactile train waiting area
vii. Ancillary space/building
   a. Janitor's closet
   b. Storage room
   c. Emergency responder equipment room
   d. Emergency responder equipment cabinet
   e. FCC and FCR
   f. Staff restroom
   g. Trash enclosure
   h. Security office
   i. Terminus station (additional to above)
      i. Supervisor's office
      ii. Crew room

822.5 SYSTEM INTERFACE REQUIREMENTS

Table 822-1 lists requirement sets that are typically coordinated, and may have dependencies, with this set.

Table 822-1: Interface Between Architecture and Other Disciplines

SET SERIES	SERIES NAME	SET 822 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	
300	Operational Communications	X
400	Vehicle	X
500	Track	X
600	Fire / Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical / Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

822.5.1 Train Control and Signals

822.5.1.1 Coordinate interfaces at tunnel stations.

822.5.2 STart Program

822.5.2.1 Coordinate with STart Program for Artwork infrastructure requirements.

822.5.3 Vehicles

822.5.3.1 Coordinate platform edge detail, top of rail, and vehicle clearances.

822.5.4 Track

822.5.4.1 Coordinate platform slope with track alignment.

822.5.5 Fire/Life Safety

822.5.5.1 Coordinate exit size, quantity, and placement.

822.5.5.2 Coordinate first responder access requirements.

822.5.5.3 Coordinate room sizes for FCC, FCR, and ERER.

822.5.5.4 Coordinate location and quantity of emergency responder equipment cabinet.

822.5.5.5 Coordinate fire protection pipe placement requirements.

822.5.6 Structures

822.5.6.1 Coordinate structural infrastructure for overhead signage.

822.5.6.2 Coordinate structural infrastructure for overhead signage.

822.5.6.3 Coordinate canopy structure requirements.

822.5.7 Civil

822.5.7.1 Coordinate fencing, drainage, and utility requirements.

822.5.8 Mechanical/Electrical and Building

822.5.8.1 Coordinate building clearances with equipment circulation diagrams

822.5.8.2 Coordinate building clearances with equipment circulation diagrams.

822.5.8.3 Coordinate room sizes with equipment clearances.

822.5.8.4 Coordinate MEP requirements for ancillary spaces.

822.5.8.5 Coordinate hose bibb requirements.

822.5.8.6 Coordinate conduit and receptacle placement requirements.

822.5.8.7 Coordinate lighting requirements.

822.5.8.8 Coordinate electrical power and conduit requirements.

822.5.8.9 Coordinate MEP requirements for vending machines, concessions, and retail spaces.

822.5.8.10 Coordinate equipment access requirements.

822.5.8.11 Coordinate mop, sink, and potable water requirements.

822.5.8.12 Coordinate generator requirements.

822.5.9 Communications/Technology

822.5.9.1 Coordinate room sizes with equipment clearances.

822.5.9.2 Coordinate equipment or device access requirements.

822.5.9.3 Coordinate PET and ETEL requirements.

822.5.9.4 Coordinate CCTV coverage and locations.

822.5.9.5 Coordinate quantities, spacing, locations, for fare vending such as TVMs and SCRs.

822.5.9.6 Coordinate access control requirements.

822.5.9.7 Coordinate station communications rooms, closets, and infrastructure.

822.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

822.7 ENGINEERING MANAGEMENT REQUIREMENTS

822.7.1 Interface and Integration Management

822.7.1.1 Account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructable documentation and functional designs.

822.7.1.2 Coordinate artwork location with Sound Transit and artist.

822.7.1.3 Coordinate artwork infrastructure requirements with the STart Program at milestones defined in EP-03 and Set 808 STart Program.

822.7.2 Design Management

822.7.2.1 Space allocation for art must be established during preliminary engineering.

822.7.2.2 CCTV coverage and locations must be reviewed by Sound Transit TSS at milestones defined in EP-03. Refer to Set 1202 CCTV for additional requirements.

822.7.3 Manufacturing and Construction Management (Not Used)

822.7.4 Installation Management (Not Used)

822.7.5 Inspection and Testing Management

822.7.5.1 Adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

822.7.6 Training, Pre-Revenue Operations (Not Used)

822.7.7 Certification Management (Not Used)

822.8 APPENDICES (NOT USED)

END SET - 822

830 PARKING FACILITIES LAYOUT

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TABLES

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SET - 830 PARKING FACILITIES LAYOUT

830.1 INTRODUCTION

830.1.1 Document Scope

830.1.1.1 This set establishes the design criteria for parking facilities. As an important part of the transit users' system experience, the design and layout of parking facilities must provide logical access to and from the adjacent station.

830.1.1.2 Parking facilities must be located at areas to minimize negative impacts on their surrounding communities and on the environment.

830.1.1.3 This set describes Sound Transit's requirements for maintainability, reliability, and maintenance access for all parking facilities, which include surface lots and garages.

830.1.1.4 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 830 owner to determine the technical source for the design criteria.

830.1.2 Regulations, Codes, Standards, and Guidelines

830.1.2.1 International Regulations, Codes, Standards, and Guidelines

830.1.2.1.1 International Building Code (IBC) with local amendments.

830.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

830.1.2.2.1 American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Handbook – HVAC Applications.

830.1.2.2.2 Crime Prevention Through Environmental Design (CPTED).

830.1.2.2.3 Federal Highway Administration (FHWA) 2000 Standard Edition font collection.

830.1.2.2.4 Manual on Uniform Traffic Control Devices (MUTCD) with local amendments.

830.1.2.2.5 Post-Tensioning Institute (PTI) Technical Note: Design of Prestressed Barrier Cable Systems.

830.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

830.1.2.3.1 City of Seattle Pavement Markings Standard Plan 700 series.

830.1.2.3.2 Washington State Building Code (WSBC).

830.1.2.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

830.1.2.5 Other Jurisdictions (Not Used)

830.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

830.1.2.6.1 Sound Transit Customer Signage Design Manual and Production Drawings.

830.1.2.6.2 Sound Transit Equipment and Facilities Numbering Standard.

830.1.3 Abbreviations and Acronyms

830.1.3.1 AFF–above finish floor

830.1.3.2 ACS–access control system

830.1.3.3 AHJ–authority having jurisdiction

830.1.3.4 BMS–building management systems

830.1.3.5 CCTV–closed circuit television

830.1.3.6 CES–customer emergency stations

830.1.3.7 CIP–cast-in-place

830.1.3.8 CMU–concrete masonry unit

830.1.3.9 EPMS–electric power management system

830.1.3.10 EV–electric vehicle

830.1.3.11 FACP–fire alarm control panel

830.1.3.12 HOV–high occupancy vehicle

830.1.3.13 HVAC–heating, ventilation, and air conditioning

830.1.3.14 IBC–International Building Code

830.1.3.15 IDS–intrusion detection system

830.1.3.16 LCC–link control center

830.1.3.17 LEFE–low emission fuel efficient vehicles

830.1.3.18 LID–low impact development

830.1.3.19 MEP–mechanical, electrical, and plumbing

830.1.3.20 MMA–methyl methacrylate-ethyl acrylate

830.1.3.21 PIMS–passenger information management system

830.1.3.22 ROW–right-of-way

830.1.3.23 SOC–security operations center

830.1.3.24 TPSS–traction power substation

830.1.3.25 UPS–uninterrupted power source

830.1.3.26 VMS–variable message system

830.1.4 Definitions and Classifications (Not Used)

830.1.5 References (Not Used)

830.2 STAKEHOLDER NEEDS (NOT USED)

830.2.1 Passenger Experience

830.2.2 Operational Needs

830.2.3 Maintenance Needs

830.2.4 Safety Needs

830.2.5 Security Needs

830.2.6 Reliability, Availability and Maintainability Needs

830.2.7 Environmental and Sustainability Needs

830.3 SYSTEM REQUIREMENTS

830.3.1 General Requirements

830.3.1.1 A site traffic analysis and parking study must be conducted during the conceptual engineering phase to aid Sound Transit in evaluating whether the preferred parking facility at a particular site will be a surface lot or a garage.

830.3.1.2 Parking facility must be provided with all service systems (such as utilities, mechanical, plumbing, fire protection, electrical, and lighting) independent from the station and the TPSS.

830.3.1.3 Service systems must be separately metered if retail or like uses are part of the service facility.

830.3.1.4 Dedicated fire alarm control panels must be provided for retail spaces within garages. These fire control panels must be accessible without needing to enter into Sound Transit-controlled spaces.

830.3.1.5 Fire alarm controls panels must share signals and monitor each other. AHJs and Sound Transit partners must have meters and disconnects and will require access to those spaces without travelling through access-controlled spaces. See Set 902 Utilities for more information.

830.3.1.6 Provide adequate access for equipment maintenance envelopes and replacement paths. Clearances must be demonstrated early in the design process. Refer to Project Implementation and Integration Plan for equipment clearance diagram deliverables.

830.3.2 Site Design and Access to Facilities

830.3.2.1 The number and location of vehicular entry and exit points of the parking facility must be determined through the site traffic analysis and parking study, with the intent of reducing peak hour traffic congestion surrounding the facilities. Their locations may be distributed over different levels of facilities, to integrate with the adjacent street system. See Set 601 Fire/Life Safety for emergency access requirements.

830.3.3 Stormwater and Utilities for Facilities

830.3.3.1 LID must be considered for all stormwater system designs. See Set 901 Storm Drainage and local standards for more information.

830.3.3.2 Drainage design and connections to off-site facilities must be coordinated through Sound Transit and designed in accordance with AHJ criteria.

830.3.3.3 Sidewalks, ramps, stairs, and entrances to buildings must comply with ADA standards. Drainage slopes must be provided in these areas to prevent the building up of obstructions, such as flood and freeze hazard caused by drainage facilities.

830.3.3.4 The amount of metal contaminates entering storm water must be eliminated or reduced. The use of exterior finishes such as zinc, lead, copper, and galvanizing must be in accordance with AHJ requirements at areas subjected to rainwater or run-off. See Set 803 Sustainability.

830.3.3.5 Oil water separators, water quality vaults, and water detention facilities must be located on the exterior and adjacent to the garages to allow for service truck access with drive aisle or parking that does not impact sidewalk or pedestrian access. Site utilization must be balanced against the preservation of potential transit-oriented development, as appropriate.

Commentary: Truck access must not use sidewalk or public street for parking as this requires permit from local AHJ every time the truck needs access. The designer must provide separate parking space and access that does not impact adjacent sidewalks or pedestrian access.

830.3.3.6 Drains must be provided at base of stairs and adjacent to elevators. See Set 805 Vertical Transportation and Set 1002 Mechanical–Plumbing.

830.3.3.7 All utility features must be secured or protected against vandalism and incidental damage, including impact by vehicles. Outlets must not be located in drive ramps or near parking stalls to avoid risk of damage by vehicles.

830.3.3.8 Landscape irrigation system must be provided in accordance with Sets 802 Landscaping, 803 Sustainability, Set 805 Vertical Transportation, and 1002 Mechanical–Plumbing.

830.3.4 Parking Types Required in Facilities

830.3.4.1 Accessible parking

830.3.4.1.1 Accessible parking, including van accessible parking, must be provided at facilities in accordance with the requirements of ADA Standards for Accessible Design as defined in the WAC 51-50, and the requirements of the AHJ.

830.3.4.1.2 Accessible spaces must be located along the shortest possible route to the elevators or station entry.

830.3.4.1.3 Accessible routes from the accessible parking stall to the accessible entrance must be protected and separate from vehicular traffic. Locate accessible routes in front of bollards or directly adjacent to the accessible building entrance. Where accessible routes must comingle with drive aisles in existing parking facilities, the route must be striped.

830.3.4.1.4 Passenger pick-up and drop-off parking must avoid conflicts with traffic entering and leaving the parking facilities.

830.3.4.1.5 One paratransit services parking space must be provided at surface lots, if required by AHJ or bus operation. See Set 820 Facility Area Planning for more information.

830.3.4.2 HOV (carpools and vanpools) parking must be provided in accordance with AHJ requirements or project specific ST requirements, whichever is more stringent.

830.3.4.3 LEFE and electric vehicle parking and charging stations must be considered and provided in accordance with AHJ and/or ST project specific requirements, whichever is more stringent. Provide access to these spaces to meet accessibility requirements.

Commentary: When providing specialty spaces, an appropriate percentage based on accessibility requirements must be designed for accessible use and meet those design requirements in addition to those required by that particular use, such as EV charging and LEFE vehicle reservation. Attention must be paid to user maneuverability and access to the vehicle and associated infrastructure, such as charging equipment, slopes, heights, access to the charging connection at the vehicle, and safe path of travel.

830.3.4.4 Motorcycle parking must be provided in accordance with AHJ and/or Sound Transit project specific requirements, whichever is more stringent. If provided, motorcycle stalls must be located in areas that would otherwise not be useable for parking single occupant vehicles.

830.3.4.5 Bicycle storage must be provided in accordance with Sound Transit guidance. See Set 807 Bike Program.

830.3.4.6 Provide single occupant vehicle parking that meets Sound Transit and local AHJ requirements.

830.3.5 Features of Facilities

830.3.5.1 Parking layouts

830.3.5.1.1 A mix of standard and compact stalls is allowed to maximize design efficiency. For single occupant vehicles, a standard stall must be 18.5 feet deep and 8.5 feet wide minimum and a compact stall must be 16 feet deep and 8 feet wide minimum. The width of stall is measured between centers of stripes.

830.3.5.1.2 Each aisle of stalls must be separated by a two-way, 23 feet minimum drive aisle.

830.3.5.1.3 The width of the end-bay turning drive aisle must be 25 feet minimum, unless justified otherwise by auto-turn/traffic movement studies.

830.3.5.1.4 Stalls must be oriented 90 degrees to drive aisles. The quantity of compact stalls must not exceed 20 percent of the total number of stalls.

830.3.5.1.5 Parking stalls that are parallel and adjoining to a wall must be compact. One foot must be added to their widths.

830.3.5.1.6 Except for accessible stalls, structural elements (such as columns and pilasters and mechanical elements (such as drain and sprinkler pipes) may impinge on the interior corners of stalls up to one foot deep and one foot wide. These items must be protected from impact with metal guards which must not encroach on the stall dimensions.

830.3.5.1.7 A motorcycle stall must be 8 feet deep and 4 feet wide minimum. Each aisle of motorcycle stalls must be separated by a maneuvering aisle measuring 10 feet minimum in width.

Commentary: Motorcycle spaces may be in smaller underutilized “leftover” spaces such as corners or other spaces too small for a car. These spaces must be visible and safe for users by being accessed from areas with clear site lines which do not interfere with pedestrian movement or accessible path of travel.

830.3.5.1.8 Stalls must have a vehicle barrier and pedestrian guard at the end if there is a change in elevation of more than ¼ inch between the parking space and the adjacent parking surface.
Commentary: This is to stop cars from traveling over an unprotected drop and to provide an accessible route.

830.3.5.2 Passenger pick-up and drop-off areas

830.3.5.2.1 Design of the areas must avoid conflicts with traffic entering and leaving the parking facilities. Layout of these areas must avoid routing pick-up and drop-off vehicles through the surface lots and garages. See Set 820 Facility Area Planning for preferred location of pick-up and drop off near stations.

830.3.5.2.2 Stalls and aisles in these areas must be larger than those for standard stall of single occupant vehicle, due to the frequent use of short-term parking. Stalls and aisles for pick-up and drop-off areas are as follows:

i. Parallel to curb: Stalls parallel to the curb must be 9 feet wide and 21 feet long.
ii. Preferred angles to curb: 45 degrees, 60 degrees, 90 degrees. Stalls must be 9 feet wide and 20 feet long. Drive through stalls are preferred.

830.3.5.3 If cable railings are used as vehicle barriers, intermediate through-posts and/or cable spacers must be provided to ensure that when collision occurs, all cables can act in unison without excessive vertical deflection. The barrier system must be corrosion protected. Cables must be treated such that their visibility is enhanced to patrons. Cable anchors must be designed to allow for ease of maintenance and replacement, without damaging existing structural elements. Provide 18 inch by 18 inch, 18-gauge aluminum hitch barriers mounted approximately 18 inches AFF to the center of the plate and centered on the stall to increase safety and protect the integrity of the barrier system. The barrier system must meet the requirements set forth in the Barrier Cable System in the Sound Transit Standard Specifications and be verified by the design engineer of record of the parking project.

830.3.5.4 All parking facilities must be illuminated in accordance with Set 1007 Electrical Lighting.

830.3.5.5 All parking facilities must adopt CPTED guidelines. Facilities must be designed to maximize the visibility of all areas within garages and from the surrounding areas of surface lots.

830.3.5.6 Eliminate alcoves in public areas.

Commentary: Alcoves create partially or fully concealed areas that cause safety, security, and maintenance issues and must be avoided.

830.3.5.7 Provide bollards with high visibility paint (yellow preferred) at all locations where cars may impact structures such as columns or railings, mechanical or electrical equipment surge zones, or waiting areas of vertical transportation, or where cars may intrude upon accessible pathways. Where bollards are provided, base plates must be recessed to prevent a tripping hazard. See 801 Architectural Materials, Elements, and Furnishings for additional requirements.

830.3.5.8 Future conduit stub-up locations must be flush with the adjacent finish floor surface and capped to avoid tripping hazards. Stub-outs on walls must terminate in junction boxes with cover plates.

830.3.6 Communications and Security Systems for Facilities
CCTV systems and any other camera systems indicated by Sound Transit must be used to provide full coverage of all publicly accessible areas, including the following:

a. Fuel ports and fuel storage
b. Meters and disconnects
c. Transformers and switches
d. Entrances to rooms, including Electrical, Mechanical, UPS, Communication Rooms, Communication Closets, storage, security office, elevator machine rooms, escalator control rooms, fire alarm control rooms, fire sprinkler valve and pump rooms, ventilation/fan plant rooms or entrances, any restroom facing the public, entrance to back of house areas
e. Maintenance access points
f. Maintenance stairways
g. Egress stairway
h. Hi-rail access points
i. Dumpster areas

Commentary: CCTV coverage of individual rooms can be combined if there are multiple rooms/doors in a corridor where the door entering that corridor has access control and camera coverage. Communications rooms always require individual camera coverage.

830.3.6.1 The positions and types of cameras must enable the recording of vehicle license plate numbers, as vehicles enter and exit the garage, with one camera in each entry/exit lane. Cameras must be located out of arms-reach. See additional comments regarding equipment clearances inside garages. See Set 1202 CCTV-TIDS.

830.3.6.2 CES must be installed at all main pedestrian access points within the parking facilities as well as on all floors of garages. Private branch phones must be installed in all back of house areas. See Set series 300 Operational Communications and 1000 Mechanical/Electrical and Building Systems for more information.

830.3.6.3 In addition to perimeter access control, ACS must be provided for high security areas, such as communications rooms within garages. See Set 1202 CCTV – IDS for more information.

830.3.6.4 Garages must have utility sub-metering communications in compliance with Sound Transit standards and interfacing with the existing EPMS head end. See Sets 803 Sustainability and 902 Utilities for more information.

830.3.6.5 All communication installations outside of the communications room must be considered an exposed exterior application. For garage communications rooms, closets, and infrastructure, see Sets 815 Telecommunication Spaces and 301 Network Infrastructure.

830.3.7 Pavement Markings for Facilities

830.3.7.1 Pavement markings, such as disabled person symbol, arrows, yield, and other markings, must be per the City of Seattle Pavement Markings Standard Plan 700 series unless local AHJ specifies otherwise "Thru" and "Turn" arrows must be 8 feet long. "Thru/Turn" combination arrows must be 13 feet, 4 inches long.

830.3.7.2 Font for letters and numbers must be from FHWA 2000 Standard Edition font collection, Highway Gothic, D (Modified)-Series (Reference 5.12).

830.3.7.3 Stall designation (such as "HOV," "ADA," and "Compact") must be provided to each non-standard parking stall next to its number. Signage must be wall mounted where possible, and if mounted on a post must be positioned such that it will not be hit by a vehicle.

830.3.8 Component Naming for Parking Facilities

830.3.8.1 All component naming must follow the current edition of the Sound Transit Equipment and Facilities Numbering Standard and Table 830-1.

830.3.8.2 Garage level naming must be coordinated with Sound Transit's Architecture, Structural, Capital Signage, Fire Protection, and Systems Engineering & Integration. Fire department concurrence on garage level naming must be obtained during conceptual design phase.

830.3.8.3 Determination of level 1 is based on the following:

830.3.8.3.1 Level 1 must discharge patrons directly to the exterior of the building and be at grade. It must lead to the public way as defined in the IBC Ch. 10 Means of Egress.

830.3.8.3.2 The level 1 must align the elevator designated (primary) recall level.

830.3.8.3.3 Levels above Level 1 must be numbered sequentially going up (e.g., L2, L3, L4, L5). Levels below Level 1 must be numbered sequentially going down (e.g., B1, B2, B3). Wayfinding, stair, room, equipment, and other signs must reflect these levels. Refer to Sound Transit Equipment and Facilities Numbering Standard for additional information on parking numbers.

Commentary: The IBC definition of stories above grade may differ from the designation outlined above. Code sheet must still determine the number of stories based upon the IBC but level designations are to be as outlined above subject to ST and fire department concurrence.

830.3.8.4 Sequential stall numbering must be provided for parking stalls. Stall numbering must start near the entrance and continue along the path of the vehicle. Stalls located on the ramp must be labeled as part of the level below. The next level begins at the top of the ramp.

830.3.8.5 Stall numbering must appear on the pavement, centered between stall lines, near the drive aisle, such that it remains visible when a vehicle is parked there. Each stall number must begin with the level number. All floor signage and pathway marker painting including stall lines, numbers, accessible indicators, and pedestrian walkway zones must be painted after substantial completion of construction to minimize wear caused by construction vehicles. Size of markings must adhere to Sound Transit and local AHJ requirements. See Table 830-1.

Table 830-1: Component Naming

	Level number	**Parking stalls if <100 stalls/floor**	**Parking stalls if >100 stalls/floor**
Below grade level	B1, B2, etc.	101-B199	1001-B1999
Surface lot	S1, S2, etc.	001-099	0001-0999
Primary at grade level	L1	101-199	1001-1999
Above grade level	L2, L3, etc.	201-299	2001-2999

830.3.8.6 Stairway closest to the primary elevators must be labeled as Number 1, and the numbering of subsequent stairways must continue clockwise.

830.3.8.7 Each garage level (including roof parking) must have an associated color distinctive from other levels. All level colors must be coordinated with accessibility requirements. The color red is prohibited.

830.3.8.8 Each level must incorporate color to support wayfinding for patrons. The associated color may be expressed in signage, located on columns, walls across from elevators, or walls that can be seen throughout the garage.

830.3.8.9 Provide large graphic numbers associated with the color scheme to identify the various levels.

830.3.8.10 The elevator call button must have a star next to the recall floor. Support labels next to the call buttons must be spelled out and color-coded with the corresponding garage level. See Set 805 Vertical Transportation for elevator call button labeling.

830.3.9 Wayfinding Graphics and Signage for Facilities

830.3.9.1 Wayfinding graphics and color coding must also be provided to assist passengers with level identification and potentially aisle identification depending on the size of the garage.

830.3.9.2 Pedestrian pathways within facilities must be clearly marked and signed to protect pedestrian from moving traffic. Coordinate with Sound Transit Customer Signage Design Manual to avoid redundancy.

830.3.9.3 MUTCD signage (such as speed limit and stop signs) and clearance height bars must be provided within garages. Clearance height bars must be located at all entries, as well as at any internal ramp leading to a level with a change in clearance height. Clearance height bars must be located ahead of parking facility entrances to prevent damage to overhead coiling grilles or vertical lift gates. Clearance bars must be located either:

i. Ahead of the garage entry as a standalone structure with clearance bar when there's ample driveway within Sound Transit property.
ii. As a suspended clearance bar ahead of the garage entry when the garage entry is immediately adjacent to a ROW.

830.3.9.4 Code/room signage must be provided within garages. See Set 806 Signage.

830.3.9.5 Signage must be provided at each dedicated specialty parking area, such as ADA, HOV, and motorcycle stalls. Individual signage is required at each ADA stall.

830.3.9.6 Where new surface parking lots are added to a station area with existing lots, wayfinding must be evaluated, and signage updated so that lot location and identification is cohesive and clear.

830.3.10 Features of Garages

830.3.10.1 Garages must be "open" structures, as defined by and in accordance with the requirements of the IBC, except where site constraint or building program requires garages to be otherwise.

830.3.10.2 Garages must be designed to minimize the use of earth-retaining structures. Where areas of the garage are below grade, waterproofing and drainage system must be provided to control water seepage through walls into structures. Shotcrete is prohibited.

830.3.10.3 Minimum vertical clearance for all garage floors must be 7 feet, 2 inches to the lowest point on standard levels. Minimum vertical clearance for garage floors must be 8 feet, 2 inches to the lowest point on the levels, where ADA van accessible stalls and Sound Transit staff parking are located, and along the travel path of the ADA vans to these stalls. Clearance means clear of any obstruction, including structure signage, sprinklers, lighting conduit, and piping.

830.3.10.4 The minimum clearance to structure is 7 feet, 2 inches. Devices, including light fixtures, radio antennas, fire alarms and strobes, exit signs, and similar devices must be mounted directly onto walls or ceilings without use of stems, and at a minimum clear height of 8 feet. In cases where stems are unavoidable, they must be robust and have diagonal bracing for seismic and vandalism resistance. Standard electrical conduit is prohibited as a stem material. Care must be taken to lay out devices centered on structural bays where possible in order to optimize coverage.

830.3.10.5 Minimum clearance height to signage must be 8 feet, 2 inches. Sprinkler lines are more robust and can remain with the 7 feet, 2 inches clearance but must not pass under beams having the minimum clearance.

830.3.10.6 A vertical height clearance bar must be provided per section 830.3.9.3.

830.3.10.7 Ramp grades must be no greater than 6 percent where parking stalls are placed along the ramp, and no greater than 16 percent where ramps are separated from parking (by speed ramps). Any ramp steeper than 8 percent must be provided with minimum ten-feet long transitions at the top and bottom of the ramp. Garages designed to allow parking on ramp surfaces are preferred. Larger garages must be evaluated, if the use of speed ramps will increase circulation efficiency.

830.3.10.8 Surfaces of both parking and drive aisles within garages must be designed to be slip resistant and easily cleaned. The surface coefficient of friction must meet requirements of ANSI A137 for interior and ANSO A326.3 for exterior locations. A traffic coating must be installed on the top parking deck, ramps, primary entrances, and all closure strips. Vertical wall and column surfaces must be coated with an application of the MMA sealer (methyl methacrylate-ethyl acrylate, semi-opaque, co-polymer resin-based sealer/stain) for concrete on walls full height with addition of Sherwin Williams 1K Siloxane also to full height.

830.3.10.9 Rumble strips or speed bumps (fastening method to be coordinated with Operations) must be provided (and not decrease minimum clearance) at the following locations to encourage vehicles to slow down as they enter and leave the facility:

i. Garage entries and exits
ii. Pedestrian entries and exits
iii. Near vertical circulation elements
iv. At major pedestrian crossings

830.3.10.10 Garages must have means to be secured during non-revenue hours. Overhead lift gates or sliding gates must be provided at vehicle entries and exits. Pedestrian access doors must have the ability to be locked. Hardware, including exit devices, must be tamper-resistant from the exterior side of doors, overhead grilles, and gates. Where doors, overhead lift gates, or gates are perforated, locate access controls so they are not accessible from the exterior side to prevent intrusion. System must be remotely monitored and allow for emergency egress. Access control and monitoring of intrusion must be coordinated with Set 1203 Access Control System. Ground floor pedestrian access must be limited to designated entryways.

830.3.10.11 Provision for two Sound Transit service or transit security vehicle parking spaces must be made reasonably close to electrical and/or communications rooms (preferably on the ground level), without interfering with the ADA clearance to the elevator(s). Each parking space must be 20 feet deep and 9 feet wide. This provision must be evaluated with the nearby station layout and be determined by Sound Transit if sufficient parking spaces have already been provided at the station.

830.3.10.12 An enclosed area for trash must be provided and located, preferably outside and adjacent to the garage. This area must house two 4 cubic yard dumpsters, one for trash and one for recycling. To hide dumpsters from view, an enclosure at least 8 feet high with no roof must be provided, or dumpsters must be located within a room that can be easily hosed down. This area must be secured by a pair of 3-foot-wide doors or gates. This area must be accessible to trash haulers and allow equipment to travel and function without height restrictions.

Commentary: Drain requirements have been reevaluated on LLE due to triggering of plumbing code. Operations uses vacuum truck to clean trash enclosures and does not need a drain; AHJ prefers not to have a drain so that any leakage from the dumpsters is visually apparent and can be corrected more quickly.

830.3.10.13 A 100 square feet storage room must be provided. This storage room must be equipped with a minimum 15 lineal feet of metal shelving for material storage, an open floor area for cleaning equipment, and a 40-inch minimum wide access doorway or a pair of 3-foot-wide doors. This storage room must be located near an entry or pedestrian plaza, with easy access to its doorway from the drive aisle. The storage room must be mechanically ventilated for storage of chemicals.

830.3.10.14 Provide an additional separate 300 square foot storage room, integrated within and exterior facing, attached to or adjacent to the garage but onsite. Configure to provide easy access and maneuverability of housed equipment such as Cushman style cart with plow and ice melt spreader, snowblower, pallets of ice melt, shovels, flammable liquids cabinet. Storage room must have one 8 foot wide by 7-foot-high secured rollup door and one 3-foot-wide swing door on exterior wall with direct access to a drive aisle. Wall and floor construction must be able to withstand washdown with hose and floor must contain at least one floor drain. Storage room must be conditioned space with mechanical ventilation for chemical storage. This storage room must be equipped with a minimum 15 lineal feet of metal shelving for material storage. Size is somewhat flexible upon coordination with Sound Transit staff for final layout and demonstration of storage capacity and easy access to and maneuverability of equipment.

830.3.10.15 A 100 square foot janitor closet must be provided for Sound Transit’s dedicated use. When restrooms are provided within the garage, the designer must consult with Sound Transit (Facilities) for the preferred proximity between the closet and restrooms. When retail spaces are accommodated within the garage, retail tenants must provide separate janitor closet within the retail space for their sole use. See Sets 801 Architectural Materials, Elements, and Furnishings and 822 Station Layout – Light Rail for additional design requirements of janitor closets.

830.3.10.16 An 80 square foot minimum security office must be provided at ground level within the garage unless one is made available in an adjacent facility within 300 feet. When restrooms are provided within the garage, the security office must be located within 50 feet of the restrooms. See Sets 801 Architectural Materials, Elements, and Furnishings and 822 Station Layout – Light Rail for additional design requirements of security offices.

830.3.10.17 In public areas, eliminate exposed horizontal surfaces that are difficult to access for regular maintenance.

Commentary: Exposed horizontal surfaces in public areas that are difficult to access by Facilities personnel are susceptible to an accumulation of trash and must be avoided. Examples of elimination include access prevention or sloping the surface at a minimum 45-degree angle to promote trash movement.

830.3.10.18 All building system equipment that is within the touch zone, including associated piping and conduit, must be secured and protected against vandalism and incidental damage.

830.3.10.19 Provide one trash receptacle and one recycling receptacle near each other at the following locations within garages. Review quantities with Sound Transit if locations share a common area. Comply with Sound Transit Standard Specifications and Set 801 Architectural Materials, Elements, and Furnishings for trash and recycling receptacle requirements.

i. Each exit/entry
ii. Each elevator lobby
iii. Main stairway

830.3.10.20 Edges of garage levels must be protected with structure, curbs, toeboards, thickened slab edges, or other mechanisms to prevent objects from rolling over the edge.

Commentary: Tools and other objects can roll under cable barriers to the surrounding areas posing a hazard and inconvenience.

830.3.11 Vertical Circulation within Garages

830.3.11.1 Stairs and elevators must be appropriately located to maximize conveyance efficiency. See Set 805 Vertical Transportation.

830.3.11.2 The stair(s) providing the most direct access to the station must be designed as primary public stair(s). Primary public stairs must have glazing at exterior walls for wind-blown weather and have weather protection from above at the roof level as well as to allow adequate visibility to comply with CPTED-coordinate with Transit Safety and Security. See Sets 805 Vertical Transportation and 801 Architectural Materials, Elements, and Furnishings for screening material requirements. Provide auxiliary stairs for exiting, as necessary, to meet code and security requirements. Stair entries at ground level must have means to be secured to prevent unauthorized entrance.

830.3.11.3 An accessible exterior door near the primary public stairs and/or elevator must be designated as the “main pedestrian entry” to the garage. The main pedestrian entry must be a minimum of 6 feet wide nominal, with no vertical stiles or other obstructions within the clear opening. There must be a clear surge zone within the garage that is at least 15 feet deep, perpendicular to the main pedestrian entry, for the entire width of the main pedestrian entry opening. The exterior door must be protected on both interior and exterior from vehicle intrusion per section 803.5.7. The main pedestrian entrance must be protected from the weather by a solid roof structure to a depth that covers the full door swing at a 15 degree rain angle.

830.3.11.4 Door openings must not open directly onto drive aisles. Doors at public stairways which are not held open during operating hours must have vision glass, as allowed by code to assist pedestrians in entering and exiting the stairway. Where doors open adjacent to drive aisles, provide protective bollards. See 801 Architectural Materials, Elements, and Furnishings for bollard requirements.

830.3.11.5 CIP or precast concrete treads/risers and landings are required. Metal-pan-concrete-filled stair construction is prohibited. Exposed stairs with no canopy coverage must have stainless-steel guardrails and handrails secured to stainless-steel embeds. Handrails and guardrails must have rounded edges and corners. Avoid horizontal rails and ornamental patterns that encourage climbing. Painted finishes in exposed stairs are prohibited.

830.3.11.6 Precast treads/risers and landings must be resistant to water, freeze-thaw cycling, de-icing salts, staining, wear and degradation from cleaning substances, and substances tracked by users.

830.3.11.7 Precast tread/riser and landing surfaces exposed to view: Medium acid wash or sandblasted non-slip finish to meet the coefficient of friction as required by ANSI A137 for interior and for exterior locations must meet ANSO A326.3, of uniform color and texture (See Set 801 Architectural Materials, Elements, and Furnishings for further clarification). Free of staining, discoloration, honeycombing, air holes, fins, and protrusions, surface cracking and minor chips or spalling at edges or ends. Color must be approved by Sound Transit Resident Engineer.

830.3.11.8 Stairs and landings exposed to the elements must be appropriately sloped toward the tread nosing for drainage, to avoid water ponding and freezing. Provide area or floor drain at the bottom of stairs and landings, hard-piped to drainage system. Slope floor at the bottom of the stairs and landings toward the area or floor drain, continue slope away from stair surge zone area to avoid ponding at foot of stair. See Set 1002 Mechanical – Plumbing.

830.3.11.9 Elevators must serve all parking floors. See Set 805 Vertical Transportation for more information. Canopy must be provided over elevator landing area on the roof level. See Sets 821 Station Layout – Commuter Rail, 822 Station Layout – Light Rail, and 805 Vertical Transportation for coverage requirement. Provide drainage at elevator entries to prevent water infiltration into the hoistway. See Sets 805 Vertical Transportation and 1002 Mechanical – Plumbing for additional information.

830.3.11.10 Provide tactile waiting areas at elevator landings. See Architecture Directive Drawings and Sets 821 Station Layout – Commuter Rail and 822 Station Layout – Light Rail for tactile waiting area and paver information.

830.3.11.11 All downspouts from rooftops and canopies must be tight-lined and integrated with the drainage system. Discharging rainwater runoff to walkway or drive surface is not allowed. Overflow drains and scuppers must outlet away from entrances, floor boxes, and any other equipment that could be damaged by water runoff.

830.3.12 Architectural Elements for Garages

830.3.12.1 For coatings and finishes, all architectural elements of the garage must be considered exposed exterior applications, except within conditioned rooms which must be painted with a durable finish. In all other locations, minimize field painted finishes. Floor finish at back of house spaces including the security office must be CIP, smooth finished and sealed.

830.3.12.2 Secured, perforated screening must be provided at the ground level of the garage and at levels where unwanted access into the garage can easily be gained to deter people from entering the facility except at designated entries. Screening must extend from the finish floor to the underside of the deck directly above. Gaps between screens and adjacent material must not exceed 2 inches. Screening must be structurally supported so that it does not buckle or deform. When screening or art-like attachment is provided on exterior facades, it must maintain the open garage designation and balance impacts on interior day lighting. All structural attachments to the garage must be designed and verified for windblown weather.

830.3.12.3 Only durable, non-combustible, low maintenance materials must be utilized. Preferences are for stainless steel, glass, aluminum, concrete, CMU, and brick, etc. Graffiti resistant coating must be applied to all finishes in public and non-public areas where Security and maintenance can assume graffiti will appear. See Sets 801 Architectural Materials, Elements, and Furnishings, 803 Sustainability, 821 Station Layout – Commuter Rail, and 822 Station Layout – Light Rail for additional standards and material requirements.

830.3.12.4 Interior partitions must be either CMU or CIP walls.

830.3.12.5 The underside of all concrete decks and beams must be stained white with a Dryfall paint for optimal light reflectance.

830.3.12.6 Comply with Set 801 Architectural Materials, Elements, and Furnishings for bird control requirements.

830.3.13 Structural Elements for Garages

830.3.13.1 Garage design must comply with the IBC as adopted and amended by Washington State and AHJ.

830.3.13.2 When using moment frames, the designer must consider using upturned moment frame beams, which may be used as vehicular barriers.

830.3.13.3 Structural columns and walls must preferably be located between adjacent rows of parking stalls, perpendicular to stalls. Columns must provide a clear span in the transverse direction to accommodate two rows of stalls with a two-way drive aisle in between.

830.3.13.4 The use of structural steel is prohibited, except for elevator towers, stairs, pedestrian bridge, and exterior attachments.

830.3.13.5 One-way post-tensioned slabs are the preferred structural system for parking decks.

830.3.13.6 To achieve effective positive drainage, all garage decks (including top level decks) must have a minimum 2 percent slope measured on the top surface along their supporting elements. At ADA accessible routes and ADA parking stalls, the cross slope must be between 1.3 percent and 1.7 percent to account for construction tolerances and ADA requirements. Low points must be located away from entrances, elevators, escalators, stairwells, and landings, and be created on each level for drainage collection. Positive drainage must be maintained around the perimeter of each level and at obstructions.

830.3.13.7 Uncovered, weather-exposed decks must be constructed with hydrophobic admixture concrete. Expansion joints must either prevent water accumulation or be provided with drains.

830.3.13.8 See Set 720 Building Structures for additional structural design requirements for garages.

830.3.14 Mechanical, Plumbing, and Fire Protection Systems for Garages

830.3.14.1 All mechanical installations and fire alarm systems must be considered exposed exterior applications, except when located within conditioned rooms.

830.3.14.2 If the garage has partial or full sub-grade levels, then the need for ventilation of automobile exhaust must be evaluated to satisfy AHJ code requirements. If ventilation of automobile exhaust is required, then the ventilation design must follow design guidance and recommended practices of current ASHRAE's HVAC Applications Handbook: Enclosed Vehicular Facilities. Ventilation volumes must ensure safe air quality throughout the enclosed levels. The noise levels of the ventilation system must be evaluated for consideration of equipment selection or the need of attenuation to ensure patron safety. Ventilation system must account for noise levels at waiting areas in and adjacent to garage and incorporate either sound attenuation or be located away from waiting areas at vertical transportation, fare vending machines, or waiting areas adjacent to the garage such as passenger pick up/ drop off and bus platforms. See Set 601 Fire–Life Safety for fire protection requirements.

830.3.14.3 The ventilation system must have a control system for managing energy performance and maintaining a safe environment. The control system must include detection of harmful emissions, such as carbon monoxide and nitrogen oxides. The detection and warning equipment must be designed in accordance with NFPA 720. Sensors must not be installed over driving lanes and must be properly protected from damage/vandalism. The control system must interface with the garage BMS. The garage BMS must provide alarm and indication of garage ventilation systems to Sound Transit Facilities and the SOC. Coordinate with Set 1000 Mechanical-Electrical and Building Systems.

830.3.14.4 Back of house areas must be conditioned in accordance with Set 1003 Mechanical-HVAC.

830.3.14.5 Where galvanized fire protection pipe is exposed to view in public spaces and tight-lined to a painted surface, the pipe, fittings, connections, and support must be painted to match the adjacent finish surface. Where piping is adjacent to an unpainted surface or concealed from view in public spaces, the galvanized pipe may remain unpainted.

830.3.14.6 Wall-mounted hose bibbs must be provided near the garage elevator lobby at each level and at each stairwell on each level. Hose bibb is not required for stairwells next to elevator lobby. All areas on all levels within the garage must be within 75 feet of a hose bibb. Additional wall-mounted hose bibbs must be provided and spaced at 150 feet maximum along the (exposed) exterior façade. One wall-mounted hose bibb must be provided at dumpster enclosure and any storage room, unless the enclosure and storage room can be reached by a 75-foot hose from an adjacent hose bibb. Coordinate hose bibb with section 1002.6.5.

830.3.14.7 Public facing wall mounted hose bibbs must be installed in lockable stainless-steel boxes with flanges flush to the wall. All hose bibbs in unheated areas must be a non-freeze type. See Set 601 Fire–Llife Safety and Set 1002 Mechanical – Plumbing for more information.

830.3.14.8 Provide means to manually drain all domestic water piping that are subject to freezing.

830.3.14.9 All domestic water piping located in heated areas and not subjected to freezing must not be drained during winter months.

830.3.14.10 All water lines must not be run through rooms with electrical or communications equipment.

830.3.14.11 Proper maintenance and service access points must be provided for enclosures that house mechanical, plumbing, and fire protection systems. Ensure oil water separators area easily accessible by Vactor trucks.

830.3.14.12 Provide housekeeping pads under all equipment in rooms with drainage.

830.3.14.13 See Set 601 Fire/Life Safety for fire extinguisher requirements.

830.3.15 Electrical and Lighting Systems for Garages

830.3.15.1 Refer to Set 1005 Electrical Power, 1006 Electrical Raceway, and 1007 Electrical Lighting.

830.3.15.2 All electrical installations must be considered exposed exterior applications, except when located within conditioned rooms. Protect from potential vehicle impacts.

830.3.15.3 Conduits from electrical, mechanical, and communications rooms to their first accessible panels must be protected within the garages when in the touch zone. Equipment and conduits must not be exposed outside of the garages.

830.3.15.4 Electrical system must be provided in accordance with Set series 1000 Mechanical- Electrical and Building Systems.

830.3.15.4.1 At elevator entrances or stair landings, receptacle must be ceiling-mounted and located away from foot traffic. If applicable, add J-hook next to receptacle box for cord support.

830.3.15.4.2 Receptacle boxes must be provided in accordance with Set 1005 Electrical Power.

830.3.15.4.3 EV charging and charger ready infrastructure must be provided per project specific requirements, and AHJ. See Set 1005 Electrical Power for electrical charging requirements.
Commentary: If EV charging or EV ready infrastructure is to be provided, it must be coordinated with Sound Transit staff for best layout for accessibility, security and safety.

830.3.15.5 Lighting system, including illuminance levels for normal and emergency lighting and lighting control, must be provided in accordance with Set 1007 Electrical Lighting.

830.3.15.6 Lighting calculation must be prepared and submitted in accordance with Set 1007 Electrical Lighting. (Note: Lighting calculation must include all structures that are visible like signage that may give conflict such glare or insufficient light level). Clearances between the top of all electrical and communication equipment and nearest structure above must be per NEC. The designer must coordinate clearance to structure, slab, and other equipment with MEP designers to ensure required equipment in the room has required clearances.

Commentary: In past projects, the required clearance to equipment was 6 feet and the equipment was 68 inches tall resulting in a need for higher than 10 feet floor to structure clearance. This was not provided and created code issues. This situation must not happen so designers need to consult the code and the size and clearances for the equipment in the space and make sure it is designed accordingly.

830.3.16 Building Control and Monitoring Systems for Garages

830.3.16.1 Refer to Set 1004 Building Monitoring and Control.

830.3.17 Parking Management for Garages

830.3.17.1 Provide accommodations for future parking payment machines or license plate reader technology as coordinated with Sound Transit Operations. Provide accommodation for future patron payment machines at the main pedestrian exits of each level of the parking structure along the access route to the station. Quantity of machines per floor to be provided by Sound Transit. Include one CES at each payment machine area. Provide electrical and data conduits with pathway to electrical and communications rooms. Include one trash receptacle and one recycle receptacle at future parking payment areas if required by Operations.

830.3.17.2 Provide accommodation for future overhead electronic PIMS/VMS signage at the main pedestrian entry/exits and main vehicle entries. Provide electrical and data conduits with pathway to electrical and communications rooms.

830.3.17.3 Provide a vehicle counting system. Integrate recessed loops at all entry and exit lanes. Provide a conduit pathway to the communications room.

830.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

830.5 SYSTEM INTERFACE REQUIREMENTS

Table 830-2 lists requirement sets that are typically coordinated, and may have dependencies, with this set.

Table 830-2: Interface Between Architecture and Other Disciplines

SET SERIES	SERIES NAME	SET 803 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	
300	Operational Communications	
400	Vehicle	
500	Track	
600	Fire / Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical / Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

830.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

830.7 ENGINEERING MANAGEMENT REQUIREMENTS

830.7.1 Interface and Integration Management

830.7.1.1 Account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructable documentation and functional designs.

830.7.2 Design Management (Not Used)

830.7.3 Manufacturing and Construction Management (Not Used)

830.7.4 Installation Management (Not Used)

830.7.5 Inspection and Testing Management (Not Used)

830.7.6 Training, Pre-Revenue Operations (Not Used)

830.7.7 Certification Management (Not Used)

830.8 APPENDICES (NOT USED)

END SET - 830

836 OPERATIONS & MAINTENANCE BASE/FACILITY–LIGHT RAIL

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SET - 836 OPERATIONS & MAINTENANCE BASE/FACILITY–LIGHT RAIL

836.1 INTRODUCTION

836.1.1 Document Scope

836.1.1.1 This set establishes the design criteria for operations and maintenance facilities (OMFs).

836.1.1.2 This set presents general criteria for the yard area and maintenance facilities to accommodate a fleet of LRV for the Link.

836.1.1.3 Using the yard and building, the design team must analyze the traffic flow of the LRVs and the flow of material and the accessibility of operation and maintenance personnel to the facility and the LRVs. The analysis must include a detailed review of the activities and functions that will be performed at each location in the yard and/or facility.

836.1.1.4 During the design process, the spatial and functional adjacency relationship requirements will be developed to ensure that the facility arrangement will provide expedient and proper traffic and workflow, and space allocations.

836.1.1.5 The facility must maximize personnel comfort and safety, be compliant with ADA standards, and meet all applicable codes of AHJ. The interior arrangement of the buildings must reflect the same considerations to ensure that the fleet will be properly maintained.

836.1.1.6 The configuration of the buildings and the yard layout must reflect accommodations for the ultimate fleet. The facility must be designed for efficiency, maintainability, and reliability and account for total cost of ownership.

836.1.1.7 Future maintenance facilities must support the mode of service they are designed for, support all Sound Transit O&M base/facilities, and duplicate functions only when necessary or serving the same purpose to support operations and maintenance on that expansion line.

836.1.1.8 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 836 owner to determine the technical source for the design criteria.

836.1.2 Regulations, Codes, Standards, and Guidelines

836.1.2.1 International Regulations, Codes, Standards, and Guidelines

836.1.2.1.1 International Building Code (IBC).

836.1.2.1.2 International Fire Code (IFC) with local amendments.

836.1.2.1.3 International Code Council ICC A117.1 Accessible and Usable Buildings and Facilities.

836.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

836.1.2.2.1 ASME A17.1 Safety Code For Elevators And Escalators Includes Requirements For Elevators, Escalators, Dumbwaiters, Moving Walks, Material Lifts, And Dumbwaiters With Automatic Transfer Devices.

836.1.2.2.2 American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).

836.1.2.2.3 Federal and State Occupational, Safety and Health Standards.

836.1.2.2.4 Federal Transit Administration (FTA) Regulation 49 CFR Part 37.

836.1.2.2.5 Federal Transit Administration (FTA) TRI Transit Security Design Considerations Final Report Nov. 2004 (FTA-TRI-MA-26-7085-05).

836.1.2.2.6 IEEE C2 National Electrical Safety Code (NESC).

836.1.2.2.7 National Fire Protection Association (NFPA) Standard for Fixed Guideway Transit and Passenger Rail Systems (NFPA 130).

836.1.2.2.8 Sheet Metal and Air Conditioning National Association (SMACNA).

836.1.2.2.9 Seattle Energy Code (SEC) amendments to Washington State Energy Code (WSEC).

836.1.2.2.10 Washington Industrial Safety and Health Act (WISHA).

836.1.2.3 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

836.1.2.4 Other Jurisdictions (Not Used)

836.1.2.5 Sound Transit Regulations, Codes, Standards, and Guidelines

836.1.2.5.1 Sound Transit Access Control Lock and Key Policy.

836.1.2.5.2 Sound Transit Customer Signage Design Manual and Production Drawings.

836.1.2.5.3 Sound Transit Equipment and Facilities Numbering Standard.

836.1.2.5.4 Sound Transit Low Impact Development Stormwater Management (LID).

836.1.2.5.5 Sound Transit Systems Guidance Drawings.

836.1.3 Abbreviations and Acronyms

836.1.3.1 AC–alternating current

836.1.3.2 AHJ–authority having jurisdiction

836.1.3.3 BMS–building management systems

836.1.3.4 CCTV–closed circuit television

836.1.3.5 CMU–concrete masonry unit

836.1.3.6 DC–direct current

836.1.3.7 EV–electric vehicle

836.1.3.8 GWB–gypsum wallboard

836.1.3.9 HVAC–heating, ventilation, and air conditioning

836.1.3.10 LRV–light rail vehicles

836.1.3.11 MOW–maintenance-of-way

836.1.3.12 NRV–non-revenue vehicle

836.1.3.13 O&M–operations and maintenance

836.1.3.14 OMF–operations and maintenance facility

836.1.3.15 OCS–overhead contact system

836.1.3.16 TES–traction electrification system

836.1.3.17 TP–traction power

836.1.3.18 TPSS–traction power substation

836.1.3.19 TSS–transit safety and security

836.1.3.20 UPS–uninterrupted power source

836.1.4 Definitions and Classifications (Not Used)

836.1.5 References (Not Used)

836.2 STAKEHOLDER NEEDS

836.2.1 Passenger Experience (Not Used)

836.2.2 Operational Needs (Not Used)

836.2.3 Maintenance Needs

836.2.3.1 Sound Transit's proposed maintenance procedures must be reviewed, and Operations personnel must be consulted to ensure that the facility provides an efficient work environment. Janitorial closets and other maintenance rooms must be located on each floor and in locations convenient for users. Floor drains, hose bibs, and janitor sinks must be located for convenience of use.

836.2.4 Safety Needs

836.2.4.1 The design must be coordinated with Sound Transit TSS, Operations, and employee health and safety, to identify and mitigate any potential safety hazards. All equipment, storage, and access points must be evaluated for safety.

836.2.5 Security Needs

836.2.5.1 The design must be coordinated with TSS and Operations for security needs. The entire site as well as individual buildings and facilities must be secured from the public while providing access for staff and emergency services.

836.2.6 Reliability, Availability, and Maintainability Needs

836.2.6.1 The design must focus on a facility that is reliable and easily maintained. Life cycle costs must be evaluated and part of decision making for determining equipment and materials. Equipment must be easily and safely accessible for maintenance. Consult Sound Transit staff in the facility design.

836.2.7 Environmental and Sustainability Needs

836.2.7.1 Maintenance facilities must comply with Sound Transit's sustainability goals and meet either LEED or Envision rating goals as outlined in Set 803 Sustainability.

836.3 SYSTEM REQUIREMENTS

836.3.1 General Requirements

836.3.1.1 Operations facilities must support necessary requirements for all normal O&M functions.

836.3.1.2 The facilities must be designed in conjunction with one another, and duplication of equipment and shop requirements must be kept to the minimum required to perform satisfactory work. This means that the facility must meet the demands of the project without providing unnecessary spaces or equipment while being resilient in the ability to meet future demands for modification or growth. Coordination with Operations and Facilities to determine the spaces and equipment needed for the project will define the project needs.

836.3.1.3 Maintenance facilities must be designed to meet Sound Transit Sustainability goals per Set 803 Sustainability.

836.3.1.4 Commissioning of the entire facility, all building envelope, systems, including LRV wash, UPSs, compressors, and other critical equipment and systems within all buildings and yard are required. All needed adjustments must be made prior to acceptance of project. Perform building commissioning in accordance with Section 836.7.5 in this set.

836.3.1.5 The designers must coordinate systems infrastructure in conjunction with Sound Transit Systems and Operations staff. Install systems infrastructure with capacity to accommodate future growth and expansion. The facility must be designed to be adaptive over time.

836.3.1.6 All facility naming and numbering must follow the current edition of the Sound Transit Equipment and Facilities Numbering Standard.

836.3.2 Site Selection Criteria

836.3.2.1 The yard and shops site must be of sufficient size to permit the construction of the facilities necessary to support the initial and ultimate revenue service and fleet sizes.

836.3.2.2 Capacity and efficiency of yard–related operations; restriction due to site footprint on yard and shop configurations.

836.3.2.3 The selected sites must be located to provide convenient access to the main line with a minimum of deadhead mileage. The site selection process must include consideration of land acquisition, adaptability, configuration, clearing, and construction costs.

836.3.2.4 Efficiency of mainline connectivity and minimization of deadhead miles.

836.3.2.5 The selected sites must comply with all environmental requirements minimizing the negative impact on adjoining land. Considerations must include air and noise pollution, traffic, aesthetics, social, economic, and safety, among others.

836.3.2.6 Configuration of the yards and shops must permit a functionally efficient layout to provide vehicle storage and workflow that minimizes train and personnel movement requirements. This must be coordinated with Sound Transit Operations.

836.3.2.7 Site shape must accommodate geometry to permit a full trackwork loop bypassing, while allowing access to the storage yard and shop.

836.3.2.8 The site must be level to store and maintain LRVs without the danger of a car rolling down any grades on the site or toward the main line.

836.3.2.9 The site must accommodate positioning of the shop and yard trackwork in such a manner to preclude entrapment of cars or trains from access to the storage yard, shop, or mainline.

836.3.2.10 The site must accommodate layouts that allow the ability to turn LRVs end-for-end.

836.3.2.11 Layout must allow for at least two entrance and exit points into the yard for fire department vehicle access. The site will accommodate fire department access to buildings and around stored vehicles as dictated by the AHJ and International Fire Code.

836.3.3 Functional Requirements

836.3.3.1 As directed by Sound Transit, Link LRT Operations Facility may house the following functions as determined through the project programming efforts in conjunction with Sound Transit. Each OMF facility must be evaluated as part of the overall system. Some functions may be needed at each location while other functions are needed only at select locations. Below is a partial list of typical functions. The actual facility may require additional or different functions which must be developed by the project team with Sound Transit for that project.

i. LRV storage
ii. Non–Revenue Vehicle support and charging stations
iii. Train make-up and yard dispatch
iv. LRV adds and drops
v. Train operator report area
vi. Operator and maintenance training
vii. Inspection offices and report area
viii. LRV service and inspection
ix. LRV interior cleaning
x. LRV exterior cleaning
xi. LRV air-conditioning, current collector and resistor unit repair
xii. Component repair and rebuild
xiii. Signal system service and inspection
xiv. Fare Collection equipment storage and inspection
xv. TES service and inspection
xvi. TES overhead service and inspection
xvii. Link track maintenance
xviii. Station cleaning
xix. Facilities maintenance
xx. LRV re-railing
xxi. Rail-bound equipment storage
xxii. Link parts storage
xxiii. Rail transportation administration
xxiv. Rail maintenance administration
xxv. Rail operations planning
xxvi. Rail maintenance engineering
xxvii. Central Control Facility (To be used either as a primary or back-up control center)
xxviii. Link training
xxix. LRV body shop
xxx. LRV paint shop
xxxi. Machine and sheet metal shops
xxxii. Wheel truing
xxxiii. Wheel assembly pressing
xxxiv. Axle component pressing
xxxv. LRV truck maintenance, repair, and overhaul
xxxvi. Electronic component repair
xxxvii. Signal relay inspection and calibration
xxxviii. Fare Collection equipment component repair

xxxix. Communications equipment component repair
xl. Covered and open storage of Link MOW materials
xli. Security
xlii. Fire Alarm System
xliii. Operator wait area
xliv. Staff lunch and locker rooms to support Maintenance and Operations staff.
xlv. Staff restroom
xlvi. Office areas for staff
xlvii. Environmental areas for storage and waste of hazardous materials
xlviii. Parking for staff including bicycle parking for staff and for visitors
xlix. Parking for visitors
l. Bicycle parking for Staff and for visitors
li. Laydown areas for Right of Way spares
lii. Signage to support all auto traffic movement in and around the shop
liii. LRV Delivery
liv. Sanding facilities at OMF and LRV storage tracks
lv. See Set 822 for related spaces for Operations at terminus stations.

836.3.3.2 Site Planning

836.3.3.2.1 The operations facility layout may include the following as determined through the project programming efforts in conjunction with Sound Transit.

i. Operations and Maintenance Yard
ii. LRV storage area LRV run around loop
iii. LRV cleaning area
iv. Non–Revenue Vehicle exterior wash with water recycling system which can be tied to LRV wash recycling system
v. Gate protected parking, service, and access roads
vi. Outside storage area for MOW, facilities, traction power and signal equipment
vii. Yard fire protection via fire hydrants at the perimeter of the yard unless otherwise required by the AHJ.
viii. Yard lighting
ix. Security/CCTV coverage
x. Refuse collection locations and hazardous material storage area
xi. Landscaping
xii. Parking including EV ready infrastructure- conduit for future EV charging stations.
xiii. Water truck filling station
xiv. LRV primary shop
xv. LRV exterior wash facility with water recycling system which can be tied to NRV wash recycling system
xvi. Maintenance vehicle storage building
xvii. Electrical supplies
xviii. Truck shop
xix. Paint booth
xx. Generator and fuel storage

836.3.4 Performance Requirements

836.3.4.1 MOW activities may be conducted and administered at the main yard. If civil constraints will not permit the MOW facility to be located in the main yard, then it must be located at a satellite facility adjacent to the mainline and with easy access to any point on the line.

836.3.4.2 Traction Power Substation Perimeter Security Fence

836.3.4.2.1 Where TPSSs are located at grade and not within an O&M yard, provide fence per Sound Transit Guidance Drawing JTP100 and see Set series 200 Traction Electrification for further requirements. Where TPSSs are located within the securely fenced yard, no additional fencing around the TPSS is required.

836.3.5 Fire/Life Safety Requirements

836.3.5.1 . Refer to Set 601 Fire/Life Safety.

836.3.5.2 Fall protection must be provided as required. Design out the need for fall protection and avoid situations that would require it. See Set 804 Fall Protection for further requirements.

836.3.5.3 Safety guards must be designed for equipment, such as wheel truing machines and others, that pose potential hazards.

836.3.5.4 The design must minimize and preferably eliminate confined spaces. In the event a confined space is required or cannot be removed, it must be designed for safe access.

836.3.5.5 Rooms storing chemicals or batteries must be designed for safe storage and designated as safe storage areas for those materials.

836.3.5.6 Occupancy classification for maintenance facilities must be in accordance with the IBC.

836.3.5.7 Hazardous storage rooms (interior and exterior) must be classified based upon preliminary hazardous material inventory provided by Sound Transit. See Set 601 Fire/Life Safety for additional requirements.

836.3.5.8 Overhead AC/DC power systems must be protected or recessed to prevent inadvertent contact with movable maintenance platforms, ladders, or mobile cranes.

836.3.5.9 Battery racks must be provided for maximum protection against battery damage, and for ease of accessibility.

836.3.5.10 Rotating or other moving machinery must be enclosed or properly guarded from personnel contact and located away from pedestrian flow and maintenance activities. See WAC 296-806 for additional requirements.

836.3.5.11 High-temperature equipment and piping must be properly guarded or covered with approved insulation in locations where contact by personnel or combustibles may occur. Routing of high-temperature liquids over maintenance activities, personnel areas, or electrical equipment must be avoided.

836.3.6 Train Yards

836.3.6.1 Water supply and distribution: Refer to Set 601 Fire/Life Safety for fire hydrant requirements.

836.3.6.2 Vehicular traffic within the yard and crossing tracks must be protected.

836.3.7 Emergency Access and Security

836.3.7.1 Emergency access must be provided to facilities within the yards and shops area through public streets or transit access roads and as required by the local jurisdiction. See Set 601 Fire/ Life Safety for additional requirements.

836.3.7.2 The yard and shop must be protected with non-climbable security fencing at least 8 feet high. CCTV and intrusion detection must be provided at access points. See Set 903 Fencing.

836.3.7.3 Access gates located in security fencing in the yard must have openings with a minimum of 25 feet of unobstructed width. Gates must be UL325 Class III minimum sliding gates and motorized operation for the main entrance and manual operation for any ancillary buildings.

836.3.7.4 Sliding gates must be industrial grade and located within hard paved surface.

836.3.7.5 Sliding track must be heavy duty and hold up to industrial type use and free of gravel areas that could cause the track to jam.

836.3.7.6 Swing gates are permitted if approved by Sound Transit only where space constraints prevent the use of sliding gates. See Set 903 Fencing.

836.3.7.7 Full access within the yard must be achieved through a perimeter road and cross lanes. Access must be provided and maintained in accordance with locally adopted street, road, and access standards.

836.3.7.8 Minimum vertical clearance must be 15 feet in height.

836.3.7.9 Yard tracks must allow a minimum clearance of 3 feet between the sides of adjacent transit vehicles. In storage areas, a minimum unobstructed access of 7 feet must be provided on one side of the vehicle.

836.3.7.10 Turning radii of access roads must be large enough to permit emergency access and road vehicle delivery of LRV. The minimum inside curb radius must be 25 feet. The minimum outside curb radius must be 50 feet. The fire marshal of the AHJ must approve the turning radius.

836.3.7.11 See Set 601 Fire–Life Safety for emergency access and egress vs security requirements.

836.3.7.12 Provide security card access where required by Operations. See Sets 801 Architectural Materials, Elements, and Furnishings and 1203 Access Control System.

836.3.8 Exterior Materials

836.3.8.1 The exterior materials to be used on the facility must be selected based on durability and appearance. Sound Transit requires a facility that will provide 30 to 50 years of low maintenance, but also provide a pleasing civic appearance to fit in to the existing area and for the people who work and visit the building. Materials such as brick, CMU, pre-cast concrete, glass, and metal siding must be used. Exterior design for materials, screening, and massing must meet local zoning requirements where applicable.

836.3.8.2 Exterior wall and roof systems must meet or exceed current energy codes and be designed for the Pacific Northwest climate best practices, including proper ventilation and rain shedding. Roof materials must be selected based on long-term durability and appearance. Glazing must be accessible for cleaning without the use of fall protection and outside of the OCS by a 10-foot range.

836.3.8.3 Flashings must be either stainless steel or baked on finish to match metal panel systems.

836.3.8.4 See Set 801 Architectural Materials, Elements, and Furnishings for acceptable materials and finishes.

836.3.8.5 Comply with Set 801 Architectural Materials, Elements, and furnishings for bird control requirements.

836.3.9 Interior Materials

836.3.9.1 See Set 801 Architectural Materials, Elements, and Furnishings for acceptable materials and finishes.

836.3.9.2 The emphasis on material selection for the interior of the facility must be on durability and low maintenance.

836.3.9.3 Finishes must be as follows:

i. Sealed concrete floors in shop areas.
ii. Non-combustible, slip-resistant surfaces must be provided in all maintenance facilities areas.
iii. Wall areas in shops must have a minimum 8 feet high concrete or concrete block wainscoting.

iv. Floor and ceiling materials must be appropriate for intended use. Sound insulation must be provided between adjacent office spaces and adjoining spaces. Walls must extend above ceilings if they are not GWB ceilings.

v. Toilet/shower areas must have porcelain ceramic tile floor and porcelain or glazed ceramic tile wall finishes. See Set 801 Architectural Materials, Elements, and Furnishings for finish requirements and Set 1002 Mechanical - Plumbing for plumbing requirements.

836.3.10 Structural

836.3.10.1 The building must be designed in accordance with the building code adopted by the city in which the building will be located.

836.3.10.2 Soil bearing pressure must be determined from the geotechnical report.

836.3.10.3 The building structure must be of non-combustible construction.

836.3.10.4 Cranes, lifts, and hoisting structures must be fully integrated into the structural design.

836.3.10.5 Fall protection must be accounted for in the structural design. See Set 720 Building Structures and 804 Fall Protection.

836.3.10.6 For further detailed structural criteria, refer to Set 720 Building Structures.

836.3.11 Mezzanine and LRV maintenance access

836.3.11.1 A mezzanine must be provided for access to the top of the LRV during maintenance. See Set 804 Fall Protection.

836.3.11.2 Mezzanine must have adequate clearance to LRV, including when doors are open. See Set 520 Vehicle Clearances and Track Spacing for required clearances.

836.3.11.3 In addition to the mezzanine, there are stepped maintenance access platforms which allow staff to enter the LRV from the OMF maintenance floor. These platforms must meet required clearances to the LRV when doors are open. Minimum horizontal clearance must be 2 inches to LRV door in the open position, confirmed against vehicle specs for all Sound Transit LRV types. Deck must be 1 inch maximum below LRV door threshold averaged between threshold heights of all ST LRV types.

836.3.12 Building Electrical and Lighting

836.3.12.1 Refer to Sets 1007 Electrical Lighting, 1004 Building Monitoring and Control and 1005 Electrical Power.

836.3.12.2 Provide an exterior generator to support essential functions of the facility as determined through coordination with Sound Transit. See Set 1005 Electrical Power for requirements.

836.3.12.3 Provide electrical service to an OMF in accordance with Set 1005 Electrical Power.

836.3.12.4 Electrical panels, distribution panels, and their spares must be provided as determined in Set 1005 Electrical Power.

836.3.12.5 All light fixtures and drivers must be located for efficient and safe access for maintenance and replacement.

836.3.12.6 See Set 1005 Electrical Power for further electrical criteria. See Set 1004 Building Monitoring and Control for further clarification on coordination with BMS.

836.3.12.7 Natural light from skylights, windows, and clerestory windows must be maximized to reduce dependence on light fixtures during daylight hours and be located such that fall protection is not required, for routine maintenance. Conduct daylighting studies during design to review and optimize daylighting solutions. Provide natural light and view through vision glazing where possible. Avoid providing natural light only through translucent glazing in work areas.

836.3.12.8 Security lighting must be placed as necessary to supplement the normal area outside work lighting.

836.3.12.9 Mechanical- Electrical and Building Systems

836.3.12.10 Per Set 803 Sustainability, evaluate the use of photovoltaics at OMFs given the size of roof areas anticipated, minimal shading with the track layout looping the site, and direct use of the power in the facility. See Set 803 Sustainability and Set 1004 Building Monitoring and Control for further requirements.

836.3.13 Corrosion Control and Safety Grounding

836.3.13.1 The maintenance facility must have equipotential grounding systems for all conductive surfaces exposed to human contact. These must be accomplished through use of a building perimeter ground.

836.3.13.2 The perimeter ground must be bonded to intermittent ground rods and bonded to the metal structure of the building and reinforcement bars of the concrete.

836.3.13.3 The reinforcing steel of the main shop floor must be bonded into a grid pattern and all shop conductive surfaces must be bonded to the grid.

836.3.13.4 The shop trackwork must be continuous and bonded to the grid. The shop grid and perimeter ground must be bonded to the shop substation ground mat.

836.3.13.5 Insulated rail joints must be located in the ends of the concrete aprons, which will define the extent of the shop grounding system and DC electrical system. See Set 222 Stray Current Corrosion Control and Set 1005 Electrical Power.

836.3.13.6 DC stray currents are prevalent in the yard and shop area. Accordingly, ferrous pipe must be coated with an electrical insulating material and tested prior to burial. Some underground services (such as natural gas) may be better served by use of plastic pipe where the code allows. Joints in piping will require bonding in some locations and insulated joints in others.

836.3.14 Acoustics

836.3.14.1 In planning the new facility, noise- and vibration-generating equipment such as air compressors and pumps must be located away from office areas and/or acoustically isolated. HVAC mechanical units must be located and specified so that noise and vibration transmission is minimized. Walls, ceilings, and floors in these spaces must be designed to further reduce noise transmission to other parts of the facility. See Sets 007 Noise and Vibration and 1007 Electrical Lighting for additional requirements.

836.3.15 Maintenance

836.3.15.1 Sound Transit’s proposed maintenance procedures must be reviewed, and staff operations personnel must be consulted to ensure that the facility provides an efficient work environment. Janitorial closets and other maintenance rooms must be located on each floor and in central locations adjacent to restrooms or lunchroom/ kitchens. Floor drains, hose bibbs, and janitor sinks shall be located per above.

836.3.16 Mechanical Systems

836.3.16.1 See Set series 1000 Mechanical-Electrical and Building Systems and Set 601 Fire/Life Safety

836.3.16.2 All equipment rooms containing heat sensitive equipment must have dedicated air conditioning and adequate ventilation to support reliable equipment operation over the course of its expected life (e.g., UPS rooms, server rooms, compressor rooms, machine and electrical rooms if required).

836.3.16.3 Provide drinking fountain with chilled water and integral bottle filler at all floors.

836.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

836.5 SYSTEM INTERFACE REQUIREMENTS

Table 836-1 lists requirement sets that are typically coordinated, and may have dependencies, with this set.

Table 836-1: Interface Between Architecture and Other Disciplines

SET SERIES	SERIES NAME	SET 803 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	X
400	Vehicle	
500	Track	X
600	Fire / Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical / Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

836.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

836.7 ENGINEERING MANAGEMENT REQUIREMENTS

836.7.1 Interface and Integration Management (Not Used)

836.7.1.1 Account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructable documentation and functional designs.

836.7.2 Design Management (Not Used)

836.7.3 Manufacturing and Construction Management (Not Used)

836.7.4 Installation Management (Not Used)

836.7.5 Inspection and Testing Management

836.7.5.1 The design must adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

836.7.6 Training, Pre-Revenue Operations (Not Used)

836.7.7 Certification Management (Not Used)

836.8 APPENDICES (NOT USED)

END SET - 836

901 STORM DRAINAGE

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SET - 901 STORM DRAINAGE

901.1 INTRODUCTION

901.1.1 Document Scope

901.1.1.1 This set addresses requirements for hydrologic and hydraulic analyses and design, maintenance access design, and additional topics concerning storm drainage on Sound Transit projects. These requirements apply to Sound Transit-owned and non-Sound Transit-owned storm drainage facilities that are impacted by Sound Transit projects. For the non-Sound Transit-owned storm drainage facilities, the owner's criteria must apply, as stated in this set.

901.1.1.2 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 901 owner to determine the technical source for the design criteria.

901.1.2 Regulations, Codes, Standards, and Guidelines

901.1.2.1 Department of Ecology's Stormwater Management Manual for Western Washington (SWMMWW), latest edition.

901.1.2.2 WSDOT Hydraulics Manual.

901.1.2.3 WSDOT Highway Runoff Manual.

901.1.2.4 WDFW Water Crossing Design Guidelines.

901.1.2.5 WDFW Integrated Streambank Protection Guidelines.

901.1.2.6 Executive Order 11988, Flood Management, May 1977.

901.1.2.7 Executive Order 13690 Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input, Jan 2015.

901.1.2.8 Guidelines for Implementing Executive Order 11988, Floodplain Management, and Executive Order 13690, Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input, Oct 8, 2015.

901.1.2.9 Executive Order 13807, Establishing Discipline and Accountability in the Environmental Review and Permitting Process for Infrastructure, Aug 2017.

901.1.2.10 Executive Order 14030, Climate-Related Financial Risk, May 2021.

901.1.2.11 American Railway Engineering and Maintenance-of-Way Association (AREMA), 2023.

901.1.3 Abbreviations and Acronyms

901.1.3.1 AHJ–authority having jurisdiction

901.1.3.2 BMP–best management practice

901.1.3.3 DOR–designer of record

901.1.3.4 EO–executive order

901.1.3.5 FRP–fiberglass reinforced plastic

901.1.3.6 WAC–Washington Administrative Code

901.1.3.7 WDFW–Washington Department of Fish and Wildlife

901.1.4 Definitions and Classifications (Not Used)

901.1.5 References (Not Used)

901.2 STAKEHOLDER NEEDS

901.2.1 Passenger Experience

901.2.1.1 The Sound Transit system must operate with minimal service disruptions to passengers during heavy rain events.

901.2.2 Operational Needs

901.2.2.1 The storm drainage systems must function during heavy rain events.

901.2.2.2 The storm drainage systems must not disrupt service or cause damage to critical facilities.

901.2.3 Maintenance Needs

901.2.3.1 Underground stormwater conveyance pipes must withstand construction traffic and maintenance vehicle traffic.

901.2.4 Safety Needs (Not Used)

901.2.5 Security Needs

901.2.5.1 The design must deter illicit vehicle visits, including illegal garbage dumping.

901.2.6 Reliability, Availability and Maintainability Needs

901.2.6.1 The storm drainage systems must be accessible for maintenance without service disruption.

901.2.7 Environmental and Sustainability Needs

901.2.7.1 Early in the design phase, the DOR must identify impacts to existing culverts or water crossings and coordinate with Sound Transit Environmental.

Commentary: WAC 220-660-190 requires upgrades to impacted culverts and water crossings that are fish-passable and involves time-sensitive coordination with Federal and Tribal authorities.

901.3 SYSTEM REQUIREMENTS

901.3.1 Engineering Reports

901.3.1.1 The storm drainage analyses and hydraulic reports (drainage technical information reports) must comply with AHJ requirements.

901.3.1.1.1 When a project encompasses more than one AHJ, the DOR must prepare a report for each AHJ and each of these reports must reference the overall project.

901.3.1.2 Hydraulic reports must document vesting agreements between Sound Transit and AHJ(s) concerning applicable requirements.

Commentary: Hydraulic reports must itemize known pending updates to AHJ stormwater manuals and their impacts to the project.

901.3.1.3 Hydraulic reports must include a narrative summarizing coordination with third party stakeholders and AHJs and reference available meeting notes and related documentation.

901.3.2 Flood Risk, Channel Migration Zones, and Water Crossings

901.3.2.1 The design must comply with federal, state, and local laws and regulations, including AHJ stormwater requirements and local floodplain ordinances and regulations.

Commentary: The National Pollutant Discharge Elimination Program (NPDES) requires AHJs to adopt equivalent or better storm drainage standards than the Department of Ecology's Stormwater Management Manual for Western Washington.

Commentary: WAC 220-660-190 must apply to water crossings over fish-bearing waters.

901.3.2.2 In the absence of AHJ stormwater requirements, the requirements of the WSDOT Highway Runoff Manual and WSDOT Hydraulics Manual must apply.

901.3.2.3 The design must comply with the following flood risk management requirements:

901.3.2.3.1 For critical facilities, build top of rail and rail system components and TPSS/Signal Bungalow facilities to a minimum of 3 feet above the 100-year (1 percent annual chance) flood elevation or to the 500-year (0.2 percent annual chance) flood elevation, whichever is higher.

Commentary: Sound Transit's flood risk management criteria is consistent with EO 13690, "Establishing a Federal Flood Risk Management Standard (FFRMS) and a Process for Further Soliciting and Considering Stakeholder Input". EO 11988, as amended by EO 13690, defines a critical action as any activity for which even a slight chance of flooding would be too great. Sound Transit has designated Sounder Rail and all Link Light Rail as critical facilities for minimum applicable flood stage elevations.

Commentary: The Federal Flood Risk Management Standard, issued in January 2015, encourages federal agencies to consider current and future risk when taxpayer dollars are used to build or rebuild near floodplains. EO 13690 of January 30, 2015, established a Federal Flood Risk Management Standard to address current and future flood risk and ensure that projects funded with taxpayer dollars last as long as intended. EO 13690 amended certain provisions of EO 11988, "Floodplain Management," of 1977. In 2017, EO 13690 was revoked by Section 6 of EO 13807.EO 13807 did not revoke or otherwise alter EO 11988. In May 2021, EO 13690 was reinstated by EO 14030, "Climate-Related Financial Risk." The "Guidelines for Implementing EO 11988, Floodplain Management, and EO 13690" of October 2015 were never revoked and thus remain in effect as of January 2023.

901.3.3 Engineering Design

901.3.3.1 This section lists the requirements for hydrologic and hydraulic design, including the engineering of storm water facilities.

901.3.3.1.1 The design must comply with AHJ stormwater requirements and federal, state, and local laws and regulations.

901.3.3.2 The minimum hydraulic capacity and pipe flow velocities of open channels, swales, gutters, storm sewer pipe systems, and culverts must meet AHJ(s) requirements and environmental permit requirements.

901.3.3.3 In the absence of AHJ criteria, the WSDOT Highway Runoff Manual and WSDOT Hydraulics Manual must apply.

901.3.3.4 Culverts and drainage facilities crossing rail corridors must meet the following requirements:

901.3.3.4.1 The 100-year flow event must not exceed the elevation of the top of rail minus one foot.

901.3.3.4.2 The 25-year flow event must not exceed the elevation of the top of subballast.

Commentary: The above criteria apply to a ballasted light rail track section. In areas of direct fixation or embedded track, apply an equivalent requirement.

901.3.3.5 Ditches must have a minimum longitudinal slope of 0.4 percent.

901.3.3.6 Subsurface drainpipes must have a minimum longitudinal slope of 0.5 percent.

901.3.3.7 The DOR must design stream culverts that cross rail corridors, per WDFW's Water Crossing Design Guidelines.

Commentary: Stream crossings require WDFW Hydraulic Project Approval(s).

901.3.3.8 The DOR must design closed storm water systems for parking lots, roadways, and track roadbeds to meet AHJ criteria.

Commentary: Parking lot design (paved maintenance areas, plazas, and loading areas) must remove stormwater by overland flow to a gutter, curb and gutter, or to an inlet. After collection in inlets, stormwater runoff will enter a closed drainage system, open ditch, or a receiving water body.

901.3.3.9 The storm drainage materials for Sound Transit facilities must meet the requirements of the AHJ.

901.3.3.9.1 In the absence of AHJ requirements, the WSDOT Hydraulics Manual must apply.

901.3.3.9.2 Pipe material for subsurface drains and underdrains for Sound Transit facilities must be PVC or HDPE.

Commentary: Underground FRP drainage systems are prohibited.

901.3.3.9.3 The design of culverts, drainage systems, and underdrain systems crossing tracks must meet or exceed AREMA technical standards.

901.3.3.10 Drainage structures must be in areas set back from crosswalks, pedestrian pathways, and electrical elements such as generator taps, electrical vaults, and transformers.

901.3.3.11 The drainage facilities and structures must withstand buoyancy loads and surface loads from anticipated maintenance and emergency response vehicles/apparatus.

Commentary: As part of the preliminary design, the DOR establishes surface load structural criteria for drainage structures and appurtenances for various areas of the site. Future design phases must develop and implement refined criteria. The design must also address anticipated surface loading regimes during construction, if applicable.

901.3.3.12 Storm drain piping crossing beneath the track must have a minimum of 6 feet clearance from the top of rail to the top of casing.

901.3.3.13 The design must encase storm drain piping where the top of piping is within ten feet laterally of the light rail guideway and within six feet vertically from the top of rail. The DOR must specify the casing's geometric design, diameter, wall thickness, and material.

901.3.3.14 The design must provide drainage structures for closed storm drainage systems at changes in pipe slope, alignment and size, and at multiple-pipe intersections.

901.3.3.14.1 For at-grade track sections, the maximum spacing for drainage structures must be 300 feet.

901.3.3.14.2 The design of storm drainage trunks and laterals must not include drainage structures in the trackway.

901.3.3.15 Aerial guideway drainage systems must meet the following requirements:

901.3.3.15.1 The design must provide cleanouts for aerial drainage systems at least every 250 feet.

901.3.3.15.2 The design must provide cleanouts at changes in pipe direction of minimum 22.5 degrees.

901.3.3.15.3 Pipe materials must be circular in cross section with a minimum diameter of 6 inches.

901.3.3.15.4 Aerial guideway drainage systems must be ductile iron or fiber reinforced plastic pipe systems.

901.3.3.15.5 Aerial guideway drainage systems at stations must comply with Sound Transit architectural requirements.

901.3.3.15.6 Aerial guideway drainage systems must consist of black, silver, or gray pipeline colors.

901.3.4 Access and Maintenance

901.3.4.1 The design must provide access to stormwater facilities per the requirements of AHJ and the facility owner.

901.3.4.2 Stormwater vaults, pipeline flow control facilities, and enclosed facilities must provide vertical and horizontal clearances for maintenance and operations activities, including repair and replacement.

901.3.4.2.1 Stormwater facilities (stormwater ponds, pond access roads, and flow control facilities) under elevated structures or guideways must provide vertical and horizontal access clearances for Vactor trucks and heavy maintenance vehicles.

901.3.4.2.2 Stormwater pumping and lift station design must provide vertical and horizontal access clearances for mobilizing crane equipment to remove and replace equipment within.

901.3.4.2.3 The design must include overhead anchors above interior stormwater facilities, such as sump pumps within parking garages, to facilitate access to and removal of equipment within.

901.3.4.3 Stormwater reports must address ownership, maintenance, operations, and access, including specific recommendations.

901.3.4.4 The DOR must confirm the ownership, operations, maintenance, and access needs of storm drainage facilities.

901.3.4.5 The design must incorporate the owner's maintenance procedures, access requirements, frequencies, and geometric design for maintenance vehicles/equipment.

901.3.4.6 For stormwater ponds adjacent to light rail trackways, the design must provide a corridor of minimum width of 10 feet between top of pond embankment and trackway embankment slope edge or retaining wall.

Commentary: This requirement intends to assure maintenance access to stormwater ponds is provided without requiring a trackway right-of-way access permit for maintenance activities.

901.3.4.7 Stormwater facilities within, or adjacent to, WSDOT Right of Way must provide maintenance access within WSDOT limited access requirements.

901.3.4.8 Design Sound Transit-owned stormwater facilities to incorporate maintenance access, parking, and turnaround capabilities. The design must not impact the traveling public using adjacent public rights-of-way.

901.3.5 Additional Requirements

901.3.5.1 The design must meet Low Impact Development methodologies per local AHJ requirements.

901.3.5.2 The DOR must design the allowable spread for gutter flow per AHJ requirements or the WSDOT Hydraulics Manual, if applicable. The maximum allowable spread for gutter flow is the shoulder width plus 2 feet for the 10-year storm.

901.3.5.3 The DOR must locate Sound Transit-owned storm drainage facilities within the Sound Transit rights-of-way.

Commentary: Certain AHJs prohibit storm drainage facilities within private parcels, and instead require that such facilities exist within AHJ public right of way. Sound Transit prefers Sound Transit-owned storm drainage facilities to be within Sound Transit-owned parcels or Sound Transit ROW to avoid or minimize AHJ permitting for Sound Transit maintenance activities.

901.3.5.4 The design must provide dedicated and separate stormwater facilities to collect, convey, treat, and/or detain stormwater runoff originating from Sound Transit facilities.

901.3.5.5 The design must exclude the following storm drainage structural elements and BMPs for Sound Transit-owned storm drainage infrastructure and AHJ-owned storm drainage infrastructure.

i. Corrugated metal pipe
ii. Pipeline Flow Control Facilities

901.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

901.4.1 System Breakdown Structure

901.4.2 System Sites and Locations

901.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 901-1: Interfaces Between Storm Drainage and Other Disciplines

SET SERIES	SET NAME	SET 901 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	
300	Operational Communications	
400	Vehicle	
500	Track	X
600	Fire/Life Safety	
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	
1200	Security	

901.5.1 Track

901.5.1.1 Coordinate with Track requirements for track drain requirements and locations.

901.5.2 Structures

901.5.2.1 Coordinate with Structures requirements for bridge drain requirements and locations.

901.5.3 Architecture

901.5.3.1 Coordinate with Architecture requirements for above ground drainage requirements and locations.

901.5.3.2 Coordinate with Architecture requirements for LEED and ENVISION requirements.

901.5.4 Civil

901.5.4.1 Coordinate with Civil requirements for the following:

901.5.4.1.1 Storm drainage pipeline and culvert crossings of rail.

901.5.4.1.2 Fencing, Bollards, and maintenance access.

901.5.5 Mechanical-Electrical and Building Systems

901.5.5.1 Coordinate with Mechanical-Electrical and Building Systems requirements for drainage and sewerage and back-up system requirements.

901.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

901.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

901.7.1 Interface and Integration Management

901.7.2 Design Management

901.7.3 Manufacturing and Construction Management

901.7.4 Installation Management

901.7.5 Inspection and Testing Management

901.7.6 Training, Pre-Revenue Operations

901.7.7 Certification Management

901.8 APPENDICES (NOT USED)

END SET - 901

902 UTILITIES

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SET - 902 UTILITIES

902.1 INTRODUCTION

902.1.1 Document Scope

902.1.1.1 This set includes requirements for utility work for Sound Transit Projects, including site utilities, utility services, relocation of third-party utilities, and additional topics concerning utility work for Sound Transit projects.

Commentary: Each utility owner possesses requirements for applicable third-party utility relocations and utility services. Refer to the technical and administrative requirements of the third-party utility owner.

Commentary: This requirement Set does not address permitting activities and real property transactions for utilities.

902.1.1.2 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 902 owner to determine the technical source for the design criteria.

902.1.2 Regulations, Codes, Standards, and Guidelines

902.1.2.1 American Railway Engineering and Maintenance-of-Way Association (AREMA), Manual of Railway Engineering.

902.1.2.2 Burlington Northern & Santa Fe (BNSF) Railway Utility Accommodation Policy.

902.1.2.3 Sound Transit Utility Relocation Guidelines Desktop Reference.

902.1.2.4 Sound Transit Engineering Procedure 15 (EP-15) Subsurface Utility Engineering (SUE).

902.1.2.5 Sound Transit Standard Operating Procedure (SOP) 6.15 Track Access Procedures.

902.1.3 Abbreviations and Acronyms

902.1.3.1 AHJ–authority having jurisdiction

902.1.3.2 AWWA–American Water Works Association

902.1.3.3 DOR–designer of record

902.1.3.4 FDC–fire department connection

902.1.3.5 ppm–parts per million

902.1.3.6 SOP–standard operating procedure

902.1.4 Definitions and Classifications

902.1.4.1 Stray Current: Current flowing through the path other than intended circuit. It is referred to the current that escapes in the ground from rail-OCS circuit.

902.1.5 References (Not Used)

902.2 STAKEHOLDER NEEDS

902.2.1 Passenger Experience

902.2.1.1 Utility services to Sound Transit facilities and utility crossings must be reliable enough that premature failures do not disrupt the regular service and comfort Sound Transit passengers rely on.

902.2.2 Operational Needs

902.2.2.1 Ensure placement and access of utilities and third-party maintenance does not disrupt Sound Transit operations.

902.2.2.2 The design criteria for Soil Corrosion and Stray Current Control must meet the following objectives:

902.2.2.2.1 Realize the design life of system facilities by avoiding premature failure from corrosion.

902.2.2.2.2 Minimize annual operating and maintenance costs for material deterioration and labor costs for manual meter reads.

902.2.2.2.3 Provide continuity of operations by reducing or eliminating corrosion-related failures of systems and subsystems.

902.2.2.2.4 Minimize detrimental effects of stray earth currents resulting from transit operations to facilities belonging to others.

902.2.3 Maintenance Needs

902.2.3.1 Locate assets and equipment owned by Sound Transit and third-party utility owners in a way that the utility owners have unrestricted access for maintenance without impeding each other's operations.

902.2.4 Safety Needs

902.2.4.1 Locate FDC points outside of the egress area in a way that the emergency responders' operation does not impede egress.

902.2.5 Security Needs

902.2.5.1 Locate assets and equipment owned by third-party utility owners in a way that the utility owners have unrestricted access without impeding Sound Transit operations.

902.2.6 Reliability, Availability and Maintainability Needs

902.2.6.1 The design must minimize interruptions of existing utility services.

902.2.7 Environmental and Sustainability Needs

902.2.7.1 When designating the Area of Potential Effect for environmental permitting, the DOR must identify potential impacts to areas of utility work, including service connections and utility relocations, in the early design phase to mitigate environmental impacts and minimize project delays.

902.3 SYSTEM REQUIREMENTS

902.3.1 General Policy

902.3.1.1 Site utilities, utility services, and relocation of third-party utilities must comply with applicable federal, state, and local laws and regulations.

902.3.1.1.1 The requirements of the utility owner must also apply.

902.3.1.2 The plans must designate utility work and distinguish contract work vs. work performed by others.

Commentary: The DOR must designate the party responsible to perform utility work, including utility relocation and utility services. An example of Sound Transit-performed utility work is the design and construction of an electrical duct bank by Sound Transit forces (i.e., contractor). An example of utility-performed work (by others) is the relocation of overhead electrical transmission facilities by the utility owner.

902.3.1.3 The DOR must identify utilities that require in-place protection.

Commentary: The contractors must notify the utilities owners to obtain approvals regarding methods of protection and follow requirements per the utilities' owners for working around existing utilities.

Commentary: Sound Transit does not allow third-party attachment to Sound Transit-owned structures.

902.3.1.4 The design must provide stray current and corrosion protection per the requirements in this Set.

902.3.2 Site Utilities and Utility Services

Commentary: Site utilities and utility services include domestic and fire protection water distribution systems (fire hydrants), sanitary sewer (sanitary side sewers), natural gas, site power, site communications, and storm drainage..

902.3.2.1 Utility services must comply with the utility service demand of the facility, the utility purveyor's administrative and technical requirements, and applicable building codes. Specify the type, size, location, alignment, and depth of the utility from the meter to the service point.

902.3.2.2 When the site has multiple utility services serving separate facilities, the DOR must label utility service and identify the owners.

902.3.2.3 The DOR must confirm that the utility demand is available from the utility purveyor.

902.3.2.4 The DOR must incorporate utility owner's electrical service requirements into the project design.

902.3.2.5 The design must not impair a utility owner's unlimited access to their utility service equipment (electrical, water, or natural gas service equipment).

902.3.2.6 The design must locate assets and equipment owned by third-party utility owners in a way that ensures the utility owners have unrestricted access without risk of conflicting with or impeding Sound Transit operations.

902.3.2.7 The design must provide dedicated and separate utility services to Sound Transit Link facilities, Sound Transit non-Link facilities, and non-Sound Transit facilities.

Commentary: For example, provide separate electric power services to a Sound Transit garage and separate electric service to a Sound Transit station. As a second example, provide separate water services for landscape irrigation serving Sound Transit facilities and for adjacent areas owned by another party.

902.3.2.8 The design must depict the type, size, and the owner of the utility services, per Sound Transit Engineering Procedure 15 (EP-15) Subsurface Utility Engineering (SUE).

902.3.3 Relocation of Existing Utilities

902.3.3.1 The design must comply with the utility owner's administrative and technical requirements.

902.3.3.2 The design must relocate utilities that are horizontally located within the following limits:

i. 10 feet from the outside edge of the light rail guideway.
ii. 10 feet from the columns of elevated sections of track.

902.3.3.3 For replaced crossings, the design must have a minimum of one foot of vertical clearance from the power and signal ducting.

902.3.3.4 The design must remove the abandoned subsurface utilities or fill with lean concrete.

902.3.3.4.1 Decommissioned utilities must comply with the utility owner requirements and industry standards.

902.3.3.5 The design must depict abandoned subsurface utilities on the project record drawings including identification of the type, size, depth of utility (if available), and the owner of the utility.

902.3.3.6 When existing utilities are removed or relocated, the design must restore existing ground and surfacing to existing conditions.

902.3.4 Utility Crossings of Rail

902.3.4.1 Aboveground and subsurface utility crossings must comply with the requirements of the utility owner, Sound Transit, the AHJ and industry standards.

902.3.4.1.1 Utilities must cross rail track at 90 degrees to the track centerline.

902.3.4.1.2 The design must specify depth of cover, encasement and/or protective measures, and design casing pipes for appropriate dead and live loading. The DOR must specify the casing geometric design, diameter, wall thickness, and material.

902.3.4.2 Sounder Rail Utility Crossings

902.3.4.2.1 Underground utilities, including additions or adjustments to existing utility installations that cross Sound Transit trackway(s), must comply with the engineering and technical requirements of the BNSF Railway Utility Accommodation Policy including Part 2, "Utilities Paralleling Railroad Property" and Part 3," Utilities Perpendicular to Railroad Property".

902.3.4.2.2 Overhead Wireline Crossings of Sounder Rail must comply with BNSF Railway Utility Accommodation Policy, Part 3," Utilities Perpendicular to Railroad Property," Section B, "Overhead Installations."

Commentary: Administrative provisions of the BNSF Railway Utility Accommodation Policy do not apply to utility crossings of Sounder rail.

902.3.4.3 Link Light Rail Utility Crossings

902.3.4.3.1 Underground Utilities including additions or adjustments to existing utility installations that cross or parallel Sound Transit trackway(s), must comply with AREMA Manual of Railway Engineering, Volume 1," Track", Chapter 1," Roadway and Ballast", and Part 5, "Utilities."

902.3.4.3.2 Overhead utilities attached to bridge structures that cross over Sound Transit Link Light Rail facilities must meet the following requirements:

902.3.4.3.2.1 The design must use roller brackets that allow for lateral expansion and contraction to attach the overhead utilities to the bridge.

902.3.4.3.2.2 The design must encase water distribution lines to ensure any cracks or leaks do not allow water to fall onto the OCS.

902.3.5 Additional Requirements

902.3.5.1 Structural Rating: Utilities facilities and structures must withstand applicable surface loading, buoyancy loads, and loading from anticipated maintenance, trash removal, and emergency response vehicles and apparatuses.

902.3.5.2 Labeling of Aboveground Utilities: The design must provide signage or labeling to above-ground utilities identifying the utility type and utility owner.

902.3.5.3 Access to Utility Structures and Facilities: The design must provide secured access (lockable lids or equivalent functionality) to utility structures and handholes where access is restricted or controlled per the utility owner's requirements.

902.3.5.3.1 The DOR must coordinate with Sound Transit Operations for access to utility structures and facilities on Sound Transit ROW.

902.3.6 Soil Corrosion and Stray Current Corrosion Control

902.3.6.1 Soil Corrosion Control: the design must meet the following criteria for the design of systems and measures to prevent corrosion of transit system fixed facilities due to contact with area soil, rock, and groundwater.

902.3.6.1.1 Materials: all pressure and non-pressure piping and conduit in contact with soil must be non-metallic.

902.3.6.1.1.1 The design must not use Aluminum and Aluminum Alloys in direct burial applications.

902.3.6.1.1.2 The material for backfilling concrete or ferrous structure excavations must meet the following criteria:

i. pH 6 to 8.
ii. Maximum chloride ion concentration of 250 parts per million (ppm).
iii. Maximum sulfate ion concentration of 200 ppm.

902.3.6.1.2 Location: route metallic piping and conduits serving tunnels and stations inside the structure or embed them in the concrete.

902.3.6.1.3 Safety and Continuity of operations: The DOR must design corrosion control protection for facilities where failure due to corrosion affects the safety of or interrupts the continuity of operations.

902.3.6.1.4 Accessibility: Permanent test facilities installed with corrosion control provisions must be accessible to allow for periodic testing, maintenance, and monitoring.

902.3.6.1.5 Special Considerations for Third-Party Facilities: Soil corrosion control measures, for facilities owned by others but designed as part of the Sound Transit project, must comply with the standards and practices of the facility owner without impacting Sound Transit operations.

902.3.6.1.6 Methods for Soil Corrosion Control: Coatings for metallic utility structures must satisfy the following design criteria:

i. Minimum volume resistivity of 10,000,000,000 ohm-centimeters (1x1010 Ω-cm).
ii. Minimum thickness as recommended for the specific system, but not less than 15 mils (0.015 inches).
iii. A chemical or mechanical bond to the metal surface. Pressure-sensitive systems are not acceptable.
iv. Minimum five-year performance record for the intended service.
v. Mill application of coatings is preferred, with field application of a compatible paint or tape system.
vi. Mechanical characteristics capable of withstanding reasonable abuse during handling and earth pressure after installation for the design life of the system.

902.3.6.1.7 Electrical Isolation of Piping: devices for the electrical isolation of piping must include non-metallic inserts, insulating flanges, couplings, unions, and/or concentric support spacers. Devices must meet the following criteria:

i. A minimum resistance of ten meg-ohms prior to installation.
ii. Sufficient electrical resistance after insertion into the operating piping system such that no more than two percent of a test current applied across the device flows through the isolator, including flow through conductive fluids, if present.
iii. Mechanical and temperature ratings equivalent to the structure in which they are installed.
iv. Internal coating, except for in completely non-metallic units, with a polyamide epoxy for a distance on each side of the isolator equal to two times the diameter of the pipe in which they are used. Where conductive fluids with a resistivity of less than 2,000 ohm-centimeters are present, internal coating requirements must be based on separate evaluation.
v. Devices (except non-metallic units) buried in soils must be encased in a protective coating.
vi. Devices (except non-metallic units) installed in chambers, or otherwise exposed to partial immersion or high humidity must have a protective coating applied over all components.
vii. Inaccessible insulating devices, such as buried or elevated isolators, must be equipped with accessible permanent test facilities.
viii. A minimum clearance of 12 inches must be provided between new and existing metallic structures.

902.3.6.1.8 Electrical Continuity of Piping: provide electrical continuity for non-welded metallic pipe joints. Pipelines with bonded joints must be electrically insulated from existing metallic pipelines at the point of connection.

902.3.6.1.8.1 Use direct-burial, insulated, stranded, copper wire with the minimum length necessary to span the joint being bonded.

902.3.6.1.8.2 Wire size must be based on the electrical characteristics of the structure and resulting electrical network to minimize attenuation and allow for cathodic protection.

902.3.6.1.8.3 Use a minimum of two wires per joint for redundancy.

902.3.6.1.8.4 Connect to the pipe with a thermite weld.

902.3.6.1.8.5 Repair damaged pipe coating.

902.3.6.1.8.6 Coat weld area and exposed conductor.

902.3.6.1.9 Cathodic Protection: Use sacrificial galvanic anodes for pipeline cathodic protection. When galvanic cathodic protection is used for new facilities, provide a compatible coating system. Where galvanic anodes are in direct contact with soils or natural waters, connect anodes to the facility by means of a cable attachment that permits the monitoring of anode current discharge.

902.3.6.1.9.1 The cathodic protection system design must be based on theoretical calculations that include the following parameters at a minimum:

i. Estimated percentage of bare surface area (minimum one percent).
ii. Cathodic protection current density — minimum one milliamp per square foot (1 mA/ft^2) of bare surface area.
iii. Estimated current output per anode.
iv. Estimated total number of anodes, size, and spacing.
v. Minimum anode life of 50 years (minimum 50 percent efficiency).
vi. Estimated anode-to-earth resistance.

902.3.6.1.9.2 Cathodic protection schemes that require connections to the transit system negative return system, instead of using a separate, isolated anode groundbed, are not permitted.

902.3.6.1.9.3 Test facilities must be designed to permit initial and periodic testing of cathodic protection levels, interference currents, and system components (anodes, reference electrodes, insulating devices, and continuity bonds). The designer must specify the locations and types of test facilities for each cathodic protection system.

Commentary: Utility owners are responsible for testing of new facilities for private or public utilities and all associated costs.

902.3.6.1.10 Ferrous Pressure Piping: All new buried cast iron, ductile iron, and steel pressure piping must satisfy the following minimum criteria:

i. Application of a protective coating to the external surface of the pipe for all metallic piping.
ii. Electrical isolation of pipe from interconnecting pipes, other structures and segregation must be designed into discrete electrically isolated sections depending upon the total length of piping. Electrical isolation fittings located within 50 feet of a rail must be provided with galvanic grounding electrodes on both sides of the insulator.
iii. Electrical continuity through the installation of insulated copper wires across all mechanical pipe joints except intended isolators.
iv. Install permanent test/access facilities at all insulated connections suitable for verification of electrical continuity, electrical effectiveness of isolators, and of stray current activity. Install additional test/access facilities at intermediate locations at intervals not greater than 500 feet.
v. Prepare a cathodic protection design for each individual structure.
vi. For pressure piping entering Sound Transit facilities below grade, electrically insulate pipe immediately inside of the wall penetration.
vii. For pressure piping entering Sound Transit facilities above grade, electrically insulate pipe immediately outside of the wall penetration.
viii. Pipe penetrations through the walls and floors must be electrically isolated from building structural elements.
ix. Piping encased in concrete, including thrust blocks, must be provided with a coating material that extends a minimum of six inches beyond the concrete-to-soil interface.

Commentary: Underground ferrous piping for standpipe systems is not continuously pressurized, so these corrosion control requirements do not apply.

902.3.6.1.11 Copper Piping: Buried copper pipe must be electrically isolated from non-buried piping and from any ferrous piping, such as that contained in a station structure, through use of an accessible insulating union installed where the piping enters through a wall or floor. Pipe penetrations through the walls and floors must be electrically isolated from building structural elements. The isolators should be located inside the structure and not buried.

902.3.6.1.12 Unpressurized Gravity Flow Piping

902.3.6.1.12.1 Cast or ductile iron piping must have the following:

i. An internal mortar lining with a bituminous coating on ductile iron pipe only (not required for cast iron soil pipe).
ii. A bituminous mill coating on the external surfaces in contact with soils.
iii. Unbonded dielectric encasement (AWWA Standard C105) must be excluded from any piping installed under the LRT contract.
iv. A bituminous mastic coating on the external surfaces of pipe six inches on each side of a concrete/soil interface.

902.3.6.1.12.2 Reinforced concrete non-pressure piping must have the following:

i. Water-to-cement ratios meeting the minimum provisions of AWWA.
ii. Minimum practical chloride concentration in the total concrete mix (mixing water, cement, admixture, and aggregates).
iii. Use of Type II cement when soil samples have water-soluble sulfate (as SO_4) between 0.1 percent and 0.2 percent or when groundwater samples have 150-1,000 ppm sulfate (as SO4).

902.3.6.1.13 Electrical Conduits.

902.3.6.1.13.1 Buried metallic conduits must have the following:

i. Galvanized steel with PVC or other coating acceptable for direct burial, including couplings and fittings. The PVC coating is not required when conduits are embedded in concrete.
ii. Electrical continuity through use of standard threaded joints or other approved bonding methods across non-threaded joints. Encase buried non-metallic conduits in concrete including couplings and fittings except at transitions where metallic materials are required (stub-ups, penetrations, etc.).

902.3.6.2 Stray Current Control for Sound Transit Utility Structures and Utilities

902.3.6.2.1 All piping and conduit must be non-metallic.

902.3.6.2.1.1 Metallic Facilities must conform to the following criteria:

i. Pressure or non-pressure piping exposed within tunnels, pipes, chases, or crawl spaces or embedded in concrete inverts must not require special provisions.
ii. Piping that contains a hazardous material and is placed in direct contact with soil or concrete must be provided with an external bonded coating, electric isolation, and cathodic protection.
iii. Internal piping that penetrates tunnel, foundation, or station walls must be electrically insulated from the external piping to which it connects on the inside of the tunnel or station.
iv. Pipe penetrations through exterior walls of underground structures must use watertight wall sleeves that electrically insulate the pipe from the structure reinforcing.

902.3.6.2.2 Stray Current Control for Third-Party Utility Structures and Utilities

902.3.6.2.2.1 Corrosion control requirements for buried utilities installed by the owner/operator as part of transit construction must be the responsibility of the individual utility owner/ operator.

902.3.6.2.2.2 Utility relocation work must comply with the utility owner’s requirements and the following provisions which are applicable to ferrous and reinforced concrete cylinder piping.

902.3.6.2.2.2.1 The need for additional measures, such as electrical isolation, application of a protective coating system, installation of cathodic protection, or any combination of the preceding, must be based on the characteristics of the specific structure and to not adversely affect the existing performance within the environment.

902.3.6.2.2.2.2 Utility rearrangements that are parallel to at-grade track must have test stations installed every 500 feet at maximum.

902.3.6.2.2.2.3 Utility owner must be responsible for all testing and maintenance of corrosion protection facilities except as otherwise covered by an interagency Operations & Maintenance Agreement.

902.3.6.2.3 Existing Utility Structures and Utilities: The need for stray current monitoring facilities must be determined by coordinating with the utility owner.

902.3.6.2.4 Stray Current Studies: Stray current studies must be performed during all phases of the work and classified as noted below.

i. Static: post installation and prior to application of cathodic protection and traction power start-up.
ii. Baseline: subsequent to cathodic protection application and prior to traction power start-up.

iii. Revenue: after the LRT starts revenue service.
iv. The design must provide the requirements for the test plan as well as the data collection and data base management required to perform the stray current studies.
v. Scheduling requirements must be presented and provide for the completion of the various stray current study tasks at appropriate points in the construction sequencing.
vi. All stray current study requirements must require the submission of data in submittals to Sound Transit.

902.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

902.4.1 System Breakdown Structure

902.4.2 System Sites and Locations

902.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement Set and other requirement sets.

Table 902-1: Interfaces Between Utilities and Other Disciplines

SET SERIES	SET NAMES	SET 902 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	
500	Track	X
600	Fire/Life Safety	X
700	Structures	
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	
1200	Security	

902.5.1 Train Control and Signals

902.5.1.1 Coordinate with Train Control and Signals requirements for the following:

902.5.1.1.1 Communications utilities serving Sound Transit facilities.

902.5.1.1.2 Electric power utility service for signal house.

902.5.2 Traction Electrification

902.5.2.1 Coordinate with Traction Electrification requirements for the following:

902.5.2.1.1 TPSS electric power utility service.

902.5.2.1.2 Clearance between OCS and overhead utility.

902.5.3 Track

902.5.3.1 Coordinate with Track requirements for the following:

902.5.3.1.1 Track circuits locations.

902.5.3.1.2 Underground utility crossings.

902.5.1 Fire-Life Safety

902.5.1.1 Coordinate with Fire/Life Safety requirements for the following:

902.5.1.1.1 Fire protection and water supply.

902.5.1.1.2 Standpipes and corrosion control measures for standpipes.

902.5.2 Architecture

902.5.2.1 Coordinate with architecture requirements for irrigation and deduct metering.

902.5.3 Civil

902.5.3.1 Coordinate with civil requirements for the following:

902.5.3.1.1 Temporary access and parking during construction.

902.5.3.1.2 Maintenance access and parking.

902.5.4 Mechanical-Electrical and Building Systems

902.5.4.1 Coordinate with mechanical-electrical and building systems requirements for the following:

902.5.4.1.1 Service capacity.

902.5.4.1.2 Utility room location.

902.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

902.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

902.7.1 Interface and Integration Management

902.7.2 Design Management

902.7.3 Manufacturing and Construction Management

902.7.4 Installation Management

902.7.5 Inspection and Testing Management

902.7.6 Training, Pre-Revenue Operations

902.7.7 Certification Management

902.8 APPENDICES (NOT USED)

END SET - 902

903 FENCING

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SET - 903 FENCING

903.1 INTRODUCTION

903.1.1 Document Scope

903.1.1.1 This set governs the selection, design, and extent of fencing to prevent vehicles, trucks, unauthorized people, animals, and other roadway users from entering Sound Transit right-of-way restricted to the public. Fencing also directs passenger movements within Sound Transit right-of-way in the vicinity of a station. This set includes the requirements of different types of fencing and gates that the Sound Transit project will install. This set also includes requirements associated with access gates and controls that are part of the fencing design.

903.1.1.2 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 903 owner to determine the technical source for the design criteria.

903.1.2 Regulations, Codes, Standards, and Guidelines

903.1.2.1 A Policy on Geometric design of Highways and Streets, American Association of State Highway and Transportation Officials (AASHTO).

903.1.2.2 Americans with Disabilities Act Standards for Transportation Facilities (ADA Standards).

903.1.2.3 Federal Railroad Administration (FRA): Track and Rail and Infrastructure Integrity Compliance Manual.

903.1.2.4 WSDOT Design Standards

903.1.3 Abbreviations and Acronyms

903.1.3.1 AHJ–authority having jurisdiction

903.1.3.2 DOR–designer of record

903.1.3.3 H–horizontal

903.1.3.4 TPSS–traction power substation

903.1.3.5 V–vertical

903.1.4 Definitions and Classifications

903.1.4.1 Hi-rail vehicle: A roadway maintenance machine that is manufactured to meet Federal Motor Vehicle Safety Standards and is equipped with retractable flanged wheels so that the vehicle may travel over the highway or on railroad tracks.

903.1.5 References (Not Used)

903.2 STAKEHOLDER NEEDS

903.2.1 Passenger Experience (Not Used)

903.2.2 Operational Needs (Not Used)

903.2.3 Maintenance Needs

903.2.3.1 The design must provide safe access for maintenance of fencing adjacent to track(s).

903.2.3.2 The design must provide safe access for maintenance and inspection of track(s) adjacent to fencing.

903.2.3.3 Fencing gates must accommodate emergency and maintenance vehicles within Sound Transit right-of-way.

903.2.3.4 Maintenance vehicle(s) parked to access Sound Transit right-of-way must not obstruct the roadway.

903.2.3.5 The design must avoid rocks from getting into an embedded tracking system and affecting the operation of a sliding gate.

903.2.4 Safety Needs

903.2.4.1 Fencing must safely direct passengers to the platform within station limits.

903.2.4.2 Fencing must protect passengers and pedestrians from falling off the side (vertical drop more than 18 inches) within walkways and stations.

903.2.4.3 Fencing in the vicinity of station and crossings must meet sight distance standards.

903.2.4.4 Fencing must provide unobstructed emergency egress.

903.2.4.5 To avoid fire hazards, the design must clear debris from getting stuck in the inter-track fencing.

903.2.4.6 The design of metallic fences must eliminate electric shock.

903.2.4.7 Fencing gates must include a locking system that does not impede emergency access.

903.2.4.8 The design must avoid maintenance vehicle intruding into roadway while crew is unlocking the access gate.

903.2.5 Security Needs

903.2.5.1 Fencing gates must prevent trespassing to Sound Transit right-of-way restricted to the public.

903.2.5.2 Fencing and gates must be anti-climbing.

903.2.5.3 The design must protect Sound Transit right-of-way from thrown or dropped objects from overhead public aerial structure.

903.2.5.4 Secure the posts and foundations of the vehicle gates.

903.2.5.5 Prevent digging underneath the high-security fencing.

903.2.6 Reliability, Availability, and Maintainability Needs (Not Used)

903.2.7 Environmental and Sustainability Needs

903.2.7.1 The DOR must identify environmental impacts and mitigation from construction and operation activities of permanent fencing and access gates within sensitive areas.

903.2.7.2 The design must provide pedestrian maintenance access along the alignment to areas that require long-term sensitive area monitoring and maintenance activities.

903.2.7.2.1 The spacing between access points must be walkable and provide maintenance crews the ability to transport maintenance materials.

903.2.7.2.2 The design must provide safe access for landscape maintenance.

903.3 SYSTEM REQUIREMENTS

903.3.1 General Criteria

903.3.1.1 The DOR must scope and design the location and type of fencing, access gates, and controls, according to processes identified in the Safety and Security Management Plan (SSMP).

Commentary: Depending on security, safety, and aesthetic reasons, the type, length, height, and location of fencing is determined on a case-by-case basis. Where the Sound Transit right-of-way within the vicinity of a station would allow passengers to trespass on the right-of-way as a shortcut to the platform, the Architecture department will identify extents of fencing to direct the passengers to the designated platform entrances. The fencing design also includes location and type of lockable gates for Sound Transit right-of-way and track maintenance. Where fencing is on top of another barrier, such as a concrete retaining wall, the height of the non-fence barrier is part of the overall height for purposes of meeting height requirements as long as the barrier portion is not climbable. Where fencing is an attachment to a concrete masonry unit, the structure and associated hardware must support the fencing and gates' weight and force of swing.

Commentary: The conformance of this requirement is met by design verification processes outlined in the Agency Safety and Security Certification Plan.

903.3.1.2 The design must locate the supporting and mounting structures for the proposed fencing within and facing inwards the Sound Transit right-of-way.

903.3.1.3 Within 150 feet of an at-grade pedestrian crossing, the height of adjacent fencing must be 42 inches.

903.3.1.3.1 The DOR must review the diagnostic report in compliance with Engineering Procedure (EP-13) for pedestrian sight distance constraints and extend this type of fencing beyond 150 feet to meet additional sight distance requirements.

903.3.1.4 The DOR must comply with Sound Transit Civil Standard Detail drawings for fencing and gate types.

903.3.2 Standard Fencing

903.3.2.1 The standard fence must be 6 feet high chain link fence or vertical picket fence.

903.3.2.1.1 The chain link standard fence must be black vinyl-coated 9-gauge steel with 2-inch mesh openings.

903.3.2.1.2 The vertical picket standard fence must be black vinyl-coated steel with horizontal and vertical intermediates.

Commentary: The Standard fence prevents trespassing to stormwater detention ponds. The Standard fence also directs passengers to designated platform entrances, within the vicinity of a station.

903.3.2.2 The DOR must design standard fencing around Sound Transit stormwater detention ponds.

903.3.3 Security Fencing

Commentary: The security fencing prevents intrusion into the train envelope by acting as an obstacle to vehicles, trucks, pedestrians, and other roadway users for Sounder and Link. The security fencing also prevents intrusion into sensitive areas.

903.3.3.1 The security fence must be 8 feet high chain link fence or vertical picket fence.

903.3.3.1.1 The chain link security fence must be black vinyl-coated 9-gauge steel with 1-inch mesh openings.

903.3.3.1.2 The vertical picket security fence must be black vinyl-coated steel with horizontal and vertical intermediates.

903.3.3.1.3 Where the Sounder trains and Link light rail run at-grade, the DOR must design security fencing along Sound Transit's exclusive right-of-way.

903.3.3.1.4 The DOR must design security fencing for environmentally sensitive area(s) defined by environmental documentation.

903.3.3.1.5 For Sounder train layover tracks, the DOR must design security fencing at a minimum 15 feet from the outside layover track center.

903.3.3.1.6 The DOR must design security fencing around the Sound Transit facilities including parking areas, vehicle storage areas, rail yards, vehicle service areas, maintenance areas, storage areas, facilities with stormwater detention ponds (standard fencing around stormwater detention ponds), signal bungalows, and TPSSs.

903.3.3.1.7 The design must include security fencing in public areas around emergency telephones and associated equipment at emergency access locations.

903.3.3.1.8 The design must include security fencing for areas where the vertical clearance underneath the guideway is less than 16.5 feet.

Commentary: The security fencing, underneath the guideway, prevents illicit activity that potentially results in significant damage to the ST infrastructure and disruption of train operations.

903.3.4 High-Security Fencing

Commentary: The high-security fencing provides additional level of security and prevents intrusion into highly secured Sound Transit facilities.

903.3.4.1 Based on the threat assessment per SSMP processes, the DOR must design high-security fencing at locations identified.

903.3.4.2 The high-security fence must be 8 to 12 feet high vertical picket fence or welded mesh panel fence. Sound Transit's Transportation Safety and Security department determines the exact height and location of the high-security fence.

903.3.4.3 The vertical picket fence must be black vinyl-coated with horizontal and vertical intermediates.

903.3.4.4 The welded mesh panel fence must be black vinyl-coated with horizontal and vertical intermediates.

903.3.4.5 The design must include a concrete block wall underneath the high-security fence.

903.3.5 Inter-Track Fencing

Commentary: An inter-track fence is located between two tracks to prevent pedestrians from unsafely crossing the tracks to get from one platform to the other platform.

903.3.5.1 At Sounder and Link stations with side platforms (two or more tracks), the design must include an inter-track fence.

903.3.5.2 For Sounder, the inter-track fence must extend to the entire length of the platform. Additionally, the fence must extend 150 feet beyond each end of the platform or to the nearest public crossing or emergency access, whichever is less.

903.3.5.2.1 The inter-track fence for Sounder must be 6-foot-high chain link fence.

903.3.5.2.1.1 The chain link inter-track fence must be black vinyl-coated 9-gauge steel with 2-inch mesh openings.

903.3.5.2.2 The spacing between the Sounder inter-track fencing (trackside face of the fence) and the centerline of the adjacent track(s) must be minimum 9 feet.

903.3.5.3 For Link, the inter-track fence must extend to the entire length of the platform and 5 feet beyond each end of the platform.

903.3.5.3.1 The inter-track fence for Link must be 42 inches high.

903.3.5.3.1.1 The inter-track fence for Link must be made from galvanized steel with vertical intermediates.

903.3.5.3.2 The design must locate the Link inter-track fencing halfway between the tracks and outside of the clearance envelope.

903.3.6 Throw-Protection Fencing

Commentary: The throw-protection fencing discourages dropping or throwing objects onto the Sound Transit right-of-way from the public aerial structures.

903.3.6.1 The DOR must design throw-protection fencing above Sound Transit right-of-way including new bridges, existing bridges, aerial structures, and retained-fill roadways.

903.3.6.1.1 The throw-protection fence must be chain link made of black vinyl-coated 9-gauge steel with 1-inch mesh openings.

903.3.6.1.1.1 For newly constructed public aerial structures above Sound Transit right-of-way, the throw-protection fence height must be 10 feet relative to the adjacent standing surface.

903.3.6.1.1.2 For existing public aerial structures above Sound Transit right-of-way, the throw-protection fence height must not be less than 8 feet relative to the adjacent standing surface.

903.3.6.1.2 When a track is perpendicular to the public aerial structure above, the design must include the throw-protection fencing for a minimum length of 20 feet from the centerline of the track on both sides.

903.3.6.1.3 When a track is parallel to the public aerial structure above, the design must include the throw-protection fencing for the extent of the public aerial structure.

903.3.6.1.4 If the public aerial structure above the track (perpendicular or parallel) has an opening less than 10 feet high, the design must enclose the opening with throw-protection fencing.

903.3.6.1.5 For Sounder, the throw-protection fencing must meet the requirements of the operating Railroad, if available.

903.3.7 Pedestrian Fencing

Commentary: The purpose of pedestrian fencing is to channel and direct pedestrians in the Sound Transit right-of-way.

903.3.7.1 The pedestrian fence must be 42 inches high chain link or vertical picket fence.

903.3.7.1.1 The chain link pedestrian fencing must be black vinyl-coated 9-gauge steel with 2-inch mesh openings.

903.3.7.1.2 The vertical picket pedestrian fencing must be black vinyl-coated steel with horizontal and vertical intermediates.

903.3.7.2 The design must include pedestrian fencing for the following conditions:

903.3.7.2.1 A vertical drop is greater than 18 inches along pedestrian pathways and station areas.

903.3.7.2.2 Side slopes are 3H:1V or steeper.

903.3.7.3 At stations where walkways extend longitudinally along the alignment beyond the station platforms, the design must include pedestrian fencing on the trackside.

903.3.8 Fencing Gates

903.3.8.1 The DOR must coordinate with Sound Transit Operations department for pedestrian and vehicular access gates/control types and locations.

Commentary: The use of locked gates prevents unauthorized access to the site. The locks for the gates must be coordinated with Sound Transit's keying system. The location of gated access points must be determined in coordination with Sound Transit's Transportation Safety and Security and Operations Departments.

903.3.8.2 The pedestrian and vehicular access gate height must match the height of the adjacent fencing.

903.3.8.3 At pedestrian maintenance access points for detention ponds, TPSSs, signal bungalows, and trash enclosure areas, the design must include a single manual swing gate with clearance width of 4 to 6 feet with chain and padlock system. Sound Transit's Transportation Safety and Security and Operations departments determine the exact width of the gate.

903.3.8.3.1 The fencing gates that provide access to snow removal equipment must be at minimum 7 feet wide.

903.3.8.4 At vehicle access points, the design must include lockable double swing gates.

903.3.8.4.1 The width of the gate must be at minimum 14 feet and maximum 24 feet. Sound Transit's Transportation Safety and Security and Operations departments determine the exact width of the gate.

903.3.8.4.1.1 The width of the double gate must be approaching roadway width with additional 1 foot on both sides.

903.3.8.4.2 The design must include manual cantilever sliding gates with chain and padlock system at TPSSs.

903.3.8.4.2.1 The minimum clearance width for TPSS vehicle access gates must be 20 feet.

903.3.8.4.3 The design must include bollards around the vehicle access gate post/foundation.

903.3.8.4.3.1 The DOR must complete the Safety and Security analysis to identify type, height, number, and location of bollards.

903.3.9 Hi-Rail (Maintenance of Way) Access Gates

903.3.9.1 The hi-rail access gates must be non-motorized double swing gates with chain and padlock system.

903.3.9.1.1.1 For paved hi-rail access roads, the rolling/sliding gates must be a cantilever system or an embedded (in asphalt or concrete) sliding track system.

903.3.9.1.1.2 For gravel hi-rail access roads, the sliding gates must be a cantilever system.

903.3.9.2 The hi-rail access gates must be minimum 20 feet wide.

903.3.9.3 The design must provide minimum 20 feet of unobstructed space in front of the gate.

903.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

903.4.1 System Breakdown Structure

903.4.2 System Sites and Locations

903.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement Set and other requirement Sets.

Table 903-1: Interfaces Between Fencing and Other Disciplines

SET SERIES	SET NAME	SET 903 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	X
400	Vehicle	
500	Track	X
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	
1100	Technology	
1200	Security	X

903.5.1 Train Control and Signals

903.5.1.1 Coordinate with Train Control and Signals requirements for the following:

903.5.1.1.1 Pedestrian swing gates and fencing near at-grade crossings.

903.5.1.1.2 Hi-rail access gates for signal coordination.

903.5.2 Traction Electrification

903.5.2.1 Coordinate with Traction Electrification requirements for the following:

903.5.2.1.1 Grounding for fences and gates.

903.5.2.1.2 TPSS Ped access gates opening direction.

903.5.3 Operational Communications

903.5.3.1 Coordinate with Operational Communications for requirements for the following:

903.5.3.1.1 Communications equipment located at public areas.

903.5.4 Track

903.5.4.1 Coordinate with Track requirements for the following:

903.5.4.1.1 Hi-rail vehicle (maintenance-of-way) access point locations.

903.5.4.1.2 Train clearance envelope.

903.5.4.1.3 Emergency egress locations.

903.5.4.1.4 Fencing gate opening direction along the guideway.

903.5.5 Fire/Life Safety

903.5.5.1 Coordinate with Fire/Life Safety requirements for the following:

903.5.5.1.1 Locking requirements.

903.5.5.1.2 Fire/Life Safety Signage on the fence/gate.

903.5.5.1.3 Additional Fire Department access.

903.5.5.1.4 Station platform end-gate requirements.

903.5.6 Structures

903.5.6.1 Coordinate with Structures requirements on the structures for the following:

903.5.6.1.1 Bridge abutments.

903.5.6.1.2 Bridge railing.

903.5.6.1.3 Fence post foundation details.

903.5.7 Architecture

903.5.7.1 Coordinate with Architecture requirements for the following:

903.5.7.1.1 Decorative fences

903.5.7.1.2 Operations and maintenance facility gates

903.5.7.1.3 Signage

903.5.7.1.4 Stations

903.5.7.1.5 Bridges

903.5.7.1.6 Facilities

903.5.7.1.7 Parking garages

903.5.7.1.8 Security card/access control

903.5.8 Civil

903.5.8.1 Coordinate with Civil requirements for clear zones.

903.5.9 Security

903.5.9.1 Coordinate with Security requirements for the following:

903.5.9.1.1 Surveillance cameras.

903.5.9.1.2 Intrusion detection.

903.5.9.1.3 Security card/access control system

903.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

903.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

903.7.1 Interface and Integration Management

903.7.2 Design Management

903.7.3 Manufacturing and Construction Management

903.7.4 Installation Management

903.7.5 Inspection and Testing Management

903.7.6 Training, Pre-Revenue Operations

903.7.7 Certification Management

903.8 APPENDICES (NOT USED)

END SET - 903

904 GRADING

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SET - 904 GRADING

904.1 INTRODUCTION

904.1.1 Document Scope

904.1.1.1 This set governs site preparation and grading design to ensure positive drainage and constructability within acceptable tolerances per current industry standards.

904.1.1.2 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 904 owner to determine the technical source for the design criteria.

904.1.2 Regulations, Codes, Standards, and Guidelines

904.1.2.1 A Policy on Geometric design of Highways and Streets, American Association of State Highway and Transportation Officials (AASHTO).

904.1.2.2 Americans with Disabilities Act (ADA) Standards for Transportation Facilities.

904.1.2.3 King County, Washington Surface Water Design Manual.

904.1.2.4 Roadside Design Guide, AASHTO.

904.1.2.5 Washington Department of Ecology Requirements.

904.1.2.6 WSDOT Hydraulics Manual.

904.1.3 Abbreviations and Acronyms

904.1.3.1 AHJ–authority having jurisdiction

904.1.3.2 DOR–designer of record

904.1.3.3 H–Horizontal

904.1.3.4 V–Vertical

904.1.4 Definitions and Classifications (Not Used)

904.1.5 References (Not Used)

904.2 STAKEHOLDER NEEDS

904.2.1 Passenger Experience (Not Used)

904.2.2 Operational Needs (Not Used)

904.2.3 Maintenance Needs

904.2.3.1 Grading must allow safe landscape, facility, and infrastructure maintenance and access.

904.2.3.2 Grade roadway slopes to eliminate the need for additional safety measures that will require maintenance.

904.2.3.3 Eliminate ponding outside detention ponds.

904.2.4 Safety Needs

904.2.4.1 Meet AASHTO sight distance standards for vehicles.

904.2.4.2 The design must address clear zone protection measures where needed.

904.2.5 Security Needs (Not Used)

904.2.6 Reliability, Availability, and Maintainability Needs (Not Used)

904.2.7 Environmental and Sustainability Needs (Not Used)

904.3 SYSTEM REQUIREMENTS

904.3.1 General Policy

904.3.1.1 The DOR must prepare grading designs that meet ADA and AASHTO requirements regarding sight distance and clear zone criteria.

904.3.1.2 The DOR must prepare grading designs that meet the AHJ and Washington Department of Ecology requirements.

904.3.1.3 If AHJ requirements are absent, the design must meet WSDOT requirements.

904.3.2 Clear and Grub

904.3.2.1 The design must identify construction areas that require clearing and grubbing.

Commentary: Per WSDOT Standard Specifications, "clearing" means removing and disposing of all unwanted material from the surface, such as trees, brush, down timber, or other natural material. "Grubbing" means removing and disposing of all unwanted vegetative matter from underground, such as sod, stumps, roots, buried logs, or other debris.

904.3.2.2 The design must include an erosion and sediment control system in compliance with AHJ stormwater code requirements.

904.3.2.2.1 The erosion and sediment control plans must outline the environmental measures to be in-place during construction.

Commentary: The erosion and sediment control system protects areas from construction activities. Acceptable methods of erosion and sediment control include seeding and mulching, sodding, application of geotextile fabrics to stabilize areas, and application of gravel or stones. The erosion and sediment control system must be in-place prior to the start of construction.

904.3.3 Grading of Cut and Fill Slopes

904.3.3.1 The grading of cut and fill slopes must comply with geotechnical recommendations.

904.3.3.2 The maximum side slope must be 3H:1V in areas where maintenance crew requires access for mowing or maintenance.

904.3.3.3 The maximum side slope must be 2H:1V along trackways where maintenance crew does not require access for mowing or maintenance.

904.3.3.4 The design of cut slopes around the curved alignments must meet AASHTO stopping sight distance requirements.

904.3.3.5 The design must meet AASHTO Roadside Design Guide standards to determine the need for clear zone protection devices.

904.3.3.5.1 The design must grade the roadway fill slopes to eliminate the need for clear zone protection devices.

904.3.4 Drainage

904.3.4.1 The DOR must design the grading for positive drainage.

Commentary: The design must prevent sheet flow into a building or structure in the event that a catch basin, trench drain, and/or drainage system fails.

904.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

904.4.1 System Breakdown Structure

904.4.2 System Sites and Locations

904.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 904-1: Interfaces Between Grading and Other Disciplines

SET SERIES	SET NAME	SET 904 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	
300	Operational Communications	
400	Vehicle	
500	Track	X
600	Fire/Life Safety	
700	Structures	X
800	Architecture	
900	Civil	X
1000	Mechanical-Electrical and Building Systems	
1100	Technology	
1200	Security	

904.5.1 Train Control and Signals

904.5.1.1 Coordinate with Train Control and Signals requirements for maintenance access.

904.5.1 Traction Electrification

904.5.1.1 Coordinate with Traction Electrification requirements for maintenance access.

904.5.2 Track

904.5.2.1 Coordinate with Track requirements for the following:

904.5.2.1.1 Vehicle and pedestrian crossings locations.

904.5.2.1.2 Hi-rail (maintenance of way) access locations.

904.5.3 Structures

904.5.3.1 Coordinate with Structures requirements for the following:

904.5.3.1.1 Bridge abutments

904.5.3.1.2 Roadway transition

904.5.3.1.3 Retaining walls protecting landslides

904.5.3.1.4 Tunnels

904.5.3.1.5 Retained cuts/fills

904.5.4 Civil

904.5.4.1 Coordinate with Civil requirements for the following:

904.5.4.1.1 Clear zones.

904.5.4.1.2 Maintenance access.

904.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

904.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

904.7.1 Interface and Integration Management

904.7.2 Design Management

904.7.3 Manufacturing and Construction Management

904.7.4 Installation Management

904.7.5 Inspection and Testing Management

904.7.6 Training, Pre-Revenue Operations

904.7.7 Certification Management

904.8 APPENDICES (NOT USED)

END SET - 904

905 SURVEY

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SET - 905 SURVEY

905.1 INTRODUCTION

905.1.1 Document Scope

905.1.1.1 This set covers the surveying requirements for Sound Transit projects.

905.1.1.2 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 905 owner to determine the technical source for the design criteria.

905.1.2 Regulations, Codes, Standards, and Guidelines

905.1.2.1 Federal Geographic Data Committee STD-007.2-1998 Guidelines, www.fgdc.gov.

905.1.2.2 Washington State Reference Network.

905.1.2.3 Washington Geodetic Survey.

905.1.2.4 Revised Code of Washington.

905.1.2.5 Washington Administrative Code.

905.1.3 Abbreviations and Acronyms

905.1.3.1 DOR–designer of record

905.1.3.2 GPS–global positioning system

905.1.3.3 LDP–local datum plane

905.1.3.4 NAD–North American Datum

905.1.3.5 NGS–National Geodetic Survey

905.1.3.6 WA SPCS–Washington Standard Plane Coordinate System

905.1.3.7 WGS–Washington Geodetic Survey

905.1.3.8 WSRN–Washington State Reference Network

905.1.4 Definitions and Classifications (Not Used)

905.1.5 References (Not Used)

905.2 STAKEHOLDER NEEDS

905.2.1 Passenger Experience (Not Used)

905.2.2 Operational Needs

905.2.2.1 Establish thorough, consistent surveying practices so that designs and as-builts of Sound Transit assets can be readily cross-referenced and inform future upgrades and repairs.

905.2.3 Maintenance Needs (Not Used)

905.2.4 Safety Needs (Not Used)

905.2.5 Security Needs (Not Used)

905.2.6 Reliability, Availability, and Maintainability Needs (Not Used)

905.2.7 Environmental and Sustainability Needs (Not Used)

905.3 SYSTEM REQUIREMENTS

905.3.1 General Requirements

905.3.1.1 Work consisting of the Practice of Land Surveying performed for Sound Transit projects must comply with requirements in this document.

905.3.1.1.1 Work must conform to all Revised Code of Washington Statutes and Washington Administrative Codes pertaining to surveying and engineering.

905.3.1.1.2 Work must be done by or under the direction of a surveyor licensed to practice in the State of Washington.

905.3.2 Standards

905.3.2.1 Accuracy Standards: The maximum linear error of closure for traverses must be 1:10,000, with a maximum angular error in seconds of 10 x N, where N = number of angles in the closed traverse for conventional traverse.

905.3.2.1.1 Terrestrial traverses must be closed or start and end on two points with known coordinates.

905.3.2.1.2 For GPS control networks, the work must comply with the Federal Geographic Data Committee STD-007.2-1998 guidelines meeting 2-centimeter accuracy.

905.3.2.2 Horizontal Control: GPS control networks and traverses, for establishing project control, must use the WSRN.

905.3.2.2.1 The plans must show a statement of accuracy.

905.3.2.3 Vertical Control: The Surveyor must establish project site benchmarks by measurement from two local benchmarks that are WSDOT benchmarks or WGS benchmarks.

905.3.3 Procedural Requirements.

905.3.3.1 The work must follow Third Order procedural requirements of the Geospatial Positioning Accuracy Standards by the Federal Geographic Data Committee (www.fgdc.gov) for project control, supplemental control, photo control, construction surveying control, topographic surveying control, and major structural points.

905.3.3.2 The work must follow Second Order procedural requirements of the Geospatial Positioning Accuracy Standards by the Federal Geographic Data Committee (www.fgdc.gov) for extending vertical control and for establishing and maintaining vertical control.

905.3.4 Project Datum - Horizontal and Vertical

905.3.4.1 Project Datum (Local Datum Planes)

Commentary: The Sound Transit survey set owner maintains custom LDPs that can be related to WA SPCS. The LDPs provide Cartesian coordinate planes along corridors of Sound Transit's systems and ensures sharing of design information between parties.

905.3.4.1.1 The Sound Transit survey set owner must approve new coordinate systems and related files, routines, and documentation, prior to use.

905.3.4.1.1.1 Units must be in U.S. survey foot.

905.3.4.2 Horizontal datum.

Commentary: All ST LDPs have been established using ground coordinates referenced to the WA SPCS, NAD 83 (1991 or 2011). Projects prior to 01/2014 used 1991 published values.

905.3.4.2.1 Projects after 01/2014 must use 2011 or current published values. Compute the values by:

i. Translating the respective state plane coordinates by the combination factors calculated for LDPs.
ii. Increasing the northing and easting.

905.3.4.2.2 Selecting a coordinate system

905.3.4.2.2.1 The surveyor must use an existing LDP if a new project falls within an existing Sound Transit LDP area. If not, use the current published values provided by Sound Transit to establish a new LDP.

905.3.4.2.2.2 The Surveyor must contact the Sound Transit set owner for information on:

i. Existing LDPs.
ii. How to establish new LDPs.
iii. Direction on what coordinate system to use.

905.3.4.2.2.3 The surveyor must provide the Sound Transit owner with the following information when establishing NEW LDPs:

i. Conversion routines
ii. Supporting electronic script routine(s)
iii. Supporting documentation
iv. Sound Transit Project Datum (LDP) - Calculation Worksheet (Figure 905-1)
v. Sound Transit Project Datum (LDP) - Derivation Form (Figure 905-2)

Figure 905-1: Calculation Worksheet

Local Datum Plane (LDP) Calculation Worksheet

Sample WA SPCS to LDP Work Sheet

Shown here is the minimum documentation required for worksheets provided for all new LDP summited for use at ST. Project narratives provided with worksheet are also encouraged.

Horizontal and Vertical Control Drawings

These drawings will indicate datum notes and the locations of all primary & secondary control survey monuments within the project area, which are required for field layout.

Included will be monument ties to reference points (where given), coordinates, elevations, distances, and bearings to adjacent control monuments.

Statement of Project Datum to be included indicating what coordinate system the project is using and how to relate it back to Washington State Plane Coordinates (WA SPCS).

WORK SHEET FOR CONVERTING STATE PLANE COORDINATES TO PROJECT DATUM

Project Name	Zone (North or South)	Minimum Latitude	Maximum Latitude	Mean Latitude	Mean Elevation	Mean Geoid Height

(SF)	(EF)	(CF)	(N) and (E) Project Datum	Conversion to US Survey Foot
Obtained by using the mean latitude from the table k value	$E.F. = \frac{R}{R+N+H}$ R = assumed radius of earth of 6,372,000 (meters) H = mean elevation from sea level for project (meters) N = mean Geoid height for project (meters)	SF × EF = CF	$N = \frac{Y}{CF} + 100{,}000$ $E = \frac{X}{CF} + 100{,}000$	$N \times \frac{39.37}{12}$ $E \times \frac{39.37}{12}$

Point ID	(Y) State Plane Northing (meters)	(X) State Plane Easting (meters)	(SF) Mean Scale factor (8 significant digits)	(EF) Mean Elevation factor (8 significant digits)	(CF) Combined Factor (8 significant digits)	(N) Project Datum Northing (meters)	(E) Project Datum Easting (meters)	Project Datum Northing (feet)	Project Datum Easting (feet)

Calculated By:	Checked By:

Figure 905-2: Derivation Form

(Name of project) Derivation Form

Name of Corridor Project Datum

Description of area

Geographic Reference Center, NAD-83

Grid Reference Center, Washington State Plane, North Zone, NAD-83(91)

Meters U.S. Feet

Reference Center Convergence Angle, NAD-83

Reference Center Scale Reduction Factor, NAD-83

Sea Level Reduction Factor for Mean Corridor Elevation of 60 Meters, NAVD-88

Spheroid Radius
Radius Plus Elevation

North Corridor Combination Sea Level and Scale Reduction Factor

Scale f x Sea Level f =

North Corridor Combination Factor = 0.9999XXXX
Horizontal shift: Increase Northing and Easting by X00,000

Note: Add any important notes about the datum or conversions to other project datums by others (WSDOT, Municipalities, etc.) working in same area.

Commentary: Examples of conversion routine types to be included:

i. LDP to WA SPCS
ii. WA SPCS to LDP
iii. Previous LDP to current/new LDP
iv. Project by others to current/new LDP

Commentary: Coordinate with the Sound Transit set owner for the coordinate system information of past projects. A few of the past projects are:

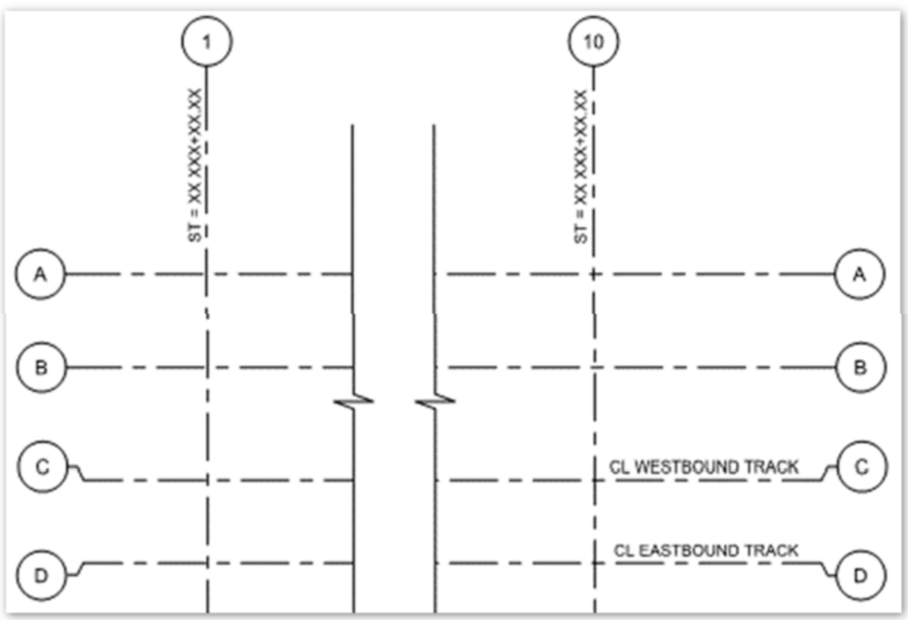
- *i. Bridgeport Way-Nisqually Sounder LDP (Bridgeport Way to Nisqually River)*
- *ii. East Link LDP (South Seattle to Redmond)*
- *iii. Lynnwood Link LDP (Northgate to Lynnwood transit center)*
- *iv. Seattle North Link LDP (Northgate to Downtown Seattle)*
- *v. Seattle Central Link LDP (Seattle Downtown to Boeing Access Road)*
- *vi. Seattle South Link LDP (Boeing Access Road to S 200th)*
- *vii. Tacoma Link LDP (Tacoma Dome to Division to MLK Jr Way to S19th Street)*
- *viii. Tacoma-Lakewood Sounder LDP (Puyallup River to Bridgeport Way SW)*

905.3.4.2.3 Grid Control

905.3.4.2.3.1 Survey work must include development of Architectural or Structural Grid, in lieu of alignment stationing or offsets, to establish and control the design layout of building elements (station structures, parking garages, maintenance facilities, and ancillary structures). At a minimum:

- i. Tie two of the grid lines into the alignment geometry at two alignment points.
- ii. Label by Station and Offset.
- iii. Tie one grid line to the centerline of track unless no alignment geometry exists within the project limits.

Figure 905-3: Grid Control Example



905.3.4.3 Vertical datum: Survey work (including mapping, platting, planning, design, right-of-way surveys, and construction surveys) must use the current NGS North American datum. See the NGS website for the current datum.

905.3.4.4 Monuments Disturbed, Destroyed, Removed, or Replaced: Provide referencing for and replace monuments that are disturbed, destroyed, or removed by the project. The surveyor must file an application for a permit to remove or destroy a survey monument with the Washington State Department of Natural Resources, pursuant to 58.24.040(8) RCW. The surveyor must transmit a copy of the approved permit and the subsequently approved completion report to Sound Transit.

Commentary: Sound Transit may, at their discretion, have 10 working days to review all information submitted for conformance to Sound Transit requirements.

905.3.5 Surveying Requirements

905.3.5.1 Field Notes

905.3.5.1.1 Field Books: The survey crew must take project survey notes on hardbound Surveyor's field book(s). Deliver digital copies (PDF or equivalent) of job survey notes to Sound Transit as part of the overall project closeout.

905.3.5.1.2 General Notations: The crew must number the pages consecutively, beginning with the number "1" on the first page.

905.3.5.1.2.1 At the top of the left-hand page at each new location and/or project phase, the crew must place the title showing the location and limits (street name or cross street) and the type of the work being done (topography, traverse, or levels).

905.3.5.1.2.2 At the top of the right-hand page, the crew must add the date, weather (temperature, barometric pressure, humidity), the name of the persons performing the work, and the instrument used. Repeat this information if the weather, date, or person performing the work changes.

905.3.5.1.3 Horizontal Control Notations: In field books, the crew must include horizontal control notes with a drawing showing the location of the control, a north arrow, and the designation of the control points. Describe in detail the monuments, corners, and other control points that are found or set. Record horizontal angles, vertical or zenith angles, slope distances, height of target, and the instrument height. When terrestrial methods are used, measure a minimum of two direct and two indirect angles to each control point.

905.3.5.2 Project Control

905.3.5.2.1 The crew must set at least two benchmarks on the site and show on the survey. Use a 16-inch minimum rebar with cap or aluminum/brass monument cast in concrete. Do not use hubs, tacks, or scribes. For surveys along streets or Sound Transit right-of-way, set at least one benchmark per 1,500 feet. For site surveys, set at least one benchmark per 5 acres.

905.3.5.3 Vertical Control Work

905.3.5.3.1 In the field books or electronically, the crew must provide the unadjusted rod readings, the raw elevations, the closing error, and the adjusted elevations of a level run or level loop. List and describe benchmarks set by the consultant in the field book. For benchmarks set, include the description, elevation, point designation, name, and Sound Transit source (field book, database).

905.3.5.3.2 For GPS-derived heights, the surveyor must refer to "Converting GPS Height into NAVD88 Elevations with the GEOID96 Geoid Height Model," found at the NGS website.

905.3.5.4 Information and Files Submission

905.3.5.4.1 The surveyor must submit available project survey information and files to Sound Transit at the 30% design review or earlier. Transmit project files to Sound Transit in digital format prior to the 100% design review.

905.3.5.4.2 The plans and surveyor's notes must include the benchmarks and horizontal control to establish ties to the datum.

905.3.5.4.3 The surveyor must provide digital copies of data collection files (original and edited) and coordinate project files.

905.3.5.4.4 The surveyor must provide a paper copy of the final survey, map or legal description, with an original wet stamp and signature from the land surveyor of record (Washington state licensed) for the project.

905.3.5.4.5 The surveyor must submit Traverse Adjustments Reports, Digital Level Run Reports, and GPS Network Adjustment Reports.

905.3.5.4.6 The surveyor must provide an electronic, comma delimited coordinate text file of data points in the following format: point number, northing, easting, elevation, descriptor.

905.3.5.4.7 The surveyor must provide the project's raw GPS data used in Trimble GPS format or Rinex export format.

905.3.5.4.8 Drawings must comply with Sound Transit CAD requirements. Provide drawing files in the Sound Transit approved format to contain a Vertical and Horizontal Control table listing the point number, elevation, description, and location of site benchmarks.

905.3.5.5 Descriptor and Line Work Codes

905.3.5.5.1 The descriptor codes and figures prefix library for surveyed points and lines must comply with Sound Transit's Design Technology Manual for symbols and line work.

905.3.5.6 Survey Control Plan Drawing Requirements

905.3.5.6.1 The drawings must show monuments, the geometry of, and the references used to establish the right-of-way, lines referencing the right-of-way, property lines, easements, and any rights in real property. Show survey control and boundary information independently of other plan, design, or topographic information (on a separate sheet), and contain the surveyor's original stamp, wet signature, contact information, and the date.

905.3.6 Control Designation Convention for Field Notes on Sound Transit Projects

905.3.6.1 Designations for control monuments and references to control must follow the following convention:

905.3.6.1.1 Designations must reference the field book number and page in the following format: nnnn-pg-pt#, where the first number represents the field book number, the second number represents the page number, and the third number is available to designate multiple entries on a given page (e.g., 3674-03-01, 2567AA-22-03).

905.3.6.2 If a page shows more than one monument, the surveyor must add the next chronological number to the designation for next monument (e.g., 3674-01-01, 3674-01-02, 3674-01-03).

905.3.6.3 When referencing control from an existing Sound Transit field book, the Surveyor must follow the same convention as for a new control designation.

905.3.6.4 When new horizontal and/or vertical values are established for an existing monument, a new designation must include a reference to the existing record (e.g., 3674-03-02 (ref 2675BB-34)).

905.3.6.5 In the field notes, the surveyor must note designations stamped on monuments in quotes following the designation. (e.g., 3674-01-01 "3674-01-01"). Existing stamped designations follows the same convention (e.g., 3677-34-02 "AB067"). Also note the city/county/agency/firm name (if known) in the description.

905.3.6.6 If a reference to an electronic point number is made in the field book, the Surveyor must add this in light pencil following the designation and circle the number. Do not use the electronic point number as a primary monument designation. An electronic point file number serves only as a supplement to a noted designation as outlined above.

Commentary: Please see the examples below.

3674-03-01 (ref 2765-31) "TC03" 316

Found 2-1/2" brass cap in Seattle Water Department Case…etc. In this example, a city monument was found from a description in book 2765 that was stamped with a project designation of "TC03". A new NAVD88 elevation was established in the current survey by differential leveling. The survey point file number is 316.

3677-11-03 "3677-11A" 121

Set 2" brass cap in conc. Sidewalk…etc.

In this example, a new monument was set for a project primary control and stamped accordingly, the point file number is 121.

3677-11-02

Set HTK…etc.

A hub and tack set for the same project as topo control noted on the same page as the preceding example.

905.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

905.4.1 System Breakdown Structure

905.4.2 System Sites and Locations

905.5 SYSTEM INTERFACE REQUIREMENTS (NOT USED)

905.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

905.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

905.7.1 Interface and Integration Management

905.7.2 Design Management

905.7.3 Manufacturing and Construction Management

905.7.4 Installation Management

905.7.5 Inspection and Testing Management

905.7.6 Training, Pre-Revenue Operations

905.7.7 Certification Management

905.8 APPENDICES (NOT USED)

END SET - 905

906 ROADWAYS AND NON-MOTORIZED FACILITIES

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SET - 906 ROADWAYS AND NON-MOTORIZED FACILITIES

906.1 INTRODUCTION

906.1.1 Document Scope

906.1.1.1 This set covers the design of roadways, non-motorized facilities, intersections, driveways, and access roads. Non-motorized facilities include walkways, sidewalks, crosswalks, shared use paths, pedestrian bridges, bike lanes, and highway shoulders.

906.1.1.2 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 906 owner to determine the technical source for the design criteria.

906.1.2 Regulations, Codes, Standards, and Guidelines

906.1.2.1 A Policy on Geometric design of Highways and Streets, American Association of State Highway and Transportation Officials (AASHTO).

906.1.2.2 Americans with Disabilities Act (ADA) Standards for Transportation Facilities.

906.1.2.3 US Access Board Public Right-of Way Accessibility Guidelines (PROWAG).

906.1.2.4 WSDOT Design Manual.

906.1.2.5 WSDOT Pavement Policy.

906.1.2.6 Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways.

906.1.3 Abbreviations and Acronyms

906.1.3.1 AHJ–authority having jurisdiction

906.1.3.2 DOR–designer of record

906.1.3.3 OMF–operation and maintenance facility

906.1.3.4 PROWAG–Public Rights-of-Way Accessibility Guidelines

906.1.3.5 TPSS–traction power substation

906.1.4 Definitions and Classifications (Not Used)

906.1.5 References (Not Used)

906.2 STAKEHOLDER NEEDS

906.2.1 Passenger Experience (Not Used)

906.2.2 Operational Needs (Not Used)

906.2.3 Maintenance Needs

906.2.3.1 The design must provide safe access and parking for maintenance vehicles.

906.2.3.2 The design must provide means of maintenance access in the vicinity of public right-of-way.

906.2.3.3 The design must provide positive drainage to eliminate ponding outside of detention ponds.

906.2.3.4 The DOR must design pavement with long design life to handle emergency and maintenance vehicles with minimal maintenance.

906.2.4 Safety Needs

906.2.4.1 Provide cross slopes and longitudinal slopes that will be safe and accessible for users.

906.2.4.2 Non-motorized facilities must meet ADA requirements.

906.2.4.3 The design must include signals and/or other treatments for pedestrian crosswalks.

906.2.4.4 The design must provide vertical clearance underneath the track guideway.

906.2.4.5 The design must provide safe access and parking for emergency vehicles.

906.2.5 Security Needs (Not Used)

906.2.6 Reliability, Availability and Maintainability Needs (Not Used)

906.2.7 Environmental and Sustainability Needs (Not Used)

906.3 SYSTEM REQUIREMENTS

906.3.1 General Policy

906.3.1.1 The design of roadways, interchanges, intersections, traffic signals, illumination, curbs, gutters, curb ramps, access roads, parking areas, and driveways must comply with AHJ requirements.

906.3.1.1.1 If AHJ requirements are absent, the above facilities must meet WSDOT requirements.

906.3.1.1.2 Within ST's right-of-way, the above facilities must meet WSDOT requirements.

906.3.1.2 The design of roadway facilities must meet AASHTO's sight distance requirements.

906.3.1.3 The signage and striping along roadway facilities must meet WSDOT requirements for WSDOT-operated facilities and MUTCD requirements for other facilities.

906.3.1.4 The DOR must coordinate with Sound Transit Real Property to obtain the right-of-way information and associated requirements.

906.3.1.5 Cross Slopes

906.3.1.5.1 The minimum cross slope on surfaces, regardless of surface material or location, must be 1.3 percent.

906.3.1.5.2 The maximum cross slopes for Sound Transit infrastructure must be per the following table:

Table 906-1: Maximum Cross Slopes

Sound Transit Infrastructure	Maximum cross slopes (%)
Portland cement concrete and asphalt concrete pavement roads	2.0
Gravel surface	3.0
Shoulders	5.0
ADA accessible routes and ADA parking stalls	1.7
Paved parking areas, excluding ADA accessible route	4.5
TPSS and Signal Bungalow facilities	2.0
Other paved non-motorized facilities	2.0

906.3.1.6 Longitudinal Slopes

906.3.1.6.1 The minimum longitudinal slope on surfaces, regardless of surface material or location, must be 1.3 percent.

906.3.1.6.2 For Sound Transit owned roadways, the maximum longitudinal slope must be 12 percent.

906.3.2 Vertical Clearances

906.3.2.1 The minimum vertical clearance to the guideway, above the traffic lanes and shoulders on public roadways, must be 16.5 feet.

906.3.2.1.1 The clearance must apply over the entire roadway width including turning lanes, non-motorized facilities, parking lanes, and shoulders.

906.3.2.2 The minimum vertical clearance to the guideway, above surface parking lots, must be 16.5 feet.

906.3.2.3 The minimum vertical clearance to the guideway, above driveways and private roads, must be 14.5 feet.

906.3.2.3.1 The design must incorporate additional vertical clearance to the guideway to account for specialized truck operations and TPSS facilities.

Commentary: If specialized trucks/equipment access these private roads and/or parking lots owned by Sound Transit and others, the design must provide additional clearance needed to accommodate these specialized trucks. The designer must coordinate with the property owner to determine the type of trucks that would access these roads. The design must not include trash enclosures under the guideway.

906.3.3 Non-Motorized Facilities

906.3.3.1 The design of non-motorized facilities must comply with AHJ requirements.

906.3.3.1.1 If AHJ requirements are absent, the above facilities must meet WSDOT requirements.

906.3.3.1.2 The design of non-motorized facilities must also incorporate ADA requirements and US Access Board PROWAG technical requirements.

906.3.3.2 The design and location of marked crosswalks and associated elements, such as Rectangular Rapid Flashing Beacons, pedestrian hybrid beacons, pedestrian signals, signage, striping, and refuge islands, must comply with AHJ requirements.

906.3.3.2.1 Within Sound Transit right-of-way, the above facilities must meet WSDOT requirements.

906.3.3.3 If the Sound Transit project impacts existing non-motorized facilities, the design must repair or replace in accordance with AHJ requirements for the impacted portion.

906.3.3.4 Where a missing connection exists between bus-loading zone and the Sound Transit station, the design must provide new sidewalk connection.

906.3.3.5 In the quadrant with a railroad signal bungalow, the design must install a mountable 6-inch-high curb per WSDOT standards in the first 30 feet from the nearest rail.

906.3.3.5.1 If there is a sidewalk in that quadrant, the sidewalk thickness must be minimum 8 inches of concrete with reinforcement.

906.3.4 Driveways

906.3.4.1 If the Sound Transit project impacts existing driveways, the design must replace in-kind the impacted driveways.

906.3.4.2 For Sound Transit owned driveways, the maximum grade must be 12 percent.

906.3.4.3 The DOR must obtain approval of the AHJ for temporary or permanent driveway closure(s) required to facilitate construction and operations.

906.3.5 Access Roads

906.3.5.1 Fire department, emergency, and maintenance access roads must comply with AHJ fire life safety requirements.

906.3.5.2 At Hi-Rail access (maintenance of way) points, the maximum longitudinal slope must be 2 percent for 15 feet exterior to the Hi-Rail Access gates.

906.3.5.3 For access roads, the design must include a minimum of two parking spaces for maintenance vehicles.

906.3.5.4 The unobstructed width of the access roads must be minimum 20 feet.

906.3.5.5 The design of access road must include a turnaround that allows a maintenance or emergency vehicle to make a 180-degree turn.

906.3.5.6 For access roads without driveway(s), the entry sidewalk thickness must be a minimum of 8 inches of concrete with reinforcement.

906.3.6 Paving

906.3.6.1 The pavement design must meet AHJ requirements and WSDOT Pavement Policy.

906.3.6.2 The pavement structural cross sections for Sound Transit facilities must incorporate a 40-year design life to support the anticipated traffic.

906.3.6.3 For bus loop usage, paved surfaces must be Portland cement concrete.

906.3.6.3.1 For other roads and parking areas, paved surfaces must be Portland cement concrete or asphalt concrete.

906.3.6.4 For streets and facilities maintained by AHJs other than Sound Transit, the pavement replacement must comply with AHJ requirements.

906.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

906.4.1 System Breakdown Structure

906.4.2 System Sites and Locations

906.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 906-2: Interfaces Between Roadways and Other Disciplines

SET SERIES	SET NAME	SET 906 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	
300	Operational Communications	X
400	Vehicle	
500	Track	X
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	
1100	Technology	
1200	Security	X

906.5.1 Train Control and Signals

906.5.1.1 Coordinate with Train Control and Signals requirements for Signal Bungalow access and parking.

906.5.2 Traction Electrification

906.5.2.1 Coordinate with Traction Electrification requirements for TPSS access and parking.

906.5.3 Operational Communications

906.5.3.1 Coordinate with Operational Communications requirements for the maintenance access for communications equipment.

906.5.4 Track

906.5.4.1 Coordinate with Track requirements for the following:

906.5.4.1.1 Maintenance access.

906.5.4.1.2 Parking along track.

906.5.4.1.3 Track clearance.

906.5.5 Fire/Life Safety

906.5.5.1 Coordinate with Fire-Life Safety requirements for the following:

906.5.5.1.1 Emergency access roads.

906.5.5.1.2 Parking for emergency vehicle.

906.5.5.1.3 Additional fire department access.

906.5.5.1.4 Station platform end-gate requirements.

906.5.6 Structures

906.5.6.1 Coordinate with Structures requirements for the following:

906.5.6.1.1 Bridge abutments.

906.5.6.1.2 Structure maintenance access.

906.5.7 Architecture

906.5.7.1 Coordinate with Architecture requirements for the following:

906.5.7.1.1 Stations access.

906.5.7.1.2 Stations landing.

906.5.7.1.3 Pedestrian and bicycle facilities at stations and facilities.

906.5.8 Civil

906.5.8.1 Coordinate with civil requirements for fencing and gates.

906.5.9 Security

906.5.9.1 Coordinate with Security requirements for the following:

906.5.9.1.1 Parking facilities.

906.5.9.1.2 Access control/intrusion detection on access roads.

906.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

906.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

906.7.1 Interface and Integration Management

906.7.2 Design Management

906.7.3 Manufacturing and Construction Management

906.7.4 Installation Management

906.7.5 Inspection and Testing Management

906.7.6 Training, Pre-Revenue Operations

906.7.7 Certification Management

906.8 APPENDICES (NOT USED)

END SET - 906

1002 MECHANICAL – PLUMBING

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SET - 1002 TABLE OF CONTENTS

TABLES

FIGURES

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SET - 1002 MECHANICAL – PLUMBING

1002.1 INTRODUCTION

1002.1.1 Document Scope

1002.1.1.1 This set establishes plumbing and drainage system design criteria for Sound Transit operation and maintenance facilities passenger stations, parking garages, and auxiliary spaces for Link light rail, sounder, and Stride bus rapid transit.

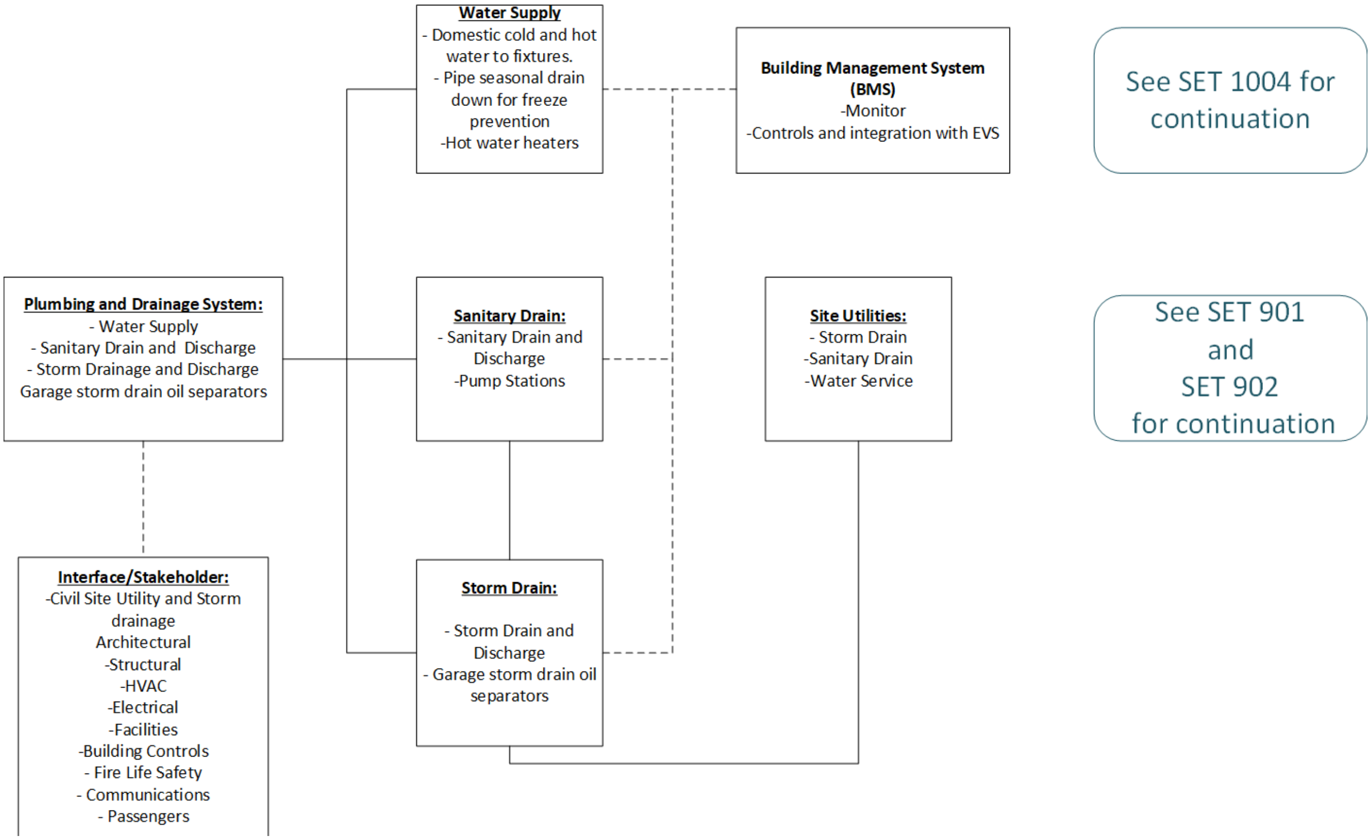
1002.1.1.2 This design criteria set establishes minimum requirements. If there is a conflict between these requirements and adopted codes and standards, the most restrictive will apply.

1002.1.1.3 Facility plumbing system design must supply cold and hot potable water to all plumbing fixtures at interior of the facilities and supply non-potable water to exterior hydrants, and site automatic irrigation system.

1002.1.1.4 Facility drainage system design criteria must include sanitary drainage and venting from plumbing fixtures, storm drain from uncovered areas and roof, including sanitary and storm subsurface drainage, and pumping station.

1002.1.1.5 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 1002 owner to determine the technical source for the design criteria.

Figure 1002-1: Plumbing and Drainage System Context Diagram



1002.1.2 Regulations, Codes, Standards, and Guidelines

1002.1.2.1 International Regulations, Codes, Standards, and Guidelines

1002.1.2.2 International Building Code (IBC) with state and local amendments.

1002.1.2.3 International Energy Conservation Code (IECC) with state and local amendments.

1002.1.2.4 International Fire Code (IFC) with state and local amendments.

1002.1.2.5 Federal and National Regulations, Codes, Standards, and Guidelines

1002.1.2.5.1 Washington State Department of Labor & Industries adopted elevator code.

1002.1.2.5.2 ASME/ A17.1 - /CSA B44-16. ASTM B88 – Standard Specification for Seamless Copper Water Tube.

1002.1.2.5.3 ANSI Z358.1 – Emergency Eyewash and Shower Standard.

1002.1.2.5.4 ANSI A21 – Ductile and Grey Iron Pipe and Fittings.

1002.1.2.5.5 ANSI B31 – Pressure Piping.

1002.1.2.5.6 ANSI B125 – Plumbing Fittings.

1002.1.2.5.7 UL 499 – Electric Heating Appliances.

1002.1.2.6 State and Local Regulations, Codes, Standards, and Guidelines

1002.1.2.6.1 WAC- Washington Administrative Codes.

1002.1.2.7 National Electrical Code (NEC) with State and local amendments.

1002.1.2.8 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

1002.1.2.9 Other Jurisdictions (Not Used)

1002.1.2.10 Sound Transit Regulations, Codes, Standards, and Guidelines

1002.1.2.10.1 Sound Transit Equipment and Facilities Numbering Standards, Rev.4.

1002.1.2.10.2 Interface Coordination and Integration Plan (ICIP), Rev 0.

1002.1.2.10.3 General Testing and Commissioning Plan, Rev. 1.

1002.1.2.10.4 Systems Guidance Drawings Set, Rev 1.

1002.1.2.10.5 ENVISION, Current version.

1002.1.2.10.6 Leadership in Energy and Environmental Design (LEED).

1002.1.3 Abbreviations and Acronyms

1002.1.3.1 ADA–Americans with Disabilities Act

1002.1.3.2 AHJ – authority having jurisdiction

1002.1.3.3 BMS – building management system

1002.1.3.4 NSF–National Sanitation Foundation

1002.1.3.5 PSO – portfolio services offices

1002.1.3.6 UL–Underwriters Laboratories

1002.1.3.7 VFD– variable frequency drive

1002.1.4 Definitions and Classifications (Not Used)

1002.1.5 References (Not Used)

1002.2 - STAKEHOLDER NEEDS

1002.2.1 Passenger Experience

1002.2.1.1 The PSO engineering's mission is to protect and uphold the integrity of the technical requirements to ensure passenger satisfaction and safe, quality, reliable, and durable operations through establishing, integrating, and managing the needs of the agency through engineering, core systems, and facility requirements.

1002.2.2 Operational Needs

1002.2.2.1 Stations and garages are operated without a continual presence of operators or maintenance people. Designs must account for unattended facilities.

1002.2.2.2 Maintenance facilities are operated 24 hours a day 7 days a week in support of operating transportation service and maintaining the associated systems, buildings, and infrastructure.

1002.2.3 Maintenance Needs

1002.2.3.1 Maintenance at stations and garages is typically reserved for periods that do not impact passengers. Maintenance windows are limited to non-revenue periods unless the scope can be performed without passenger impact. Designs must account for narrow maintenance windows. Water and drainage pipes must not be routed through communication rooms/closets, elevator machine rooms, escalator control rooms, or electrical rooms.

1002.2.4 Safety Needs

1002.2.4.1 Passenger, operator, and maintainer safety for normal operations and emergency operations must be accounted for in designs.

1002.2.4.2 Provide fall protection to eliminate fall hazards for equipment located at four feet or higher and as required in Set 804 Fall Protection.

1002.2.4.3 Before working on equipment safely, it must be de-energized from electrical hydraulic, mechanical, or other stored energy. Follow lockout/tagout procedure to secure equipment. The designer must provide documentation for the lockout/tagout procedure. Coordinate with Set 1005 Electrical Power.

1002.2.5 Security Needs

1002.2.5.1 Station and garage elements accessible to passengers must incorporate theft and vandalism prevention, including material selection and placement, and must adhere to Sound Transit Crime Prevention Through Environment Design policies.

1002.2.5.2 Plumbing equipment must be protected from tamper or vandalism when in passenger areas.

1002.2.6 Reliability, Availability and Maintainability Needs

1002.2.6.1 Material and equipment selection must consider the operating environment and small maintenance windows associated with public transportation. Materials and equipment in exterior area of stations and parking garages must be rated for outdoor installation.

1002.2.6.2 Design the layout above the ceiling system with an access path for ease of maintenance. Coordinate system layout with fixed furniture and equipment for servicing plumbing equipment without interference. Coordinated embedded/recessed plumbing equipment with fixed furniture and building features for servicing equipment without interference.

1002.2.6.3 Equipment replacement components must be either stocked by the manufacturers or available through commercial plumbing parts suppliers. See Set 001 General for equipment reliability needs.

1002.2.6.4 Provision to remove or service equipment must be demonstrated through BIM 3D modeling in accordance with Sound Transit's Integration Process. The design must illustrate how equipment is installed, removed, and replaced from the station or facilities equipment room to the loading area outside the facilities. Coordinate structural floor support for equipment with Set 720 Building Structures.

1002.2.6.5 Plumbing equipment must be positioned to ensure service and maintenance of the equipment will not disrupt station operation. Equipment must be accessible for service and must not be located within 10 feet of OCS, or within the trackway.

1002.2.6.6 Sump Pump Access

1002.2.6.6.1 Design must include maintenance and replacement access to sump pumps.

1002.2.6.6.2 Design must include permanent mechanical hoisting to remove sump pumps over 50-pounds dry weight.

1002.2.6.6.3 Provide required clearance around access points and hoist equipment in accordance with manufacturer's printed operation and maintenance manual.

1002.2.6.6.4 Provide for the installation and removal of factory-built equipment according to the manufacturer's operation and maintenance manual.

1002.2.6.6.5 Provide lifting hooks and removable panels for the installation and removal of equipment located in underground sumps or vaults.

1002.2.6.6.6 Structural openings must be sized to accommodate installation and removal of factory-built equipment without disassembly or special construction/demolition.

1002.2.6.6.7 Coordinate with Set 800 Architecture to provide additional buffer space for equipment to clear door frames, door swings, and required rotation of equipment around corners of facilities.

1002.2.7 Environmental and Sustainability Needs

1002.2.7.1 Facility designs must promote stewardship of resources. Select material and equipment that operates efficiently to meet Sound Transit environmental and sustainability targets.

1002.3 - SYSTEM REQUIREMENTS

1002.3.1 General Requirements

1002.3.1.1 Plumbing/drainage system servicing Sound Transit facilities must include water service, soil, and waste system, and plumbing fixtures.

1002.3.1.2 When stations, parking garages, or end of the line facilities are on the same site, provide water, soil, and waste system service separately to each facility.

1002.3.1.3 Coordinate site storm drainage with Set 901 Storm Drainage.

1002.3.1.4 Coordinate site water service and sanitary drain with Set 902 Utilities.

1002.3.2 Water Service

1002.3.2.1 Water service connection at each facility for fire protection systems and irrigation systems must be separate from that for domestic potable water systems.

1002.3.2.2 The domestic water service connection to underground station must be 2 inches or larger in diameter and sized to meet peak demand, plus 10 percent for future expansion.

1002.3.2.3 For other facilities, services are sized to meet peak demand plus 10 percent for future expansion.

1002.3.2.4 Service for facility must have a main shut-off valve and backflow preventer device as required by applicable AHJ plumbing codes and ordinance. The valve assembly must locate inside the facility. For locations without a facility or structure, backflow devices are placed in a below grade vault.

1002.3.2.5 Install pressure regulator downstream next to backflow preventer device to maintain service water under 60 pounds per square inch.

1002.3.2.6 Minimum fixture service requirements must be in accordance with local codes and amendments.

1002.3.2.7 Size the domestic water distribution lines to maintain uniform pressure for plumbing fixtures at the same level.

1002.3.2.8 Maintain water pressure over 15 pounds per square inch at flush valve.

1002.3.2.9 Maintain water pressure over 8 pounds per square inch at end of the line fixture.

1002.3.2.10 Install water hammer arrestors at flush valves, quick closing valves, and end of the water distribution lines to reduce shock.

1002.3.2.11 Water hammer arrestors must be accessible. Provide a shut-off valve at water hammer arrestor to isolate the arrestor from water line during replacement.

1002.3.2.12 Hot water pipes serving more than a single fixture are sized for the demand of multiple fixtures. Hot water pipe serving fixtures must be ¾ inch or larger.

1002.3.2.13 Isolation valves must be provided on each branch of distribution mains and on each floor level to facilitate maintenance in individual areas without losing service for the entire facility.

1002.3.2.14 Isolation valves must be provided on both sides of water heaters, in-line accessories, equipment that requires removal, and isolation from pressure for maintenance.

1002.3.2.15 Valves and accessories located within mechanical rooms must be installed at height below 4 feet to allow access for operation without the use of chains or additional operating platforms.

1002.3.2.16 Valves must be in non-public spaces. Valve located in public areas must be above touch zone.

1002.3.2.17 HVAC equipment is connected to the potable water system must be provided with pressure-reducing valves and backflow preventers device as required by applicable AHJ plumbing codes and ordinance.

1002.3.3 Drainage and Vent

1002.3.3.1 Soil and waste pipes must be sized for fixture demand and as required by applicable AHJ plumbing codes and ordinances.

1002.3.3.2 Underground, concealed, or embedded in structural slabs, soil and waste piping must be 4 inches or larger in size for future maintainability of access restricted piping.

1002.3.3.3 All floor, area, and roof drains must be bottom outlet type.

1002.3.3.4 Drains must have grating that prevents debris from entering the drainage system.

1002.3.3.5 All drains used in membrane waterproof floors and roofs must be provided with flashing collars securely clamped to the waterproof membranes or flashing.

1002.3.3.6 Drain finish must be coordinated with the architectural requirements as indicated in Set 800 Architecture.

1002.3.3.7 Vent risers for underground facilities, terminating in planting areas at street level, must be provided with vandal-proof and rodent-proof caps.

1002.3.3.8 Roof drainage systems must be designed to handle the rainfall intensity for 100-year frequency.

1002.3.3.9 Tunnel and underground stations require subsurface drainage. Coordinate drainage invert elevations and the location of drainage facilities at the interface between contract units with related designers.

1002.3.3.10 Grease, oil, and sand interceptors must be provided as required by AHJ and in accordance to plumbing code and must be drained by gravity. When interceptors cannot be drained by gravity install sump pumps in accordance with Section 1002.6.3 Pumping Station.

1002.3.3.11 Interceptors must be accessible for service and must not be located within the trackway.

1002.3.3.12 Fire protection system requires 6-inch drain with 8-inch diameter funnel that is minimum of 30 inches high above finished floor for fire protection full flow 2-inch drain test in fire sprinkler valves room. See Set 601 Fire/Life Safety.

1002.3.4 Plumbing Fixtures

1002.3.4.1 All water supplies to fixtures in public areas must have key-operated service valves.

1002.3.4.2 Quantity of fixtures, fixture type, accessories, and layout must comply with AHJ code and accessibility requirements.

1002.3.4.3 If the facility only has a single restroom, fixtures must meet AHJ code and accessibility requirements.

1002.3.4.4 Gender neutral restrooms and single use restrooms to contain 1 accessible water closet, 1 wall mounted urinal, and 1 accessible lavatory, 1 floor drain.

1002.3.4.5 If the facility only has a single restroom, fixtures must meet AHJ code and accessibility requirements.

1002.3.5 Piping and Fittings

1002.3.5.1 All pressure piping systems must be designed to meet the requirements of the code for pressure piping, ANSI A21, B31, and B125 in all applicable sections.

1002.3.5.2 All pipe fittings, flanges, valves, and accessories must comply with the requirements of ANSI B16 in all applicable sections for dimensional requirements.

1002.3.5.3 Piping systems must be arranged for neat appearance and venting piping must be sloped as required by AHJ code.

1002.3.5.4 Pipe with pressured water must not be placed above, or in front of, electrical panels.

1002.3.5.5 Piping must be supported, guided, and anchored to maintain the integrity of piping systems without damage or leaks during extremes of operating conditions.

1002.3.5.6 Piping must be accessible for maintenance. Piping must not be embedded in concrete structures unless embedment is unavoidable due to architectural or structural requirements.

1002.3.5.7 Piping must be hydrostatically tested before covered with concrete.

1002.3.5.8 Piping in public areas of stations must be concealed unless noted otherwise. Piping exposed in public areas must be painted in a color that blends in with the surrounding areas. Stainless steel piping is not required to be painted. Coordinate with Set 800 Architecture for additional exposed piping criteria.

1002.3.5.9 Sleeves and escutcheons must be provided wherever pipes pass through structures.

1002.3.5.10 Corrosion control measures must be provided as appropriate for the application and in accordance with industry standards. Also see current system Standard Drawings for additional information.

1002.3.5.11 Dielectric couplings must be provided for the connection of pipes of dissimilar metals and in all metallic piping entering a facility.

1002.3.5.12 Refer to Set 601 Fire/Life Safety for fire protection piping and fittings.

1002.3.6 Piping Accessories

1002.3.6.1 Dials of gauges and indicators must be in English or English/International System of Units (SI) units of measurement. Gauges must be large enough to be easily seen and read from operating floor levels.

1002.3.6.2 Piping expansion joints must be coordinated with the structural design in accordance with Sound Transit's Integration Process. Pipe expansion joints must be selected to provide at least 150 percent of the calculated traverse movements.

1002.3.7 Freeze Protection

1002.3.7.1 All water, soil, or waste piping exposed to exterior temperatures must be protected from freezing.

1002.3.7.2 Designers must analyze the piping installation at each station and other unheated spaces for possible freezing of domestic water lines during winter months and provide freeze protection measures.

1002.3.7.3 Provide manual drain down valves for hose bibbs at parking garages. Drain down valves must not be in public areas.

1002.3.7.4 BMS interface: Provide automatic BMS connected drain down valves for hose bibbs at stations. BMS must open and close to prevent pipe from freezing and monitor valves. See Set 1004 Building Monitoring and Control.

1002.3.7.5 Drains provided at low points in water lines located in spaces under station platforms must be extended to trackway areas for accessibility. Low point drain(s) must have a valve connection.

1002.3.8 Rough In

1002.3.8.1 Identify matching sleeves and block-out locations in design documents for stations or buildings constructed under separate contracts.

1002.3.8.2 The locations and sizes of the sleeves and block-outs must be accurately dimensioned for coordination with structural elements.

1002.3.8.3 Sleeves must be 2 inches larger than the proposed pipe diameter of piping system, including insulation or flanges.

1002.4 - SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

1002.4.1 System Breakdown Structure

1002.4.1.1 Plumbing system

1002.4.1.2 Drainage

1002.4.1.3 Subsurface drainage

1002.4.1.4 Pumping station

1002.4.1.5 Plumbing pumps

1002.4.1.6 Plumbing fixtures

1002.4.1.7 Domestic water heater

1002.4.1.8 Emergency eyewash station

1002.4.1.9 Piping and fittings

1002.4.2 System Sites and Locations

1002.4.2.1 Stations

1002.4.2.2 Parking garages

1002.4.2.3 Facilities

1002.4.3 Operation and Maintenance Facilities

1002.4.3.1 Guideway: tunnel and above ground

1002.5 - SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 1002-1: Interface Between Plumbing and Other Disciplines

SET SERIES	SET NAME	SET 1002 INTERFACE
100	Train Control and Signal	
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	
500	Track	
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical/Electrical and Building Systems	X
1100	Technology	
1200	Security	

1002.5.1 General

1002.5.1.1 Coordinate maximum plumbing equipment design life and service life requirement with Set 001 General.

1002.5.1.2 Architectural

1002.5.1.2.1 Coordinate with Set 800 Architecture to select plumbing fixtures and floor and roof area drains.

1002.5.1.2.2 Coordinate domestic water consumption measurement with Set 803 Sustainability and Set 1004 Building Monitoring and Control.

1002.5.1.3 Structural

1002.5.1.3.1 Coordinate structural floor support with Set 720 Building Structures.

1002.5.1.4 Civil

1002.5.1.4.1 Coordinate the design of site drainage and water supply with Set 901 Civil Storm Drainage and Set 902 Civil Utilities.

1002.5.1.5 Electrical

1002.5.1.5.1 Coordinate plumbing and drainage equipment power supply requirements with Set 1005 Electrical Power.

1002.5.1.5.2 Coordinate with Set 220 Traction Power with traction power sump pumps.

1002.5.1.6 Mechanical/Electrical and Building Systems

1002.5.1.6.1 Coordinate the design of equipment monitor and control interface with BMS systems as indicated in Set 1004 Building Monitoring and Control.

1002.5.1.7 Fire/Life Safety

1002.5.1.7.1 Coordinate the design of fire protection water supply with Set 601 Fire/Life Safety.

1002.6 - SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

1002.6.1 Drainage Systems

1002.6.1.1 Floor Drains

1002.6.1.1.1 Floor drains must be provided in accordance with AHJ code for restroom facilities and in trash rooms, janitorial, mechanical, and fire sprinkler/water riser rooms of the stations.

1002.6.1.1.2 Floor drain must be fabricated from cast iron.

1002.6.1.1.3 Floor drain grating in public spaces must be high-heel-proof, installed with vandal-proof screws, and compliant with ADA and AHJ codes.

1002.6.1.1.4 Floor drain must be provided at base of stairs for parking facilities. Coordinate floor drain location with Set 830 Parking Facilities Layout.

1002.6.1.1.5 The design must evaluate drainage requirements for additional rooms based on station type, location, and function.

1002.6.1.1.6 Floor construction must slope to provide positive drainage to top of drain elevation.

1002.6.1.1.7 Floor drains in spaces beneath station platforms, ventilation shafts, ventilation grating areas, and other areas subject to clogging must have bronze dome strainers.

1002.6.1.1.8 Floor drains must be provided beneath hose bibbs inside buildings.

1002.6.1.1.9 Floor drains beneath hose bibbs are not required at station platforms with a slope toward the trackway of at least one percent.

1002.6.1.1.10 Floor drains beneath hose bibbs are required at station platforms with a lesser slope.

1002.6.1.2 Area and Trench Drains

1002.6.1.2.1 Area and trench drains must be fabricated from cast iron.

1002.6.1.2.2 Area and trench drains grating in public spaces must be high-heel-proof, installed with vandal-proof screws, and compliant with ADA and AHJ codes.

1002.6.1.2.3 Area and trench drains for use in areas with vehicle or pedestrian traffic must be flat-surface type with load rating based on area traffic, level with finished floor.

1002.6.1.2.4 Area and trench drains must have an inlet area at least two times the area of the connected pipe.

1002.6.1.3 Roof

1002.6.1.3.1 Roof drain must be fabricated from cast iron or cast bronze.

1002.6.1.3.2 Where visible in public areas, downspout drainage pipes and gutters must be stainless steel Type 316.

1002.6.1.3.3 Where exposed to view, drainage pipes/gutters, locations must be coordinated with the station design Set 821 Station Layout–Commuter Rail.

1002.6.1.3.4 Roof drains must not daylight on the platform, walk paths, or concrete decks with pedestrian traffic.

1002.6.1.3.5 Roof drains must be equipped with strainers extending no less than 4 inches above the roof surface.

1002.6.1.3.6 Drain inlet area must be at least one and a half times the area of the connected pipe.

1002.6.1.3.7 Roof deck drain strainers for use in areas with vehicle or pedestrian traffic must be flat-surface type with load rating based on area traffic, level with the deck.

1002.6.1.3.8 Roof deck drains must have an inlet area at least two times the area of the connected pipe.

1002.6.1.4 Escalators and Elevators

1002.6.1.4.1 Escalator and elevator pits must meet the requirements of the WAC and Washington State Department of Labor & Industries adopted code ASME A17.1. If elevator pit is not able to drain by gravity, it must have small sump for pumping out accumulated water by means of a sump pump drain must comply with AHJ currently adopted IBS and UPC. See 1002.6.3.4 for sump pump controller interface.

1002.6.1.4.2 Provide means of access to remove sump pumps for maintenance.

1002.6.1.4.3 All escalators must be an outdoor escalators type per ASME A17.1 and pits must have gravity drains to prevent the accumulation of water.

1002.6.1.4.4 Service access to pits drainage system must not interfere with elevator or escalator operation.

1002.6.1.4.5 To prevent the buildup of sewage gas, the drain must not be directly connected to the sanitary system in accordance with the current Washing State Department of Labor & Industries adopted code ASME A17.1, and AHJ currently adopted IBC and UPC.

1002.6.1.4.6 Floor drains serving elevator machine room mechanical equipment must be located outside of the elevator machine room or in accordance with ASME 17.1. Condensate drains from elevator machine room cooling equipment shall drain to receptacle or location outside of elevator machine room. Coordinate floor drain and condensate drain locations with Set 805 Vertical Transportation.

1002.6.1.4.7 Trench drain serving elevators must be in front of all elevator doors. Coordinate trench drain locations with Set 805 Vertical Transportation.

1002.6.1.5 Traps

1002.6.1.5.1 When permitted by the AHJ, use waterless trap primers for infrequently used floor drains.

1002.6.1.5.2 All traps must be plain pattern having a seal measuring between 2 ½ and 4 inches with the same material as that used for the piping system.

1002.6.1.5.3 All exposed traps in toilet rooms must have chrome finish.

1002.6.1.6 Clean-outs

1002.6.1.6.1 Clean-outs must be provided on all storm, waste, and drain lines for each pair of 45-degree and each 90-degree bend.

1002.6.1.6.2 Clean out must be provided at each 50 feet of straight run, except track drainage, where the drainpipes will be maintained through the catch basins.

1002.6.1.6.3 All clean-outs brought to finished floors must terminate with removable clean-out brass covers at paved tile floors or stainless-steel covers on concrete floors. The removable covers must be flush with the floor.

1002.6.1.6.4 Floor clean-outs in public areas are not permitted. Floor clean-outs must be extended to non-public areas.

1002.6.1.7 Sewage Ejector Station

1002.6.1.7.1 In underground stations and subsurface facilities with toilets, wastewater must drain to underground sewage ejector stations. Sewage ejector stations must comply with Section 1002.6.3 Pumping Stations.

1002.6.2 Subsurface Drainage - Tunnel and Below Grade Level of Parking Garages.

1002.6.2.1 The criteria of this paragraph pertain to the design of tunnel drainage facilities. The following must apply:

i. Invert elevations and the location of drainage facilities at the interface between contract units must be coordinated with related designers.
ii. The subsurface drainage system must intercept surface water (except seepage water from platforms, in underground stations, and tunnels) from entrances, ventilation shafts, and similar openings. It must not drain into the track drainage system.
iii. Water from subsurface drainage must divert to the public sewer system in accordance with the requirements of Section 1002.3 System Requirements.

1002.6.2.2 Locations of Tunnel Subsurface Drain

1002.6.2.2.1 Drainage pumps must be provided at low points that cannot be drained by gravity.

1002.6.2.2.2 In tunnel line sections, invert drainage slots must carry drainage to pumping stations. Drainage slot inlets or sumps must be no more than 300 feet apart to comply with clean-outs or manholes spacing requirements.

1002.6.2.2.3 In stations, drainage slot inlets or sumps must be placed in intervals no more than 100 feet apart along the trackway.

1002.6.2.3 The criteria of this paragraph pertain to the design of below grade level of parking garage drainage facilities. The following must apply:

I. Invert elevations and location of drainage facilities at the interface between building and civil contracts must be coordinated with related designers.
II. Below grade drainage system must intercept surface water from ventilation shafts and similar openings.
III. Water from subsurface drainage must drain into facility oil/sand interceptor, as required by local AHJ, before diverting into the public sewer system in accordance with the requirements of Section 1002.3 System.
IV. Sump pumps must be provided at low points that cannot be drained by gravity in accordance with the requirements of Section 1002.6.3 Pumping Station.

1002.6.2.4 Drainage Fittings

1002.6.2.4.1 A drain inlet, made of cast iron grating, shall be provided at each drainage inlet, with a connection to the main track drain.

1002.6.2.4.2 A scupper drain shall be provided at the drain inlet from fan shafts and vent shafts.

1002.6.2.5 Drainage Piping

1002.6.2.5.1 Drainage piping materials must comply with AHJ plumbing code.

1002.6.2.6 Drainage Volumes

1002.6.2.6.1 The volume of water received by each system must account for drainage of open areas into the subsurface drainage system. This includes water from decks, entrances, ventilation shafts, and horizontal openings.

1002.6.2.6.2 Drainage volumes in subsurface material, designed to collect groundwater to relieve hydrostatic pressure, must be based on the following formula:

$$q = (a/14) + (L/50)$$

q = Volume, in gallons per minute

a = Horizontal projected area, in square feet, of all surface openings, such as station entrances, and fan shafts

L = Linear feet of subsurface structure in the drainage system

1002.6.2.7 Grades

1002.6.2.7.1 Subsurface drainage piping must have the minimum grades indicated in Table 1002-2.

Table 1002-2: Drainage Piping Minimum Grades

Pipe Diameter (Inches)	Minimum Grade
4	2.0 percent or 0.25 per foot
6	1.0 percent or 0.125 per foot
8 or greater	.70 percent or 0.085 per foot

1002.6.2.7.2 For main drains, the designer must consider increasing the size of the drain line to permit a close correlation between the drain profile and the top of the rail profile.

1002.6.2.7.3 Main drain lines must be designed with pipe grades to produce water flow velocity of at least 2.5 feet per second with the pipe water flow no more than 50 percent full.

1002.6.3 Pumping Station

1002.6.3.1 Link Tunnel and Underground Stations

1002.6.3.1.1 Each track drainage sump pump station, or sewage ejector station, must consist of a concrete wet well, with two redundant submersible pumps, for track drainage and a seepage water (interceptor) pump.

1002.6.3.1.2 Pump controllers must manage sump water levels using remote indication of high-water condition, electric pump "on-off-automatic" switch, lead lag control, electric alternators, and level rise indicator.

1002.6.3.1.3 Pump motor disconnect switch must comply with Set 1005 Electrical Power.

1002.6.3.1.4 BMS interface: The pump controller must interface with the BMS to provide remote monitoring of critical points. Pump controllers must be in a secured non-public area. Coordinate with Set 1004 Building Monitoring and Control.

1002.6.3.1.5 Sump pumps must be hermetically sealed to exclude moisture, abrasive materials, corrosive gases, and other matter that contributes to wear. Pumps must be the non-clog sewage, vertical centrifugal, or submersible, wet basin type. Sewer ejector pump impellers must be grinding type, with clearance large enough to pass solids up to three inches.

1002.6.3.1.6 The capacity of each track drainage pump in pumping stations at the low point must be 500 gallons per minute or larger. The capacity of each seepage water or interceptor pumps at the low point in the track drainage system must be 150 gallons per minute or larger.

1002.6.3.1.7 The pump head (total dynamic head) must suit the static and friction heads of pumping system installation. The friction head must be calculated with two pumps operating. Investigate the existing sewers to determine the pump head. If the existing sewer is liable for an overcharged head, the pump discharge must increase to exceed the overcharge.

1002.6.3.1.8 Provide an alternate power source for sump pumps for tunnels and underground stations. Coordinate with Set 1005 Electrical Power.

1002.6.3.1.9 Provide an alternate power source for sewer ejector pumps for tunnels and underground stations. Coordinate with Set 1005 Electrical Power.

1002.6.3.2 Parking Garage

1002.6.3.2.1 Drainage sump pump station or sewage ejector station must consist of a concrete wet well with two redundant submersible pumps for drainage and a seepage water (interceptor) pump.

1002.6.3.2.2 Pump controllers must manage sump water levels using remote indication of high-water condition, electric pump "on-off-automatic" switch, lead lag control, electric alternators, and level rise indicator.

1002.6.3.2.3 Pump motor disconnect switch must comply with Set 1005 Electrical Power.

1002.6.3.2.4 BMS interface: The pump controller must interface with the BMS to provide remote monitoring of critical points. Pump controllers must be in a secured non-public area. Coordinate with Set 1004 Building Monitoring and Control.

1002.6.3.2.5 Sump pumps must be hermetically sealed to exclude moisture, abrasive materials, corrosive gases, and other matter that contributes to wear. Pumps must be the non-clog sewage, vertical centrifugal or submersible, wet basin type. Sewer ejector pump impellers must be grinding type, with clearance large enough to pass solids up to three inches.

1002.6.3.2.6 The capacity of each seepage water or interceptor pumps at the low point in the garage drainage system.

1002.6.3.2.7 The pump head (total dynamic head) must suit the static and friction heads of pumping system installation. The friction head must be calculated with two pumps operating. Investigate the existing sewers to determine the pump head. If the existing sewer is liable for an overcharged head, the pump discharge must increase to exceed the overcharge.

1002.6.3.2.8 Provide an alternate power source for sump pumps for the garages. Coordinate with Set 1005 Electrical Power.

1002.6.3.2.9 Provide an alternate power source for sewer ejector pumps for the garages.. Coordinate with Set 1005 Electrical Power.

1002.6.4 Plumbing Pumps

1002.6.4.1 Domestic Water Pressure Booster Pump System

1002.6.4.1.1 When domestic water pressure cannot maintain 15 pounds per square inch of pressure or higher at plumbing fixture flush valve or 8 pounds per square inch for other fixtures, provide domestic water pump to maintain uniform pressure at plumbing fixtures in the same facility.

1002.6.4.1.2 The design must specify prefabricated and tested VFD duplex packaged pumping system to maintain the required water supply pressure.

1002.6.4.1.3 The pump packaged must be UL listed and NSF listed for drinking water.

1002.6.4.1.4 The pump motor must be integrated with VFD.

1002.6.4.1.5 VFD must be provided with integrated radio frequency interference filter.

1002.6.4.1.6 BMS Interface: Interface for remote monitoring of pump operation must be in accordance with Set 1004 Building Monitoring and Control.

1002.6.4.1.7 Pump motor disconnect switch must comply with Set 1005 Electrical Power.

1002.6.4.1.8 Booster pump system must include integrated microprocessor-based controller to operate pumping system to maintain facility domestic water supply pressure.

1002.6.4.2 Domestic Circulation Pump

1002.6.4.2.1 Provide hot water circulation pumps and controls for domestic water temperature maintenance system in accordance with current energy and AHJ codes.

1002.6.4.2.2 Pump packaged must be UL listed and ETL certified for water circulating pump to operate at maximum water temperature of 230 degrees Fahrenheit and minimum 35 degrees Fahrenheit.

1002.6.4.2.3 Pumps must be quiet wet rotor centrifugal in-line type with integrated variable frequency drive motor.

1002.6.4.2.4 BMS Interface: Interface for remote monitoring of pump operation must be in accordance with Set 1004 Building Monitoring and Control.

1002.6.4.2.5 Pump motor disconnect switch must comply with Set 1005 Electrical Power.

1002.6.5 Plumbing Fixtures

1002.6.5.1 Water closets must be vandal-resistant stainless steel for public restrooms and porcelain for staff restrooms, wall-hung, and of the elongated-bowl type.

1002.6.5.2 Lavatories must be wall-hung type and supported by industry standard floor mounted and concealed arm fixture supports.

1002.6.5.3 Service sinks must be of stainless steel and be furnished with a vacuum breaker and hose end.

1002.6.5.4 Showers must have private compartments complete with partitions, receptors, curtain rails, and curtains, and be compliant with accessibility requirements.

1002.6.5.5 Gender neutral showers must have private compartments complete with partitions, receptors, curtain rails, and curtains, and be compliant with accessibility requirements.

1002.6.6 Hose Bibbs and Box Hydrants

1002.6.6.1 Hose bibbs must be accessible for maintenance and replacement. Hose bibbs must be provided with an integral vacuum breaker.

1002.6.6.2 All hose bibbs inside buildings must be installed in walls in stainless steel boxes with flanges flush with the wall.

1002.6.6.3 All exterior, public areas, hose bibbs must be ¾ inch, operated with keys, and installed in exterior walls in lockable stainless-steel boxes with flanges flush with the wall.

1002.6.6.4 All hose bibbs and box hydrants in unheated areas must be a non-freeze type.

1002.6.6.5 Hose bibbs layout must fully cover the station platform, plaza, shelter, fare vending area, each level of a garage and its perimeter, and solar array panels with a 75-foot hose. Coordinate with facilities sets in the 800 series for hose bibb placement.

1002.6.6.6 Provide hose bibbs that fully cover co-located transit facilities and public areas maintained by Sound Transit.

1002.6.6.7 Provide hose bibbs inside of trash rooms and enclosures, outside of staff and public restrooms, in the vicinity of elevators and escalator pits, and stations entrances and concourses.

1002.6.7 Domestic Water Heaters

1002.6.7.1 Water heaters must be UL listed and ASME stamp.

1002.6.7.2 Water heaters must be the electric instantaneous type unless facility hot water demands warrant a storage type. Locate water heater where it can be inspected and maintained without interfering adjacent building components. Coordinate water heater location with Set 800 Architecture.

1002.6.7.3 Storage type water heaters must be electric heat pump type with auxiliary electric resistant heating elements. Coordinate water heater location with Set 800 Architecture.

1002.6.7.4 Water heater disconnect switch must comply with Set 1005 Electrical Power.

1002.6.7.5 Provide hot water circulation systems as required by code.

1002.6.8 Eyewash and Safety Shower Stations

1002.6.8.1 Eye wash facilities must be provided where required by WAC 296-800-15030 and DOSH Directive 13.00.

1002.6.8.2 Equipment and installation must comply with IPC 416, ANSI/ISEA Z358.1 and the manufacturer’s installation instruction.

1002.6.8.3 Combination eyewash and safety shower stations must be provided when there is potential for major portions of an employee’s body to contact corrosives, strong irritants, or toxic chemicals.

1002.6.8.4 Eyewash and safety shower stations located in heated space must connect to building potable water system. Must add mixing valves to supply tempered water to eyewash and safety shower.

1002.6.8.5 Self-contained eyewash stations are acceptable in other areas. Provide swing-over or swing-down type eyewash for sink installation emergency eyewashes.

1002.6.8.6 Eyewash and safety shower must be located in batteries storage room, rooms containing UPS, and shop areas at Link stations, garages, operation, and maintenance facilities.

1002.6.8.7 In passenger stations and wayside facilities, where required, eye wash stations must be wall-mounted, self-contained, emergency eye-and-face-wash fixture.

1002.6.8.8 The eye wash stations must be capable of a 15-minute eye flush and meet the requirements of the WAC and ANSI Z358.1.

1002.6.9 Piping and Fittings

1002.6.9.1 Valves

1002.6.9.1.1 Water and compressed air valves must be bronze, with screwed ends for 2-inch and smaller sizes, iron body bronze mounted with flanged ends for 2-1/2 inches and larger sizes valves. Provide tags and charts for valves.

1002.6.9.2 Pipe and Fittings

1002.6.9.2.1 Acceptable vent pipes are galvanized steel threaded pipe, service-weight cast iron pipe with bell /spigot fittings, or hubless.

1002.6.9.2.2 Vent pipes must pitch and slope in the direction of fixture. Vent pipe must exit the structure.

1002.6.9.2.3 Cold-water pipe embedded in structures must be hard-drawn copper tubing type “K.” Hot-and cold-water pipe not embedded must be hard-drawn copper tubing type “L.” Pipe fitting must be wrought brass or copper. Copper tubing type “K” and “L” must comply with ASTM B88.

1002.6.9.2.4 Force mains must be of ductile iron pipe with joints as required by applicable AHJ plumbing codes and ordinance.

1002.6.9.2.5 Water service piping must be ductile iron with dual mechanical-joint type for pipe 2 inches and above, and type “K” copper with wrought fittings for pipe sizes less than 2 inches.

1002.7 - ENGINEERING MANAGEMENT REQUIREMENTS

1002.7.1 Interface and Integration Management

1002.7.1.1 Account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructable documentation and functional designs.

1002.7.2 Design Management (Not Used)

1002.7.3 Manufacturing and Construction Management (Not Used)

1002.7.4 Installation Management (Not Used)

1002.7.5 Inspection and Testing Management

1002.7.5.1 Design must adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

1002.7.6 Training, Pre-Revenue Operations

1002.7.6.1 Contractor must provide operation and maintenance manual and training for Sound Transit and partner agency maintainers on procedure to operate and maintain the energy control program (lockout/tagout). Coordinate with Set 1005 Electrical Power.

1002.7.7 Certification Management (Not Used)

1002.8 - APPENDICES (NOT USED)

END SET - 1002

1003 MECHANICAL – HVAC

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SET - 1003 TABLE OF CONTENTS

TABLES

FIGURES

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SET - 1003 MECHANICAL – HVAC

1003.1 INTRODUCTION

1003.1.1 Document Scope

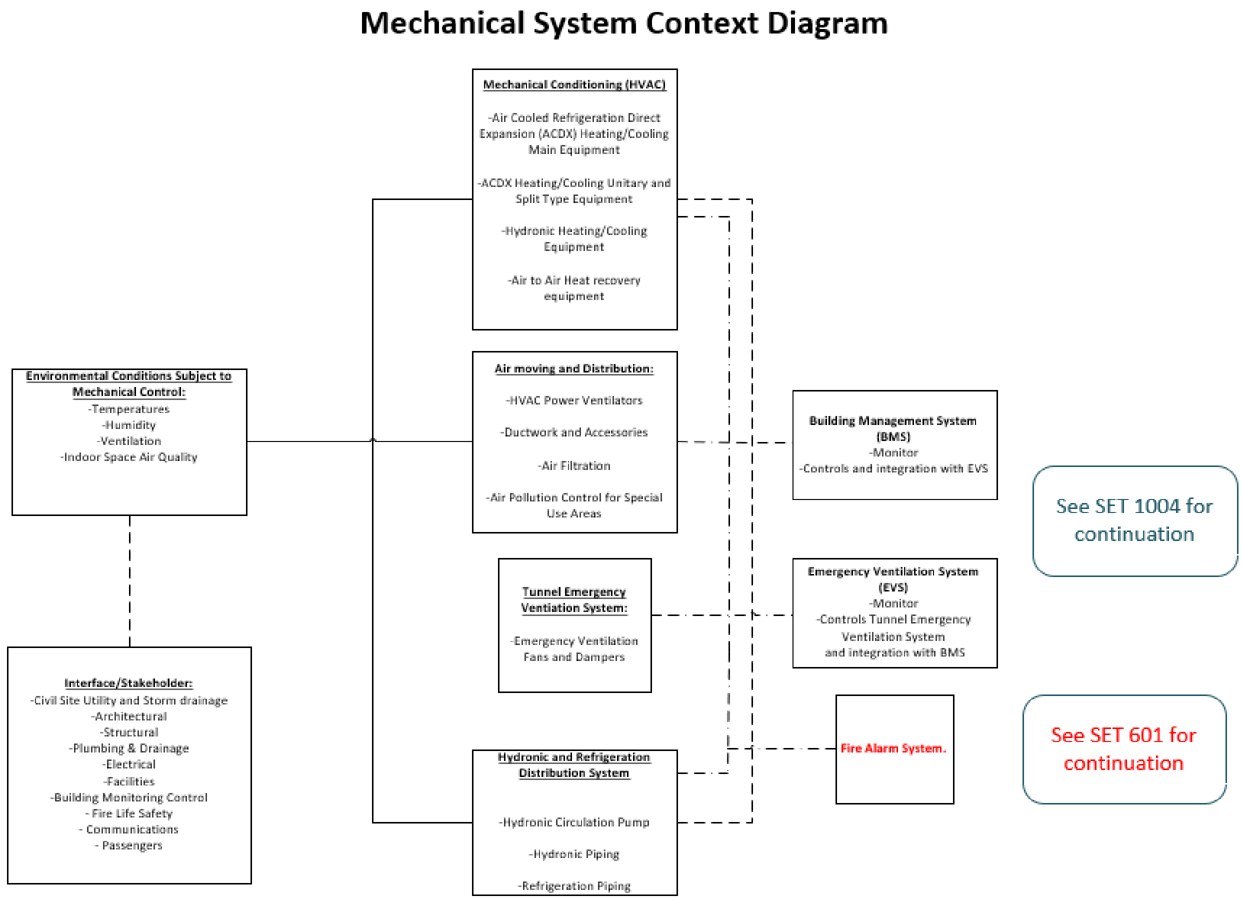
1003.1.1.1 This set establishes heating, ventilation, and air conditioning systems (HVAC design criteria) for operation and maintenance facilities, passenger stations, parking garages, and auxiliary spaces for Link light rail, Sounder, and Stride bus rapid transit.

1003.1.1.2 This design criteria set establishes minimum requirements. If there is a conflict between these requirements and adopted codes and standards, the most restrictive will apply.

1003.1.1.3 The HVAC are utilized to maintain the required environment for equipment spaces and year-round indoor comfort for occupants. The systems also ventilate and exhaust contaminated air from maintenance shop areas and parking garages. In case of a fire in underground tunnel, the emergency ventilation system will exhaust smoke and heat from the tunnels and stations to evacuate passengers and Sound Transit personnel to safety, see Set 601 Fire/Life Safety and Set 1004 Building Monitoring and Control.

1003.1.1.4 Where the DOR encounters cases of special designs not specifically covered by these criteria, the DOR must bring them to the attention of the Requirements Set 1003 owner to determine the technical source for the design criteria.

Figure 1003-1: Mechanical System Context Diagram



1003.1.2 Operational Environment

1003.1.2.1 Exterior and interior design conditions in determining the required capacities for HVAC systems must be in accordance with current State of Washington Energy code Chapter 3 General Requirements or AHJ. For additional outside conditions, refer to ASHRAE Climatic Design Conditions for the Puget Sound Area.

1003.1.2.2 Indoor temperatures must be based on indoor space function. Occupied spaces must comply with local AHJ energy code requirements and should consider ASHRAE Standard 55. Additionally, designers must analyze each room individually, and must design an HVAC system that will provide a room climate suitable for efficient equipment operation. Rooms that contain temperature sensitive equipment must be maintained at or below 75 degrees Fahrenheit DB (cooling) and at or above 72 degrees Fahrenheit (heating). For conditioned occupied spaces, provide thermostatic set back controls as required by energy code.

1003.1.2.3 Air velocities design must provide the required system performance and to minimize pressure loss and energy consumption, air-borne noise generation, draft, and the intake of dust particles.

1003.1.3 Regulations, Codes, Standards, and Guidelines

1003.1.3.1 Federal and National Regulations, Codes, Standards, and Guidelines (Not Used)

1003.1.3.2 State and Local Regulations, Codes, Standards, and Guidelines

1003.1.3.2.1 WAC – Washington Administrative Codes.

1003.1.3.2.2 International Building Code (IBC) with state and local amendments.

1003.1.3.2.3 International Energy Conservation Code (IECC) with state and local amendments.

1003.1.3.2.4 International Fire Code (IFC) with state and local amendments.

1003.1.3.2.5 International Mechanical Code (IMC) with state and local amendments.

1003.1.3.2.6 Occupational Safety and Health Administration (OSHA).

1003.1.3.3 Industry Regulations, Codes, Standards, and Guidelines

1003.1.3.3.1 ASHRAE Standards.

1003.1.3.3.2 Standard 55 – Thermal Environmental Conditions for Human Occupancy.

1003.1.3.3.3 Standard 62.1 – Ventilation for Acceptable Indoor Air Quality.

1003.1.3.3.4 SMACNA 1780 HVAC Systems Testing, Adjusting, and Balancing.

1003.1.3.3.5 American Society of Mechanical Engineers (ASME)

1003.1.3.3.6 Air Movement and Control Association International (AMCA)

1003.1.3.3.7 American Society for Testing Materials (ASTM), including E84.

1003.1.3.3.8 Air Conditioning, Heating, and Refrigeration Institute (AHRI).

1003.1.3.3.9 National Fire Protection Association (NFPA) Standard for the Installation of Air-Conditioning and Ventilating Systems (NFPA 90A).

1003.1.3.3.10 National Fire Protection Association (NFPA) National Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids (NFPA 91).

1003.1.3.3.11 HVAC Duct Construction Standards by the Sheet Metal and Air-Conditioning Contractors National Association, Inc. (SMACNA).

1003.1.3.3.12 ENVISION, Current version.

1003.1.3.3.12.1 Leadership in Energy and Environmental Design (LEED).

1003.1.3.4 Other Jurisdictions (Not Used)

1003.1.3.5 Sound Transit Regulations, Codes, Standards, and Guidelines.

1003.1.3.5.1 Sound Transit Equipment and Facilities Numbering Standards, rev 4.

1003.1.3.5.2 Interface Coordination and Integration Plan – Rev 0

1003.1.3.5.3 General Testing and Commissioning Plan, Rev 1.

1003.1.3.5.4 Systems Guidance Drawings Set, Rev 1.

1003.1.4 Abbreviations and Acronyms

1003.1.4.2 AHJ – authority having jurisdiction

1003.1.4.3 ASTM–American Society for Testing Materials

1003.1.4.4 BMS – building management system

1003.1.4.5 DOR-designer of record

1003.1.4.6 ECM–electronically commutated motors

1003.1.4.7 FD–fire damper

1003.1.4.8 FDD– fault detection and diagnostics

1003.1.4.9 FSD– fire/smoke damper

1003.1.4.10 HVAC – Heating Ventilation and Air Conditioning

1003.1.4.11 PSO– portfolio services office

1003.1.4.12 TPSS– traction power substation

1003.1.4.13 UL–Underwriters Laboratories

1003.1.4.14 VAV– variable air volume

1003.1.5 Definitions and Classifications (Not Used)

1003.1.6 References (Not Used)

1003.2 STAKEHOLDER NEEDS

1003.2.1 Passenger Experience

PSO Engineering's mission is to protect and uphold the integrity of the technical requirements to ensure passenger satisfaction and safe, quality, reliable, and durable operations through establishing, integrating, and managing the needs of the agency through engineering, core systems, and facility requirements.

1003.2.2 Operational Needs

1003.2.2.1 Stations and garages are operated without a continual presence of operators or maintenance people. Designs must account for unattended facilities.

1003.2.2.2 Maintenance facilities are operated 24 hours a day 7 days a week in support of operating transportation service and maintaining the associated systems, buildings, and infrastructure.

1003.2.2.3 The vendor and contractor must submit operation and maintenance training programs to be reviewed and approved by Sound Transit prior to training operation technicians.

1003.2.3 Maintenance Needs

1003.2.3.2 Maintenance at stations and garages is typically reserved for periods that do not impact passengers. Maintenance windows are limited to non-revenue periods unless the scope can be performed without passenger impact. Designs must account for narrow maintenance windows.

1003.2.3.3 The equipment vendor must be able to provide replacement parts promptly during the warranty period and for the expected life cycle of the equipment.

1003.2.4 Safety Needs

1003.2.4.1 Passenger, operator, and maintainer safety for normal operations and emergency operations must be accounted for in designs.

1003.2.4.2 Equipment that is installed above 4 feet will require appropriate fall protection to eliminate fall hazards as described in Set 804 Fall Protection.

1003.2.4.3 HVAC equipment that is installed above 4 feet must be provided with safe access for equipment and component maintenance. Fall hazards and other anticipated hazards must be anticipated and addressed. The design must provide Sound Transit employees and contractors safe means to enter and exit HVAC component spaces to perform maintenance. Portable ladders are a last resort but can be an option. Better options are provided stairs and fixed ladders.

1003.2.4.4 Provide means to lockout/tagout equipment. Before working on equipment safely, it must be de-energized from electrical, hydraulic, mechanical, or other stored energy. The designer must provide documentation for lockout/tagout procedure. For safe disconnection and enclosure requirements, see Set 1005 Electrical Power.

1003.2.5 Security Needs

1003.2.5.1 Station and garage elements accessible to passengers must consider theft and vandalism prevention, including material selection and placement.

1003.2.6 Reliability, Availability, and Maintainability Needs

1003.2.6.1 Material and equipment selection must consider the operating environment and small maintenance windows associated with public transportation.

1003.2.6.2 If necessary, they must be provided with ease of maintenance access path, and system layout must be coordinated with fixed furniture and equipment to access and service HVAC equipment without interference.

1003.2.6.3 HVAC equipment must be in a location where service and maintenance of the equipment will not disrupt station operation.

1003.2.6.4 Floor mounted HVAC piping must not be installed in access path created tripping hazards. Air Conditioning Units (ACU) Condensate drain must be drained indirectly at plumbing system provided receivers or floor drains. Condensate water must not drain on the floor before draining into floor drain and create slipping hazard.

1003.2.6.5 System equipment must continue to operate in extreme outside conditions in accordance with AHRI standards associated with the specific class of equipment.

1003.2.6.6 Equipment replacement components must be either stocked by the manufacturers or available through commercial HVAC parts suppliers. See Set 001 General for equipment reliability needs.

1003.2.6.7 Provision to remove or service equipment.

1003.2.6.7.1 Provision must be made for the installation and removal of each completely factory-built item of equipment. All ventilation shafts extending up to grade, openings into shafts, hatches, hatchways, removable gratings, access plates, and doors intended for use in the installation and removal of mechanical equipment must be sized, with adequate clearances, so that it can be moved between grade and its location without the need for special disassembly. The installation and removal of equipment from underground mechanical equipment rooms preferably must be accommodated by providing hatches in slabs and/or providing removable gratings at grade.

1003.2.6.7.2 Monorails, lifting hooks, and removable panels must be provided for the installation and removal of equipment.

1003.2.6.7.3 Structural openings must be sized so that each complete factory-built item of equipment can be installed or removed without disassembly or special construction or demolition.

1003.2.6.8 The design must include an illustrated study showing how equipment can be installed originally and removed and replaced through station and maintenance facilities structure openings and doorways, and removal path from equipment rooms to loading area exterior of facilities through BIM 3D modeling in accordance with Sound Transit's Interface Coordination and Integration Plan. Coordinate structural floor support for equipment with Set 720 Building Structures.

1003.2.6.8.1 Coordinate with Set 800 Architecture to provide additional buffer space for equipment to clear door frames, door swings, and required rotation of equipment around corners of facilities.

1003.2.7 Environmental and Sustainability Needs

1003.2.7.1 Facility designs must promote stewardship of resources and utilities when selecting material, equipment, and operational strategies with the goal of conservation and efficiency.

1003.3 SYSTEM REQUIREMENTS

1003.3.1 General Requirements

1003.3.1.1 HVAC systems for occupied areas must maintain an acceptable environment for passengers and operating and maintenance personnel. Design parameters with the capacity to operate throughout the year based on Pacific Northwest seasonal changes.

1003.3.1.2 HVAC system requirements must be based on cooling and heating load calculations for the whole stations or facilities and individual room. Equipment and occupant's information for each room must be provided to Sound Transit.

1003.3.1.3 HVAC system capacity shall be based on a summation of the following internal heat gains:

1003.3.1.3.1 Lighting load of 3 watts per square foot. Use actual lighting load when available.

1003.3.1.3.2 Radiation and transmission gains where applicable.

1003.3.1.3.3 Heat rejected by the electrical equipment

1003.3.1.4 The designer must design HVAC systems for acceptable pressure and temperature limits for the equipment located within the enclosed area.

1003.3.1.5 The system must prevent and reduce air borne contamination by utilizing design options as recommend in ASHRAE standards and required by applicable codes and standards, such as select filtration efficiency that is high enough to prevent harmful contaminate from entering occupied spaces.

1003.3.1.6 The system must be designed with vibration and noise level at or below maximum permissible levels with local municipal codes and ordinances.

1003.3.1.7 All HVAC system materials must be non-combustible as defined by the IBC chapter 6.

1003.3.1.8 Combustible per IBC 603 are allowed. Where NFPA is not adopted for construction type, use applicable criteria from IBC, including state and local amendments.

1003.3.2 Functional Requirements

1003.3.2.1 The system must be automatically controlled to maintain pre-set temperature and capable of set-back during non-operation and unoccupied hours. The HVAC system must be integrated with BMS. The HVAC system must be integrated with life safety system, fire protection, and fire alarm as required by AHJ.

1003.3.3 System Architecture

1003.3.3.1 The HVAC system must consist of unitary or split-package air-conditioners for heating and cooling the facilities. The system building control must be compatible with existing control systems implemented by Sound Transit.

1003.3.3.2 Unitary packages must be suitable for exterior installation.

1003.3.3.3 The condensing units for split-package systems must be located within the maximum distance recommended by manufacturers. Air handling units must be in the mechanical equipment room or areas easily accessible with adequate space to maintain the equipment as recommended by the manufacturer.

1003.3.3.4 Noise Criteria

1003.3.3.4.1 The maximum permissible sound level of HVAC system serving station and facilities must be in accordance with Set 007 Noise and Vibration, noise and vibration criteria established in the Federal Transit Administration (FTA) guidelines in Transit Noise, and Vibration Impact Assessment, current edition, and from state and local AHJ noise regulations.

1003.3.3.4.2 The maximum permissible sound levels criteria for station and facilities ancillary rooms are indicated in Set 007, Noise and Vibration, Table 7-2: Design Criteria for Patron Noise Exposure in Stations.

Commentary: Coordinate placement of HVAC equipment or provide sound attenuation for equipment when units are located in public areas to minimize impact passengers who use sound to navigate ST facilities.

1003.3.3.5 Design Goals

1003.3.3.5.1 The station and facilities sound control goals for HVAC must be designed in accordance with procedure outlined in Set 007 Noise and Vibration, ASHRAE guidelines, and must comply with FTA guidelines and state and AHJ noise regulations.

Commentary: Due to a wide range of activities, appropriate indoor acoustic design levels will vary considerably from room to room and acceptable outdoor levels will depend on local ambient sound conditions.

1003.3.3.6 Vibration Isolation

1003.3.3.6.1 All equipment which produces vibrations must be isolated from the structure by spring or rubber-in-shear vibration isolators.

1003.3.3.6.2 All piping and ducts attached to rotating and oscillating equipment must be isolated from such equipment by flexible connections. Inertia blocks must be provided as required.

1003.3.3.6.3 Vibration control for environmental control systems must be designed in accordance with the sound and vibration control chapter of the ASHRAE Handbook of Systems and Applications.

1003.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

1003.4.1 System Breakdown Structure and HVAC System Elements

1003.4.1.1 Hydronic Piping and Pumps

1003.4.1.2 Refrigerant Piping

1003.4.1.3 Ductwork and Accessories

1003.4.1.4 HVAC Power Ventilators

1003.4.1.5 Air Filtration

1003.4.1.6 Air Pollution Control for Special Use Areas,

1003.4.1.7 Enclosed and Underground Facilities

1003.4.1.8 Spray Paint Booth

1003.4.1.9 UPS/Battery Storage/Maintenance Areas

1003.4.1.10 HVAC Conditioning Systems Equipment

1003.4.1.10.1 Packaged Compressor and Condenser Units

1003.4.1.10.2 Central Chiller and Heat Pump

1003.4.1.10.2.1 Hydronic Heating and Cooling Equipment

1003.4.1.10.2.2 Radiant Heating and Cooling Hydronic Piping

1003.4.1.10.3 Energy Recovery Units

1003.4.1.10.4 Dedicated Outside Air Units (DOAS)

1003.4.1.10.5 Distributed Heat Pumps and Variable Refrigerant Flow

1003.4.1.10.6 Electric Cabinet Unit Heaters and Duct Heaters

1003.4.1.11 HVAC Conditioning Systems Equipment

1003.4.2 System Sites and Locations

1003.4.2.1 Stations, Garages, and Operation and Maintenance Facilities

1003.4.2.1.1 Communication, Signaling, Fire Command Center Rooms

1003.4.2.1.1.1 The air-conditioning system must be designed to efficiently maintain temperatures at or below 75 degrees Fahrenheit DB for equipment and provide the minimum outside air. To maintain room positive pressure to adjacent spaces, 10 percent of supply air must be exhausted by exfiltration.

1003.4.2.1.1.2 Supply air must be filtered with minimum of MERV 7air filters.

1003.4.2.1.1.3 The cooling load must be based on a summation of appropriate heat gains and using applicable codes. The design must account properly for equipment heat rejection and manufacturer recommendations for temperature requirements as indicated in Set 815 Communication Spaces.

1003.4.2.1.2 Auxiliary Rooms

1003.4.2.1.2.1 Ventilation must be provided for each room shown on the project definition drawings. Ventilation air must be provided as required and must be taken from adjacent areas or outside as applicable. When ventilation air is taken from outdoors, room pressure must be maintained at positive pressure. Air must be filtered as indicated in the Section 1003.6.6 of this set, Air Filtration.

1003.4.2.1.2.2 If room ventilation system is provided to serve the rooms and equipment closets, the cooling load must be based on a summation of appropriate heat gains and using applicable codes. The design must account properly for equipment heat rejection and manufacturer recommendations for temperature requirements.

1003.4.2.1.2.2.1 Heat the room as required by equipment or freeze protection for contents in the room.

1003.4.2.1.2.2.2 For the operation and control, an exhaust fan and heater must be provided with room thermostat to turn on/off fan when the temperature is above set point. The status of the fan and room temperature must be monitored by BMS. Coordinate with Set 1004 Building Monitoring and Control.

1003.4.2.1.2.2.3 The ventilation system must operate continuously in the following rooms: trash, sewage ejector, and sump-pump.

1003.4.2.1.2.2.4 Exhaust system serving rooms with no automatic time clock, or thermostatic control must be actuated by the occupancy sensor light switch with time delay off in accordance with AHJ energy code. Coordinate with Set 1007 Electrical Lighting for occupancy sensor light switch requirements.t Room temperature and ventilation fan must be monitored by BMS. Coordinate with Set 1004 Building and Monitoring.

1003.4.2.1.2.2.5 The BMS system must monitor filter differential pressures. Coordinate with Set 1004 Building and Monitoring.

1003.4.2.1.2.2.6 A positive pressure within the room must be maintained when the system is in operation except negative pressure for janitor room, trash, sewage ejector and sump-pump~~.~~

1003.4.2.1.3 Operation and Maintenance Facilities

1003.4.2.1.3.1 The design concepts for operation and maintenance facilities described in these criteria must apply to HVAC systems, equipment, operation, and controls in the indicated areas of major repair shops, service and inspection shops, and yards.

1003.4.2.1.4 General Office Areas and Shops

1003.4.2.1.4.1 The HVAC system serving office areas and shop must be designed to efficiently maintain environment as indicated in section 1003.1.2.2, and 1003.5.1.6 Subsystem and System Element (Detail) Requirements.

1003.4.2.1.5 Link Control Center (LCC)

1003.4.2.1.5.1 The LCC HVAC system must consist of two split-package air-conditioning units with two remote air-cooled condensers.

1003.4.2.1.5.2 Each unit must be capable of providing 100 percent of the total cooling/heating load and must be powered as prescribed in the LCC Set 1005 Electrical Power.

1003.4.2.1.5.3 One of the two systems must be provided as a standby. The operating and standby units should alternate functions every 1 to 2 weeks.

1003.4.2.1.5.4 The air distribution ductwork must be common and provided with backdraft dampers. Outside air for ventilation must be provided as required by applicable codes.

1003.4.2.1.5.4.1 BMS interface: Room temperature and ventilation fan must be control and monitored by BMS. Coordinate with Set 1004 Building and Monitoring.

1003.4.2.1.6 Train Operators' Lounge

1003.4.2.1.6.1 The train operators' lounge and lunchroom must be provided with heat and A/C either from the general office unit or its own packaged HVAC unit.

1003.4.2.1.7 Locker Rooms

1003.4.2.1.7.1 The locker rooms must receive heat and conditioned air from the general office HVAC unit. If HVAC cannot be provided from the general office area, a packaged HVAC unit must be provided.

1003.4.2.1.8 Toilets in Stations, Garage, Operation and Maintenance Facilities

1003.4.2.1.8.1 When adjacent to locker rooms, toilet rooms must be heated with secondary air transferred from adjacent locker rooms.

1003.4.2.1.8.2 Toilet rooms in the general office area must receive heated and conditioned air from the general office unit. Toilet room exhaust fans must operate continuously when offices are occupied or during office operating hours.

1003.4.2.1.8.3 Other toilet rooms located within a general shop area or in stations and garage unconditioned areas must be heated and ventilated.

1003.4.2.1.8.4 Toilet room exhaust fans must be controlled by an occupancy sensor and an adjustable switch with a time delay on light off. Exhaust fans status must be monitored by BMS. Coordinate with Set 1004 Building Monitoring and Control.

1003.4.2.1.9 Electrical Room

1003.4.2.1.9.1 The heating and ventilation system must be provided for electrical equipment room to prevent condensation and must meet code requirements. Ventilation air must be taken from adjacent areas or outside as applicable. When ventilation air is taken from outdoors, room pressure must be maintained at positive pressure. Air must be filtered as indicated in the Section 1003.6.6 of this set, Air Filtration.

1003.4.2.1.9.2 The design of heating and ventilation system to serve electrical rooms must account properly for equipment heat rejection and manufacturer recommendations for temperature requirements.

1003.4.2.1.9.3 Ventilation system for electrical rooms must operate continuously while maintaining positive pressure within the rooms.

1003.4.2.1.9.4 Where additional heating is required, electric heaters controlled by a room thermostat must be provided.

1003.4.2.1.9.5 BMS interface: Interface for ventilation fan, heater, and filter differential pressures must be monitored remotely. Coordinate with Set 1004 Building Monitoring Control.

1003.4.2.1.9.6 Traction Power Substation TPSS

1003.4.2.1.9.6.1 Air conditioning is required in all enclosed TPSSs to remove heat generated by the equipment and to limit the operating temperatures within substations below 75 degrees Fahrenheit DB.

1003.4.2.1.9.6.2 Exhaust air must discharge to the outdoors. Intake air shall be filtered using MERV 11 rated filtration. Filter differential pressures must be monitored by the SCADA system.

1003.4.2.1.9.6.3 A positive pressure shall be maintained within the room when the system is in operation.

1003.4.2.1.9.6.4 The system shall consist of two identical air conditioning units with motorized or backdraft dampers, filters, an air distribution system, automatic temperature controls, and an alternator to change lead-lag sequence.

1003.4.2.1.9.6.5 The design of supply and exhaust ducts must be based on two-unit operation.

1003.4.2.1.9.6.6 Ventilation air must not be taken from a tunnel or exhausted into a tunnel.

1003.4.2.1.9.6.7 Equipment sound power levels must ensure the noise level in the substation does not exceed the maximum allowable noise level as prescribed in Set 007 Noise and Vibration with both supply units in operation.

1003.4.2.1.9.6.8 The operation and control of the units must be by adjustable thermostats located within the substation. The BMS must provide control for TPSS that are contained within station rooms. See Set 1004 Building Monitoring and Control for additional information.

1003.4.2.1.9.6.9 When the space temperature rises to 75 degrees Fahrenheit, the first (or lead) unit will start. On a continued rise above 85 degrees Fahrenheit, the second (or lag) unit will start.

1003.4.2.1.9.6.10 On a fall in temperature to 75 degrees Fahrenheit, the lag unit will stop. On a continued fall in temperature 2 degrees below 75 degrees Fahrenheit, the lead unit will stop.

1003.4.2.1.9.6.11 By means of an alternator, the lead fan of one cycle will become the lag fan on the next cycle. This will keep the number of starts and hours of operation approximately equal.

1003.4.2.1.9.6.12 Local manual control (a time switch) must be provided so that the units can be turned on during human occupancy of the substation.

1003.4.2.1.9.6.13 The final sizing of the equipment will be concurred with by Sound Transit on a case basis and must consider one unit out of service, the physical size of equipment, and system efficiency.

1003.4.2.1.9.6.14 The system must be automatically shut down as outlined in SET 601 Fire - Life Safety.

1003.4.2.1.9.6.15 The system shall have provisions so that a high-temperature, filter status and a unit fault will transmit an alarm indication to the SCADA system.

1003.4.2.1.9.6.16 The ventilation system will automatically shut down when required by code.

Commentary: Sound Transit prefers to keep local ventilation system operating and only be provided with automatically shut down via smoke detection when only required by code. See IMC Section 606 for criteria. Note – there is a threshold for system size and exception for system serving a single room.

1003.4.2.1.9.6.17 Ventilation system serving these rooms with critical systems must only shut down upon detection associated with their respective duct detectors, when required, or with detection associated with the room served. However, the critical system, such as a clean agent system, must have provisions so that high temperature indicators can transmit a summary fault indication to the SCADA system.

1003.4.2.1.9.6.18 Prefabricated Wayside Structures, Communications, and Signal Houses

1003.4.2.1.9.6.19 Ventilation and conditioning requirements must be evaluated by the manufacturer.

1003.4.2.1.9.6.20 The cooling load must be based on a summation of appropriate heat gains.

1003.4.2.1.9.6.21 The design must account for equipment heat rejection and manufacturer recommendations for temperature requirements.

1003.4.2.1.9.6.22 HVAC units must be provided with the enclosure.

1003.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 1003-1: Interface Between HVAC And Other Disciplines

SET SERIES	SET NAME	SET 1003 INTERFACE
000	General	X
100	Train Control and Signal	X
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	
500	Track	
600	Fire/Life Safety	X
700	Structures	X
800	Architecture	X
900	Civil	
1000	Mechanical/Electrical and Building Systems	X
1100	Technology	
1200	Security	

1003.5.1 General

1003.5.1.1 Coordinate with Set 007 Noise and Vibration for station and facilities sound control for HVAC.

1003.5.1.2 Architectural

1003.5.1.2.1 Coordinate with Set 801 Architectural Materials, Elements, and Furnishings for fire dampers and Fire and smoke dampers locations and installation.

1003.5.1.2.2 Coordinate with Set 822 Station Layout –Light Rails, Set 830 Parking Facilities Layout, Set 836 Operation and Maintenance Base Facilities- Light Rail for auxiliary spaces and toilet rooms HVAC requirements.

1003.5.1.3 Structural

1003.5.1.3.1 Coordinate with Set 720 Building Structure for equipment seismic bracing and support.

1003.5.1.4 Electrical

1003.5.1.4.1 Coordinate HVAC equipment power supply requirements with Set 1005 Electrical Power. Coordinate with Set 220 Traction Power for TPSS HVAC.

1003.5.1.5 Mechanical/Electrical and Building Systems

1003.5.1.5.1 Coordinate the design of HVAC system monitor and control interface with BMS and EVS systems as indicated in Set 1004 Building Monitoring and Control.

1003.5.1.6 Fire/Life Safety

1003.5.1.6.1 Coordinate the design of HVAC system function during an emergency event with Set 601 Fire/Life Safety.

1003.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

1003.6.1 Hydronic Piping and Pumps

1003.6.1.1 General

1003.6.1.1.1 All piping systems must be designed to meet the requirements of ASME/ANSI B31.9 in all applicable sections. Pipe fittings, flanges, valves, and accessories must comply with ASME/ANSI B16 in all applicable sections.

1003.6.1.1.2 All piping systems must be designed and arranged for neat appearance. Piping must be properly sloped for drainage and venting, and properly supported, guided, and anchored to provide complete flexibility and to maintain the integrity of all systems without any damage or leaks under all operating conditions.

1003.6.1.1.3 Sleeves and escutcheons must be provided wherever pipes pass through walls. Provide fire-rated assemblies for pipe passing through fire-rated walls and floor/ceiling assemblies.

1003.6.1.2 Condensate Drainage System

1003.6.1.2.1 All condensate drainage from HVAC systems must be removed through waste drains only. Indirect drain connectors with an air gap must be used.

1003.6.1.3 Pipe Unions or Flanges

1003.6.1.3.1 To facilitate easy removal for servicing, unions or flanges must be provided on both the inlets and the outlets of all apparatus, isolation valves, control valves, and accessories. Wherever two pipes made of dissimilar metals are connected, a dielectric union must be used to isolate the two pipes from each other. Dielectric unions and flanges may also be required for cathodic protection.

1003.6.1.4 Valves

1003.6.1.4.1 Isolation valves must be provided on both sides of such apparatus as chillers, cooling towers, pumps, heating coils, control valves, multiple installations, piping accessories, and piping branches.

1003.6.1.4.2 The installation of all valves must be designed to give a neat appearance and provide easy grouping with all parts accessible for operation and maintenance.

1003.6.1.5 Piping Accessories

1003.6.1.5.1 To ensure the trouble-free operation of all piping systems, all required piping accessories must be provided. These accessories must include strainers, vent cocks, dirt-and-drip legs with drain-and-flush connections, expansion tanks, liquid flow indicators, balancing cocks, relief valves, pressure and temperature gauges, and all other piping accessories.

1003.6.1.5.2 All piping accessories requiring maintenance or replacement of parts must be of sufficient size and noted to be in accessible places.

1003.6.1.6 Pipe Expansion and Seismic Joints

1003.6.1.6.1 The use of pipe expansion joints must be avoided wherever possible. Pipe systems must be arranged to have sufficient offsets and expansion loops to accommodate thermal expansion and vibration.

1003.6.1.6.2 Pipe expansion joints may be used only where pipe expansion loops are impractical. All expansion joints must be flanged to facilitate easy and quick replacement.

1003.6.1.6.3 Coordinate the use of expansion and seismic joints with Set 720 Building Structure.

1003.6.1.7 Flexible Pipe Connections

1003.6.1.7.1 The use of flexible pipe connectors to connect piping to heating and cooling apparatus must be restricted to cases where providing piping offsets for flexibility is impractical.

1003.6.1.7.2 Where flexible pipe connectors are used, such as on resiliently mounted air-handling units and pumps, these flexible pipe connectors must be of stainless steel or Monel construction with flanged ends for quick and easy dismantling from the pipe systems. They must be of sufficient length to provide an overall stiffness less than the resilient mounts used for supporting the apparatus.

1003.6.1.8 Pipe Supports

1003.6.1.8.1 Pipe Supports, Hangers, Guides and Anchors

1003.6.1.8.1.1 Pipe supports, hangers, guides, and anchors must be designed to ensure proper alignment of all pipes for operating conditions.

1003.6.1.8.1.2 The forces caused by seismic events, the motion of the fluid, the weight of the fluid, piping valves and insulation, and thermal expansion/contraction must be considered as appropriate.

1003.6.1.8.1.3 All hangers and supports must arranged to prevent the transmission of vibration from the piping to the structure.

1003.6.1.8.1.4 Anchors and guides must allow pipes to expand and contract without a build-up of excessive stress.

1003.6.1.8.1.5 Pipe rollers must be used with all hangers where pipe movement, due to expansion or contraction, exceeds 0.5 inch.

1003.6.1.8.1.6 Spring hangers of constant or variable load types must be used when piping is connected to vibrating equipment and when supporting vertical pipes.

1003.6.1.8.1.7 Seismic calculations for piping supports must be sealed by a structural engineer registered in the State of Washington.

1003.6.1.9 Insulation

1003.6.1.9.1 Composite insulation and adhesives must not exceed a flame spread of 25, a fuel contribution of 50, and a smoke development of 50. Accessories such as adhesives, mastics, cements, tapes, and cloths for fittings must have similar component ratings.

1003.6.1.9.2 Insulation R-values and thicknesses must be in accordance with local AHJ energy code requirements.

1003.6.1.9.3 Insulation for chilled water and heating hot water supply and return piping, and cooling tower condenser return (to water chiller) piping must be two-piece, heavy density, sectional insulation jacketed with an embossed vapor barrier laminate.

1003.6.1.10 Freeze Protection

1003.6.1.10.1 The designer must analyze each piping installation at unheated spaces for the potential of water lines freezing during winter months. Where required, electric-resistance tape must be provided in addition to insulation. Provisions must be made to allow for the drainage of piping that will be subject to freezing temperatures.

1003.6.1.10.2 BMS interface: Interface for remote monitoring of electric-resistance tape must be in accordance to Set 1004 Building Monitoring and Control.

1003.6.1.11 Pumps

1003.6.1.11.1 As conditions dictate, pumps shall be either single- or double-suction.

1003.6.1.11.2 Pumps shall be arranged so that they can be serviced without any removal of the piping system. This must include any disconnection of piping from the pumps. Pumps shall have characteristics as indicated in Table 1003-2 Pump Characteristic below.

Table 1003-2: Pump Characteristics

Maximum Pump Speed rate:	1,800 RPM.
Operating Efficiency at design flow	Within 5 percent of maximum efficiency.
Pump Type:	Non-overloading.

1003.6.1.11.3 Provide duplex pumps for all services with 100% stand-by capacity.

1003.6.1.11.4 Provide variable flow control for pumps where variable flow is required in accordance with local AHJ energy code requirements.

1003.6.1.11.5 BMS interface: Interface for remote monitoring of pump operation must be in accordance to Set 1004 Building monitoring and control.

1003.6.2 Refrigerant Piping

1003.6.2.2 Refrigerant copper tube piping systems must meet the requirements of ASTM B280, Type ACR for copper tube.

1003.6.2.2.1 Refrigerant wrought-copper fittings and unions must meet requirements of ASME B16.22.

1003.6.2.2.2 Refrigerant copper fittings solder filler metal must meet requirements of ASTM B32, and blazing filler metals meet requirements of AWS A5.8/A5.8M.

1003.6.2.2.3 Piping must be designed to meet equipment or refrigerant type line test pressure.

1003.6.2.2.4 All piping systems must be designed and arranged for neat appearance.

1003.6.2.2.5 They must be properly supported, guided, and anchored to provide complete flexibility and to maintain the integrity of all systems without any damage or leaks under all operating conditions.

1003.6.2.2.6 Sleeves and escutcheons must be provided wherever pipes pass through walls. Provide fire-rated assemblies for pipe passing through fire-rated walls and floor/ceiling assemblies.

1003.6.2.2.7 As applicable and permitted by Sound Transit, utilize pre-insulated refrigerant pipe in compliance with ASTM B280, Type ACR with set insulation equal to item 1003.6.2.2.1.

1003.6.2.3 Refrigerant piping insulation

1003.6.2.3.1 Insulation for refrigeration suction piping must be a 1-inch-thick minimum, flexible closed-cell, elastomeric thermal insulation in tubular form for exposed and outdoor installation.

1003.6.2.3.2 Insulation R-values and thicknesses must be in accordance with local AHJ energy code requirements.

1003.6.2.3.3 Provide UV-resistant factory applied polymeric protective covering to the insulation.

1003.6.3 Ductwork and Accessories

1003.6.3.2 General

1003.6.3.2.1 All air-distribution duct systems must be designed in accordance with information contained in the latest edition of the ASHRAE Handbook of Fundamentals, SMACNA technical standards, and NFPA 90A.

1003.6.3.2.2 Supply duct sizes must be selected for an equal pressure drop or static regain method as appropriate.

1003.6.3.2.3 Air distribution ductwork for ancillary area ventilation systems must be arranged so that air is not exhausted into or obtained from station public occupancy areas.

1003.6.3.2.4 Ducts must be constructed of galvanized steel, to a pressure class greater than the anticipated working pressure, but not less than 2- inches. water gauge., Seal Class C, and in accordance with HVAC Duct Construction Standards by the Sheet Metal and Air-Conditioning Contractors National Association, inc. (SMACNA).

1003.6.3.3 Pressure Losses

1003.6.3.3.1 Pressure loss calculations must be performed in accordance with the ASHRAE Handbook of Fundamentals. The static pressure differential across any supply or return air terminal must not exceed 0.25-inch water gauge when the system is operating at full capacity.

1003.6.3.4 Supply Air Registers and Diffusers

1003.6.3.4.1 All supply air registers and diffusers must be selected to provide the required throw and spread within the noise criteria.

1003.6.3.4.2 All supply air registers must be provided with adjustable and double-deflection louvers and spin taps.

1003.6.3.4.3 All supply air volume dampers must be located as far from outlets as possible to maintain sound levels. Where required, opposed-blade adjustment volume dampers with key-operable through the face of the register.

1003.6.3.4.4 All supply air ceiling diffusers must be square, rectangular, circular, or linear type with adjustable throw and adjustable air extractors.

1003.6.3.5 Exhaust and Return Air Grilles

1003.6.3.5.1 Either exhaust or return air grilles shall be equipped with fixed, non-see-through blades or louvers, or the duct behind the grille shall be painted matte black.

1003.6.3.5.2 All exhaust grilles shall be equipped with opposed-blade, adjustable volume dampers key-operated through the face.

1003.6.3.6 Variable Air Volume Terminal Units

1003.6.3.6.1 When provided, VAV terminals must be pressure-independent and reset air volume as determined by the space thermostat regardless of any changes in system air pressure.

1003.6.3.6.2 VAV terminals must be system powered and require no more than 1-inch water gauge static pressure regardless of air quantity.

1003.6.3.6.3 VAV casing must be double shell construction meeting SMACNA standards with sandwiched "foamed in place" insulation.

1003.6.3.6.4 VAV terminals must have factory furnished system powered actuators, controls, and thermostats. Interface for remote monitoring of VAV terminal operation must be in accordance to Set 1004 Building Monitoring and Control.

1003.6.3.6.5 Outside air requirements must be maintained throughout the range of VAV operation. See Section 1003.6.11.5.2 when VAV terminal units are fitted with hydronic reheat coils.

1003.6.3.7 Volume Dampers

1003.6.3.7.1 Adjustable, opposed-blade volume dampers must be provided for all branch ducts serving multiple supply and exhaust outlets and for each individual supply and exhaust outlet where possible.

1003.6.3.7.2 All dampers must be equipped with locking quadrants with blades sufficiently stiffened at the edges to effectively close off the duct.

1003.6.3.7.3 Dampers must be free from vibration under all operating conditions.

1003.6.3.8 Splitter Dampers

1003.6.3.8.1 Splitter dampers may be used in multiple duct fittings for initial balancing in place of individual opposed-blade volume dampers in each branch of the multiple duct fitting. These splitters must be single-bladed and adjustable through locking quadrants and. The blades must have edges sufficiently stiffened to avoid vibration under all operating conditions.

1003.6.3.9 Fire Dampers and Fire/Smoke Dampers

1003.6.3.9.1 Fire dampers (FD) or fire/smoke dampers (FSD) must be provided in ducts which pass through fire-rated assemblies when required by the IBC and NFPA 130. Coordinate with Set 801 Architecture Materials for fire rated wall demarcation.

1003.6.3.9.2 FSDs (leakage rated dampers) shall be provided where required for smoke control or containment of clean agent systems. FSDs must have electric actuator for smoke control.

1003.6.3.9.3 FSDs associated with passive fire walls, barriers, and partition must be monitored by BMS. See set 1004 Building Monitoring and Control. FSDs must be controlled by fire alarm system or clean agent system. See Set 601 Fire–Life Safety for emergency ventilation and smoke control systems.

1003.6.3.9.4 All FDs must be UL listed. Dampers must be tested in accordance with UL 555 for fire dampers, and UL 555S for fire smoke dampers.

1003.6.3.9.5 FDs, including their sleeves, smoke dampers, and ceiling dampers, must be installed in accordance with the conditions of their listings and the manufacturer’s installation instructions.

1003.6.3.10 Backdraft and Relief Dampers

1003.6.3.10.1 Backdraft or motorized shutoff dampers must be used on exhaust and supply systems where more than a single fan discharges into or draws from a common duct.

1003.6.3.10.2 Weighted relief dampers must be used in ducts and openings where a positive pressure is required to be maintained.

1003.6.3.10.3 All backdraft and relief dampers must be the multi-bladed gravity type with neoprene cushioning on blade edges.

1003.6.3.11 Turning Vanes

1003.6.3.11.1 All elbows must have a full centerline radius at least 1.5 times the width of the duct. Where full-radius curves are not feasible, elbows must be provided with turning vanes. Turning vanes must be in according to SMACNA duct construction standards.

1003.6.3.12 Access Doors and Panels

1003.6.3.12.1 Access doors and/or panels must be included in ducts and plenums to provide access to fans, dampers, duct-smoke detectors, fire dampers, coils, filters, other devices, and where required by code.

1003.6.3.12.2 Door edges must rest against neoprene gaskets to form an airtight enclosure.

1003.6.3.12.3 Access doors in plenums must be hinged and furnished with latches operable from both inside and outside.

1003.6.3.12.4 Duct access doors must be hinged or fastened by toggle tabs or wing nuts.

1003.6.3.12.5 Access doors in insulated ducts and plenums must be insulated sheet metal construction.

1003.6.3.12.6 Access door size must be appropriate for the task and have a fire rating equivalent to the associated duct or plenum.

1003.6.3.12.7 Where ducts are stacked and access is needed to the upper ducts, special consideration must be given to the access method and must comply with section 1003.2.6Reliability, Availability, and Maintainability Needs.

1003.6.3.12.8 Access doors must be designed for their intended purpose and must be in accordance with NFPA 91 2-3.

1003.6.3.13 Flexible Duct Connectors

1003.6.3.13.1 Flexible duct connectors must be used on all fan and air-handling units to connect units to ductwork. The length of each joint must be selected to adequately accommodate both horizontal and vertical deflections of the fan units. The flexible material must not be less than 4 inches.

1003.6.3.13.2 The indoor ductwork insulation must be composite insulation with a metal jacket or an aluminum facing. The adhesive used to adhere a jacket or facing to the insulation must meet fire and smoke hazard ratings as tested by the ASTM E84 procedure, the NFPA 255 procedure, and the UL723 procedure.,

1003.6.3.13.3 The adhesive must not exceed a flame spread of 25, a fuel contribution of 50, and a smoke development of 50. Accessories such as adhesives, mastics, cements, tapes, and cloths for fittings must have similar component ratings.

1003.6.3.14 Insulation must be provided for the following:

1003.6.3.14.1 Heating and A/C outside air, supply and return ducts as required by building/energy codes.

1003.6.3.14.2 Ducts subject to condensation, including those inside conditioned space.

1003.6.3.15 Supports

1003.6.3.15.1 Support for pressure class 2-inches water gauge and less duct must conform to SMACNA standards as appropriate for the pressure class and seismic zone. Hangers and supports must be designed to carry weight of duct and must be in accordance with NFPA 91 2-5.

1003.6.3.16 HVAC Power Ventilators

1003.6.3.17 General requirements

1003.6.3.17.1 Fan sound power level ratings and performance ratings must comply with applicable ANSI/AMCA.

1003.6.3.17.2 Fan wheel must be statically and dynamically balanced.

1003.6.3.17.3 Minimum medium life rating for fan shaft must meet ABMA L50 standard of 200,000 hours.

1003.6.3.17.4 Vibration isolators fans must be mounted on vibration isolators.

1003.6.3.17.5 Fans must be UL listed and comply with NFPA.

1003.6.3.17.6 Fans must be direct drive type.

1003.6.3.17.7 Fans with motors less than 1 horsepower must be ECM with integral motor speed controllers in accordance with the current energy code.

1003.6.3.17.8 Fans with motor larger than 1 horsepower must meet current energy code minimum efficiency requirements. The motor service factor must not be less than 1.15.

1003.6.3.17.9 Fan motors must be NEMA rated motors.

1003.6.3.17.10 Fan motor disconnect switch must comply with Set 1005 Electrical Power.

1003.6.3.17.11 BMS interface: Interface for remote controlling and monitoring of fan operation must be in accordance to Set 1004 Building Monitoring and Control.

1003.6.3.18 Sound Transit Facility Fans

1003.6.3.18.1 Three types of fans are commonly selected and installed at Sound Transit facilities for environmental conditioning: in-line cabinet fans, power roof exhaust fans, and axial fans.

1003.6.3.18.2 In-line Cabinet Fans

1003.6.3.18.2.0 Non-overloading type centrifugal fans contained in same housing with motor, lined interior of housing with acoustical material secured in place. Provide integral inlet/outlet for duct connections.

1003.6.3.18.2.1 Fan housing must be provided with acoustically isolated mounting bracket.

1003.6.3.18.2.2 Fan and motor bearing must be permanently lubricated.

1003.6.3.18.2.3 Fan must be provided with field wiring NEMA rated disconnect receptacle to accommodate different mounting positions.

1003.6.3.18.3 Power Roof Exhaust Fans

1003.6.3.18.3.1 Roof exhaust fans with louver housing, aluminum construction, hinge top cover on top of housing to allow unrestricted access to fans.

1003.6.3.18.3.2 Louver blades must be storm proof type, blades stacked vertically from top of housing down to beyond top of roof curb. Housing must be provided with aluminum bird screen.

1003.6.3.18.3.3 Fan must be non-overloading type centrifugal fans and contained in the same housing with motor.

1003.6.3.18.3.4 Provide UL-listed disconnect switch inside fan housing.

1003.6.3.18.3.5 Each fan must be provided with a self-flashing sound attenuating prefabricated roof curb size as required to suit roof opening and fan base.

1003.6.3.18.3.6 Back draft dampers must be provided with each fan.

1003.6.3.18.3.7 Coordinate with Set 804 Fall Protection to provide safe access path to roof exhaust fans and provision for fall protection.

1003.6.3.18.4 Axial Fans

1003.6.3.18.4.1 Direct-driven with fixed blades, hot-rolled finished steel housing continuously welded and mechanical expanded for concentric forming.

1003.6.3.18.4.2 Aluminum construction fan rotor and airfoil blades. Blade tip clearance to fan housing shall not exceed 0.05 inch for rotor size 36 inches and smaller and 0.1 inch for larger size.

1003.6.3.18.4.3 Critical speed must be 125 percent of maximum design speed. Maximum operating speed must not exceed 90 percent of maximum design speed and not be whole number derivative of the critical speed or natural resonance frequency for the blade.

1003.6.3.18.4.4 Aluminum inlet bell with steel discharge cones.

1003.6.3.18.4.5 Bearing: self-aligning ball bearing with AMBA 9 (L10 life at 50.000 hours), or roller bearing AMBA 11 (L10 life at 120,000 hours).

1003.6.3.18.4.6 Fan shafts: Hot-rolled steel, ground and polished, with keyway, protectively coated. For installation in corrosive environment 316 Stainless steel shafts

1003.6.3.18.5 In-line Cabinet Fans

1003.6.3.18.5.1 Non-overloading type centrifugal fans contained in same housing with motor, lined interior of housing with acoustical material secured in place. Provide integral inlet/outlet for duct connections.

1003.6.3.18.5.2 Fan and motor bearing must be permanently lubricated.

1003.6.3.18.5.3 Fan must be provided with field wiring NEMA rated disconnect receptacle to accommodate different mounting positions.

1003.6.3.18.6 Power Roof Exhaust Fans

1003.6.3.18.6.1 Roof exhaust fans with louver housing, aluminum construction, hinge top cover on top of housing to allow unrestricted access to fans.

1003.6.3.18.6.2 Louver blades must be storm proof type, blades stacked vertically from top of housing down to beyond top of roof curb. Housing must be provided with aluminum bird screen.

1003.6.3.19 Air Filtration

1003.6.3.19.1 Supply air fans and air-conditioning units must be provided with replaceable media filter sections arranged in banks as appropriate.

1003.6.3.19.2 Air filter material must be rated UL Class I. Filters must be 30 percent MERV 7, and not less than MERV 4 for ductless mini-split system.

1003.6.3.19.3 The spaces required greater levels of filtration, use 30 percent MERV 7 pre-filters and 65 percent MERV 11 final filters.

1003.6.3.20 Supply air fans and units serving occupiable spaces each with capacity more than 500 CFM must be provided with a filter box capable of housing a filter with minimum of MERV 13 or as required by the AHJ. Units with 100% recirculated air do not require this type of filter box.

1003.6.3.20.1 Fans must be sized for design airflow at loaded filter condition.

1003.6.3.20.2 High filter pressure differential alarms are to be reported through the BMS. Coordinate with Set 1004 Building Monitoring and Control.

1003.6.3.21 Air Pollution Control for Special Use Areas

1003.6.3.21.1 Enclosed and Underground Facilities

1003.6.3.21.1.1 Below-ground or enclosed parking garages and motor vehicles operating areas must be provided with applicable mechanical and AHJ codes-compliant systems to both detect and prevent accumulation of carbon monoxide and nitrogen dioxide.

1003.6.3.21.1.2 The ventilation system shall be energy efficient and capable of modulating based on input from the carbon monoxide and nitrogen dioxide sensors.

1003.6.3.21.1.3 BMS interface: Interface for gas detection and ventilation system operation shall be in accordance to Set 1004 Building Monitoring and Control.

1003.6.3.21.2 Ventilation Shafts and Air Terminals at Grade

1003.6.3.21.2.1 The maximum air velocity through a grating or louver must be computed using the gross free face area of the grating or louver, exclusive of any supports, and must be in accordance with current local codes and national standards.

1003.6.3.21.2.2 No intake or exhaust shall terminate in a street or roadway.

1003.6.3.21.2.3 Air intakes must be located on the roof or at a minimum of 10 feet or more above grade or away from public areas,

1003.6.3.21.2.4 The peak intake air velocity shall not exceed 1,200 feet per minute. For outside air intakes less than 10 feet above grade, the peak intake air velocity must not exceed 1,000 feet per minute.

1003.6.3.21.2.5 Air discharges must be located 10 feet or more above sidewalk level or away from public areas.

1003.6.3.21.2.6 The peak discharge velocity shall be limited by the noise criteria but shall not provide a pressure loss greater than 0.50-inch water gauge.

1003.6.3.21.2.7 Shaft location shall be reviewed by safety and security personnel to prevent possibilities of public endangerment and/or acts of terrorism.

1003.6.3.21.3 Shaft Design

1003.6.3.21.3.1 Shafts shall be designed so that sudden transitions in the shaft cross section are avoided, and the minimum number of bends and elbows are used.

1003.6.3.21.3.2 Turning vanes may be used to reduce pressure losses, and the streamlining of obstructions in fan shaft passages shall be undertaken where required.

1003.6.3.21.3.3 Air passages shall be constructed of smooth concrete or sheet metal ductwork.

1003.6.3.21.3.4 Exhaust airshafts may be combined into a common shaft. Outside air intake shafts may be combined into a common shaft.

1003.6.3.21.3.5 Under no circumstances shall exhaust and intake shafts be combined into a common shaft.

1003.6.3.21.3.6 Ventilation air intake and discharge facilities shall be designed so that an adequate distance is provided between intake and exhaust to prevent recirculation and as required by applicable AHJ codes.

1003.6.3.21.3.7 Ventilation shaft terminals at grade level shall be separated by a minimum required horizontal distance of 40 feet from the closest air intake.

1003.6.3.21.3.8 For emergency ventilation requirements, see Set 601 Fire/Life Safety.

1003.6.4 Spray Paint Booth

1003.6.4.2 Ventilation and heating system must be provided and sized as recommended by the spray paint equipment manufacturer/supplier.

1003.6.4.3 The ventilation system for the paint spray booth must comply with applicable mechanical and fire codes and AHJ requirements for flammable paint application.

1003.6.4.4 Specific local code requirements for spray paint finishing operations must be identified and as required by applicable AHJ codes and ordinance.

1003.6.4.5 The ventilation system for the paint booth must maintain negative pressure to the exterior of the building.

1003.6.4.6 The filtration for supply and exhaust air must be provided as recommended by the spray paint equipment manufacturer/supplier and in compliance with applicable codes and standards.

1003.6.4.7 BMS interface: Interface for remote monitoring of spray paint system operation must be in accordance to Set 1004 Building Monitoring and Control.

1003.6.5 UPS/Battery Storage/Maintenance Areas

1003.6.5.2 Rooms housing valve-regulated and non-valve-regulated lead-acid battery systems used for facility standby power, emergency power, or uninterrupted power supplies must be ventilated in accordance with the International Fire Code Chapter 12, International Mechanical Code, and as adopted and amended by the local AHJ.

1003.6.5.3 Ventilation system serving rooms housing batteries shall be controlled by BMS using hydrogen sensors to maintain hydrogen concentration level below applicable codes and ordinances limit.

1003.6.5.4 BMS Interface: Interface for remote control and monitor of ventilation system operation must be in accordance to Set 1004 Building Monitoring and Control.

1003.6.6 HVAC Conditioning Systems Equipment

1003.6.6.2 Heating and air conditioning system will maintain occupied and unoccupied spaces in stations and facilities at preset temperatures throughout the year when outdoor temperatures are below or above space temperature set points.

1003.6.6.3 Provided fault detection and diagnostics (FDD) system to monitor HVAC system's function,and performance and automatically identify faults as required by the current State of Washington and AHJ Energy Code. BMS interface: Interface for remote monitoring of HVAC system FDD must be in accordance to Set 1004 Building Monitoring and Control.

1003.6.6.4 The specifications must disallow the use of refrigerants that have been banned or already identified for scheduled phase out by EPA. Refrigerant that is used by HVAC equipment must comply with the current Federal, State of Washington laws and AHJ.

1003.6.6.5 HVAC equipment must be rated for the available fault current at their respective locations in the power distribution system. Coordinate with Set 1005 Electrical Power.

1003.6.6.6 HVAC equipment motor disconnect switch must comply with Set 1005 Electrical Power.

1003.6.6.7 Electrical disconnect for each piece of HVAC equipment must not be located where it would interfere with inspection and maintenance of the equipment.

1003.6.6.8 To comply with Sound Transit carbon neutral policy, heating and air conditioning systems must be all electric equipment.

1003.6.6.9 Heating and air conditioning elements must be of the types identified in this set.

1003.6.7 Packaged Compressor and Condensing Units

1003.6.7.2 Compressor and condensing units must be factory assembled and tested and consisted of compressor, condenser coil, fan, refrigerant reservoir, and controls,

1003.6.7.3 Unit performance in accordance with AHRI and must comply with State of Washington Energy code and AHJ.

1003.6.7.4 The compressor must be scroll hermetic compressor, single-speed, or variable capacity with inverter control motor. The compressor must be mounted on vibration isolators

1003.6.7.5 The compressor motor must comply with NEMA designation with thermal and current overload protection.

1003.6.7.5.1 The compressor must include manual-reset, high/low-pressure switches, and automatic reset.

1003.6.7.5.2 BMS Interface: Unit must be provided with local automatic controllers to monitor and maintain supply air temperature and monitored remotely via BMS systems as indicated in Set 1004 Building Monitoring and Control.

1003.6.7.5.3 The condenser coils must be seamless copper-tube, aluminum fin coils, with circuit for integral liquid sub-cooler and brass service valves with service ports.

1003.6.7.5.4 The condenser fan must be direct-drive fan with permanently lubricated, NEMA rated, totally enclosed fan motor with thermal-overload protection.

1003.6.7.5.5 The unit must be housed in baked enamel finished galvanized steel housing with removable panels for service and maintenance access.

1003.6.8 Central Chiller and Heat Pump

1003.6.8.2 Packaged refrigeration type chiller/heat pump equipment must supply hot and/or chilled water to air handlers, DOAS, and terminal units.

1003.6.8.3 The chiller shall be air-cooled and water-cooled. The equipment varies based on the compressor type with selection based on capacity. The compressor types below are listed from smallest to greatest capacity:

1003.6.8.3.1 Positive displacement: scroll, reciprocating, screw

1003.6.8.3.2 Dynamic: centrifugal

1003.6.8.4 Heat pump compressor types are the same as chiller above. Air is the most common source of energy for heat pumps. During equipment selection, consider the specific operation ranges for the heat pump, especially limits on minimum and maximum outdoor air temperatures. Heating capacity is reduced as outdoor air temperature decreases.

1003.6.8.5 Propose other energy sources to Sound Transit, such as ground or water from lake or reservoir, if available and cost effective.

1003.6.8.6 Heat pump component has a two-pipe configuration and four-pipe configuration.

1003.6.8.6.1 Two-pipe: provides either heating or cooling but not both simultaneously. The unit contains one connection for supply pipe and one for return.

1003.6.8.6.2 Four-pipe: provides heating and cooling and can do so simultaneously. The unit contains two connections for heating supply and return pipes, and two for cooling supply and return pipes.

1003.6.8.6.3 Electric boilers or hot water storage tanks with supplementary heat source must be provided as required by State of Washington and AHJ energy code.

1003.6.8.7 BMS interface: Equipment must be provided with local automatic controllers to monitor and maintain supply water temperature and monitored remotely via BMS systems as indicated in Set 1004 Building Monitoring and Control.

1003.6.8.8 Applicable codes: AHRI, ASHRAE, IMC, IBC, IEC, Revised Code of Washington (RCW), WAC, Washington State Energy Code, NFPA, NEC, UL, and AHJ.

1003.6.9 Hydronic Heating and Cooling Equipment

1003.6.9.2 Air handling equipment must have hydronic cooling and heating coils.

1003.6.9.2.1 Unit casing must have double-wall galvanized steel insulated panels with access panels or doors to allow access to internal parts and components. The access panel frame must be gasketed around the perimeter.

1003.6.9.2.2 Surface in contact with airstream must comply with requirements in ASHRAE 62.1.

1003.6.9.3 Fan and drive assemblies must be statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower.

1003.6.9.3.1 Fan must be direct drive centrifugal type with internal vibration isolation.

1003.6.9.3.2 Fans with motors less than 1 horsepower must be ECM with integral motor speed controllers in accordance with the current energy code.

1003.6.9.3.3 Fans with motors larger than 1 horsepower require NEMA rated motors and must meet current energy code minimum efficiency requirements. The motor service factor must not be less than 1.15.

1003.6.9.3.4 Copper tube, with mechanical bonded aluminum fins hydronic cooling and heating coils must comply with AHRI 410.

1003.6.9.3.4.1 Drain pans for cooling coils must be stainless steel and in compliance with ASHRAE Standard 62.1.

1003.6.9.3.4.2 Coils must be accessible for service and maintenance. Each coil section must be removable for replacement.

1003.6.9.3.5 Air filter section, see item 1003.6.3.18 Air Filtration for type of filter, and must be accessible for filter replacement.

1003.6.9.3.6 Air mixing box with outside air and return air in let must be multiblade, able to mix air to prevent stratification, and able to let 100 percent outside air into box during economizer mode.

1003.6.9.3.7 BMS interface: Equipment must be provided with local automatic controllers to monitor and maintain supply air temperature, and remotely via BMS systems as indicated in Set 1004 Building Monitoring and Control.

1003.6.9.4 Propeller unit heaters

1003.6.9.4.1 The propeller unit heater assembly must include casing, coils, fan, and motor in vertical/horizontal discharge configuration with adjustable discharge louvers. The propeller unit heater must be UL listed.

1003.6.9.4.2 Electrical components are listed and labeled as defined in NFPA 70 and marked for intended location and application.

1003.6.9.4.3 Copper tube, with mechanical bonded aluminum fins hydronic heating coils must comply with, be tested, and rated according to ASHRAE 33.

1003.6.9.4.4 The propeller unit heater must have a propeller type fan with aluminum wheel mounted directly to the motor.

1003.6.9.4.5 Fans with motors less than 1 horsepower must be ECM with integral motor speed controllers in accordance with the current energy code.

1003.6.9.4.6 Fan with motor larger than 1 horsepower must be NEMA rated motors and meet current energy code minimum efficiency requirements. The motor service factor must not be less than 1.15.

1003.6.9.4.7 Provide unit mounted fan-speed switch and wall mounted thermostat.

1003.6.9.4.8 BMS interface: Equipment must be provided with local automatic controllers. BMS must monitor equipment status remotely as indicated in Set 1004 Building Monitoring and Control.

1003.6.10 Radiant Heating and Cooling Hydronic Piping

1003.6.10.2 Hydronic Radiant Floor Heating system

1003.6.10.3 Radiant heating system must utilize crosslinked polyethylene/aluminum/crosslinked polyethylene (PEX-AL-PEX) type pipe and fittings casted directly into the facility heated floor

1003.6.10.4 Pipe: The PEX must meet the ASTM F876 standard with oxygen barrier on pipe surface in accordance with DIN 4726. The pipe minimum pressure/temperature rating must be 100 pound-force per square inch and 180 degrees Fahrenheit with 30 years warranty.

1003.6.10.5 System Distribution Manifolds

1003.6.10.5.1 Brass or stainless-steel manifold minimum 1NPS, with shutoff valves at supply and return connections, manual air vents, balancing valves, and thermometers.

1003.6.10.5.2 BMS interface: The zone control valve with electric actuator for each zone must be controlled by zone wall mounted thermostat and monitored by BMS system. See Set 1004 Building Monitoring and Control.

1003.6.10.5.3 Piping specialties: Cable ties, floor mounted staples, floor mounting clamps, floor mounting tracks, and modular interlocking blocks must be provided to hold PEX pipe in place prior to pouring the casted floor or substrates.

1003.6.10.5.4 See item 1003.6.1, “Hydronic Piping and Pumps,” for additional piping requirements.

1003.6.10.6 Chilled Beam

1003.6.10.6.1 The active chilled beam must consist of a sheet metal primary air plenum box to house the secondary chilled-water coil and heating- water coil assembly and must be mounted on bracket support.

1003.6.10.6.2 The chilled beam must have accessories including flexible water connection hose with shutoff valves, flow balancing, and control valve.

1003.6.10.6.3 See item 1003.6.1, “Hydronic Piping and Pumps,” for additional piping requirements.

1003.6.10.6.4 BMS interface: The chilled beam must be provided with local automatic controllers to monitor and maintain supply air temperature, and remotely via BMS systems as indicated in Set 1004 Building Monitoring and Control.

1003.6.11 Energy Recovery Units (ERU)

1003.6.11.2 Provide energy recovery system to treat outside ventilation air as required by current energy code.

1003.6.11.3 Applicable codes: AHRI, ASHRAE, IMC, IBC, IEC, Revised Code of Washington (RCW), WAC, Washington State Energy Code, NFPA, NEC, UL and AHJ.

1003.6.11.4 BMS interface: The equipment must be provided with local automatic controllers to monitor and maintain supply air temperature, and remotely via BMS systems as indicated in SET 1004 Building Monitoring and Control.

1003.6.11.5 ERU, normally located indoors, supply the required, pre-conditioned, outdoor ventilation air for the facilities.

1003.6.11.6 The pre-conditioned outdoor air from ERU units is delivered directly to the air terminal units serving the occupied spaces.

1003.6.11.7 ERU are comprised of energy recovery section to precondition outside air with return air utilizing air-to-air heat exchanger and supply/exhaust fans.

1003.6.11.8 Typical air-to-air heat exchangers are fixed plate, energy recovery wheel, or enthalpy wheel.

1003.6.11.9 Supply/Exhaust fans must be direct drive with variable speed control as applicable.

1003.6.11.10 Provide filters at the heat exchanger as required in Section 1003.6.3.18 Air Filtration, and by AHJ codes and manufacturer requirements.

1003.6.12 Dedicated Outside Air Units (DOAS)

1003.6.12.2 Provide DOAS to treat outside ventilation air as required by current energy code.

1003.6.12.3 Applicable codes: AHRI, ASHRAE, IMC, IBC, IEC, Revised Code of Washington (RCW), WAC, Washington State Energy Code, NFPA, NEC, UL and AHJ.

1003.6.12.4 BMS interface: The equipment must be provided with local automatic controllers to monitor and maintain supply air temperature, and remotely via BMS systems as indicated in Set 1004 Building Monitoring and Control.

1003.6.12.5 The DOAS supply and condition the required outdoor ventilation air for the facilities.

1003.6.12.6 The conditioned outdoor air from DOAS units is delivered either directly to the occupied spaces, or indirectly to subsequent conditioning by air terminal units serving the occupied spaces.

1003.6.12.7 DOAS are comprised of energy recovery section to precondition outside air with return air utilizing air-to-air heat exchanger, supply/exhaust fans, heating/cooling coils and air filter sections

1003.6.12.8 Typical air-to-air heat exchangers are fix plate, energy recovery wheel, or enthalpy wheel.

1003.6.12.9 Supply/exhaust fans must be direct drive with variable speed control as applicable.

1003.6.12.10 Heating and cooling coils that supply conditioned air to occupied spaces can be hydronic hot and chilled water coils or refrigerant DX coils.

1003.6.12.11 Provide filters at the heat exchanger as required in Section 1003.6.3.18 Air Filtration and by AHJ codes and manufacturer requirements.

1003.6.12.12 Mechanical ventilation system must utilize fans to provide air circulation, bring in fresh outside air, exhaust contaminated air, and provide heat from occupied and unoccupied spaces in stations and facilities.

1003.6.13 Distributed Heat Pumps and Variable Refrigerant Flow

1003.6.13.2 Heat Pumps and air conditioning equipment have two major elements. These include evaporator-fan units and compressor-condenser units.

1003.6.13.3 Air is the most common source of energy for heat pumps. During equipment selection for the air source heat pump, consider the specific operation ranges for the heat pump, especially limits on minimum and maximum outdoor air temperatures. Provide supplementary heat as required by State of Washington and AHJ energy code.

1003.6.13.3.1 Propose other energy sources to Sound Transit, such as ground or water from lake or reservoir, if available and cost effective.

1003.6.13.3.2 Two types of heat pumps commonly selected and installed at Sound Transit facilities are as follows.

1003.6.13.3.2.1 Unitary Heat Pump: The evaporator and compressor-condenser are in the same housing. The unit can be installed indoor and outdoor.

1003.6.13.3.2.2 Split-System Heat Pump: The evaporator is located indoors, and the compressor-condenser is located outdoors. There are two types of evaporator-fan units as follows,

1003.6.13.3.2.2.1 Ducted – ceiling mounted or floor mounted.

1003.6.13.3.2.2.2 Ductless – wall mounted.

1003.6.13.3.2.2.3 Provide filters at the upstream of indoor coils as required in Section 1003.6.3.18 Air Filtration, and by AHJ codes and manufacturer requirements.

1003.6.13.3.3 The heat pump compressor must be a scroll hermetic compressor, single-speed or variable capacity, with inverter control motor. The compressor must be mounted on vibration isolators

1003.6.13.3.4 BMS interface: Heat pumps must be provided with local automatic controllers to monitor and maintain space temperature, and remotely via BMS systems as indicated in Set 1004 Building Monitoring and Control.

1003.6.13.3.5 Heat pumps must comply with applicable AHRI, ASHRAE, IMC, IBC, IEC, Revised Code of Washington (RCW), WAC, Washington State Energy Code, NFPA, NEC, UL and AHJ.

1003.6.14 Electric Cabinet Unit Heaters and Duct Heaters

1003.6.14.2 Electric heaters must utilize electricity to heat spaces.

1003.6.14.3 Three types of heaters are commonly selected and installed at Sound Transit facilities:

1003.6.14.4 Electric wall heater: electric fan wall heater cabinet can be surface or recessed wall mounted.

1003.6.14.4.1 Electric unit heater: electric heaters with propeller fan ceiling or wall mounted.

1003.6.14.4.2 Electric duct heater: electric heating elements mounted in enclosures for mounted in supply air duct work.

1003.6.14.5 Electric heaters must be provided with local automatic controllers to monitor and maintain space or supply air temperature.

1003.6.14.6 BMS interface: Electric heaters monitor remotely via BMS systems as indicated in Set 1004 Building Monitoring and Control.

1003.6.14.7 Electric heaters must comply with applicable NFPA, IMC, IBC, IEC, Revised Code of Washington (RCW), WAC, Washington State Energy Code, NEC, UL and AHJ.

1003.7 ENGINEERING MANAGEMENT REQUIREMENTS

1003.7.1 Interface and Integration Management

1003.7.1.1 The design must consider and account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries and provide constructable documentation and functional designs.

1003.7.2 Design Management (Not Used)

1003.7.3 Manufacturing and Construction Management (Not Used)

1003.7.4 Installation Management

Commentary: Technicians who install and service equipment that could release refrigerant into the atmosphere must be certified under EPA regulations 40CFR Part 82, Subpart F under Section 608 of the Clean Air Act.

1003.7.4.1 Identify matching sleeves and block-out locations in design documents for stations or buildings constructed under separate contracts.

1003.7.4.2 Equipment Foundation

1003.7.4.2.1 Equipment foundation: All floor-mounted equipment must be placed on reinforced concrete housekeeping pads at least 4 inches high. Pads must be tied to the floor by floor-reinforcing bar grid, dowels, or anchor bolts.

1003.7.5 Inspection and Testing Management

1003.7.5.1 The design must adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

1003.7.6 Training, Pre-Revenue Operations

1003.7.6.1 Provide and document training for Sound Transit and partner agency maintainers on the energy control program, including lockout/tagout. Coordinate with Set 1005.

1003.7.7 Certification Management (Not Used)

1003.8 APPENDICES (NOT USED)

END SET - 1003

1004 BUILDING MONITORING AND CONTROL

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SET - 1004 TABLE OF CONTENTS

TABLES

FIGURES

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SET - 1004 BUILDING MONITORING AND CONTROLS

1004.1 INTRODUCTION

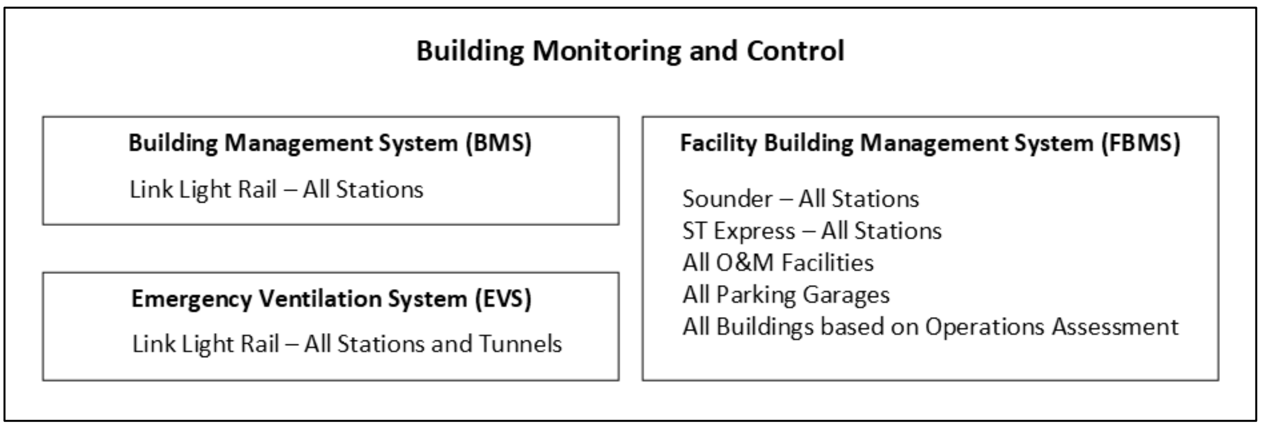
1004.1.1 Document Scope

1004.1.1.1 This set covers the requirements for building monitoring and control systems design for Sound Transit assets. Link light rail stations require designs for two distinct systems: a building management system (BMS) at all stations and an emergency ventilation system (EVS) only at grade separated and tunnel stations. All other buildings require the design of a facility building management system (FBMS).

Commentary: Sound Transit often refers to the control and monitoring platform for Link light rail stations as "BMS," and refers to the control and monitoring platform for all other buildings as "FBMS".

1004.1.1.2 This set applies to all modes of transportation, though each mode will have specific requirements that are unique to that mode or facility type.

Figure 1004-1: Building Monitoring and Control Systems and Locations



Commentary: The BMS and FBMS is composed of a network of devices throughout a building designed to monitor and optimize building equipment performance. See Figure 1004-2 for BMS equipment example interfaces including HVAC and lighting systems.

1004.1.1.3 All BMS and FBMS deployments must provide scheduling features, historical trends, and alarm indications via networked and web browser-based graphical interfaces.

Commentary: BMS deployments in all Link light rail stations are based on programmable logic controller hardware, specifically RX3i hardware. FBMS deployments in other buildings are based on Johnson Controls Facility Explorer / Metasys hardware.

1004.1.1.4 The EVS is composed of a network of devices throughout a Link station designed to provide fire and life safety functions and monitoring at LCC.

1004.1.1.5 In all Link stations equipped with fire alarms, the EVS must interface with fire alarm systems and associated passenger information systems.

1004.1.1.6 Due to the variety of building functions, it is important that design teams coordinate with operations and maintenance teams. Project teams must liaise with multiple departments within Sound Transit regularly between design milestones to ensure unique facility needs are met.

1004.1.1.7 System Context Diagram

Commentary: System context diagrams (Figures 1004-2 and 1004-3) are to be used for new installations. Existing systems have equipment that will differ from what is shown.

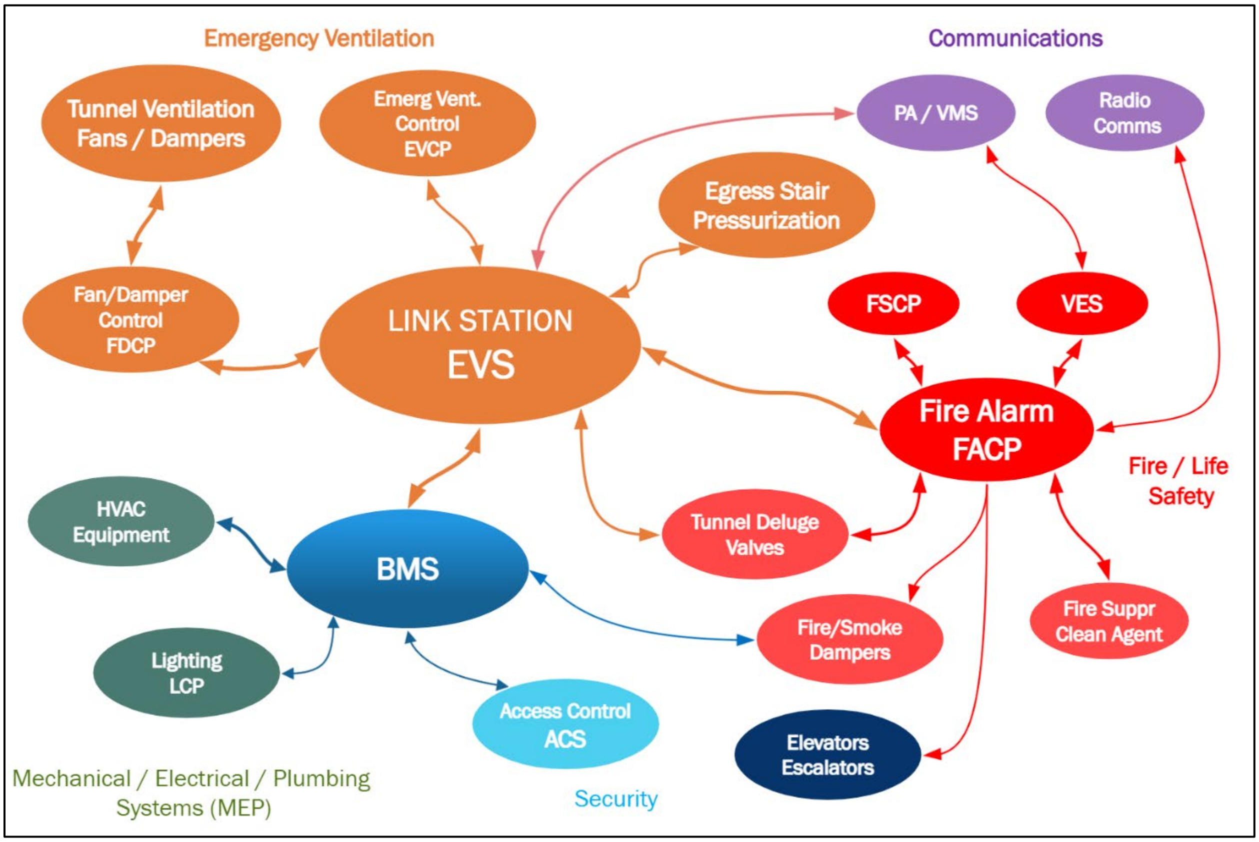
1004.1.1.7.1 Sound Transit has enterprise wide BMS architecture standardized on two different hardware platforms. These include PLC hardware for Link station building control, and industry recognized DDC controllers for all other facilities.

1004.1.1.7.2 Sound Transit operates an enterprise wide EVS architecture standardized on PLC-based hardware. EVS systems interface with the systems and equipment providing fire/life-safety functions. Typical equipment integrated with EVS is shown in Figure 1004-3, however note that the mechanical emergency ventilation systems required by NFPA 130 specifically apply to tunnels and enclosed stations.

1004.1.1.7.3 BMS and EVS operator interfaces are composed of both local and integrated SCADA access to provide situational awareness of Sound Transit assets, as shown in Figure 1004-12. BMS and EVS operator interfaces are composed of both local and integrated SCADA access to provide situational awareness of Sound Transit assets, as shown in Figure 1004-12.

Figure 1004-2: BMS System Context Diagram

Figure 1004-3: EVS System Context Diagram



1004.1.1.8 Where the designer encounters cases of special designs not specifically covered by these criteria, the designer must bring them to the attention of the Requirements Set 1004 owner to determine the technical source for the design criteria.

1004.1.2 Regulations, Codes, Standards, and Guidelines

1004.1.2.1 International Regulations, Codes, Standards, and Guidelines (Not Used)

1004.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

1004.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

1004.1.2.3.1 51-11 WAC, Washington State Energy Code.

1004.1.2.3.2 296-46B WAC, Electrical Safety Standards, Administration, and Installation.

1004.1.2.3.3 International Building Code (IBC) with State and local amendments.

1004.1.2.3.4 International Fire Code (IFC) with State and local amendments.

1004.1.2.3.5 Local Municipal Codes that amend and/or complement the IBC, IBF and other fire/life safety Codes and standards.

1004.1.2.3.5.1 Throughout this set local amendments are referenced periodically when anticipated but not throughout. All local amendments apply, including those adopted during design unless the design has been formally vested in writing with the AHJ.

1004.1.2.3.6 National Electrical Code (NEC) with State and Local amendments (aka NFPA 70).

1004.1.2.3.7 National Fire Protection Association (NFPA) National Fire Alarm and Signaling Code (NFPA 72).

1004.1.2.3.8 National Fire Protection Association (NFPA) Standard for Fixed Guideway Transit and Passenger Rail Systems (NFPA 130).

1004.1.2.3.9 National Fire Protection Association (NFPA) Standard on Clean Agent Fire Extinguishing Systems (NFPA 2001).

1004.1.2.3.10 ANSI ASME 17.1, Safety Code for Elevators, Dumbwaiters and Escalators.

1004.1.2.4 Industry Regulations, Codes, Standards, and Guidelines.

1004.1.2.4.1 ASHRAE Guideline 13-2015 Specifying Building Automation Systems.

1004.1.2.4.2 ANSI/TIA-568 Commercial Building Telecommunications Cabling Standard.

1004.1.2.4.3 UL Standard 508A Edition 3 – Industrial Control Panels.

1004.1.2.4.4 IEEE Standard 802.3X – IEEE Standard for Ethernet.

1004.1.2.4.5 EIA/TIA-485 – Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems.

1004.1.2.4.6 ANSI/TIA-606 Cable Labeling Standards.

1004.1.2.4.7 ANSI/ASHRAE Standard 135-2016 BACnet™ - A Data Communication Protocol for Building Automation and Control Networks.

1004.1.2.4.8 MODBUS Application Protocol Specification V1.1b3.

1004.1.2.4.9 MODBUS Messaging on TCP/IP Implementation Guide V1.0b.

1004.1.2.4.10 MODBUS Messaging on TCP/IP Implementation Guide V1.0b.

1004.1.2.4.11 NIST Special Publication 800-82: Guide to Industrial Control Systems (ICS) Security.

1004.1.2.5 Other Jurisdictions (Not Used)

1004.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

1004.1.2.6.1 Architectural Standard Drawings Set.

1004.1.2.6.2 Control System BMS Guidelines.

1004.1.2.6.3 Control System EVS Guidelines.

1004.1.2.6.4 Control System FBMS Guidelines.

1004.1.2.6.5 Interface Coordination and Integration Plan.

1004.1.2.6.6 General Testing and Commissioning Plan.

1004.1.2.6.7 Sound Transit Equipment and Facilities Numbering Standards.

1004.1.2.6.8 Systems Standard Drawings Set.

1004.1.3 Abbreviations and Acronyms

1004.1.3.1 ACS–access control system

1004.1.3.2 ACU–air conditioning Unit

1004.1.3.3 AHU–air handling unit

1004.1.3.4 AI/AO–analog input/output

1004.1.3.5 ATS–automatic transfer switch

1004.1.3.6 BDC–backup data center

1004.1.3.7 BMS–building management system

1004.1.3.8 BTL–BACnet Testing Laboratories

1004.1.3.9 CB–communications backbone

1004.1.3.10 CMP–communications multipurpose plenum

1004.1.3.11 CCTV–closed circuit television

1004.1.3.12 CCS–central control system

1004.1.3.13 CES–customer emergency station

1004.1.3.14 DDC–direct digital control

1004.1.3.15 DI/DO–digital input/output

1004.1.3.16 DSTT–Downtown Seattle Transit Tunnel

1004.1.3.17 EFN–emergency fan network

1004.1.3.18 EMP–emergency management panel

1004.1.3.19 ERM–emergency response matrix

1004.1.3.20 ETEL–emergency telephone system

1004.1.3.21 EVCP–emergency ventilation control panel

1004.1.3.22 EVS–emergency ventilation system

1004.1.3.23 EPMS–energy/power management system

1004.1.3.24 FBMS–facility building management system

1004.1.3.25 FACP–fire alarm control panel

1004.1.3.26 FAT–factory acceptance test

1004.1.3.27 FCC–fire command center

1004.1.3.28 FCP–fan control panel

1004.1.3.29 FCR–fire control room

1004.1.3.30 FCS–field control system

1004.1.3.31 FCU–fan coil unit

1004.1.3.32 FDCP–fan/damper control panel

1004.1.3.33 GEN–generator

1004.1.3.34 HVAC–heating ventilation and air conditioning

1004.1.3.35 HMI–human machine interface

1004.1.3.36 IO–input / output

1004.1.3.37 IT–Information Technology

1004.1.3.38 ITC–interface terminal cabinet

1004.1.3.39 JACE–java application control engine

1004.1.3.40 LCC–link control center

1004.1.3.41 LCP–lighting control panel

1004.1.3.42 MCC–motor control center

1004.1.3.43 OBC–on-board controller

1004.1.3.44 OFNP–optical fiber nonconductive plenum

1004.1.3.45 O&M–operations and maintenance

1004.1.3.46 OMF–operations and maintenance facility

1004.1.3.47 PA–public address

1004.1.3.48 PBX–office phone system

1004.1.3.49 PET–passenger emergency telephone

1004.1.3.50 PLC–programmable logic controller

1004.1.3.51 RIO–remote input/output

1004.1.3.52 SAT–site acceptance test

1004.1.3.53 SCADA–supervisory control and data acquisition

1004.1.3.54 SOC–security operations center

1004.1.3.55 SIDT–systems interface data table

1004.1.3.56 SWGR–switchgear

1004.1.3.57 TCP/IP–transmission control protocol/internet protocol

1004.1.3.58 TCS–train control system

1004.1.3.59 TCN–train control network

1004.1.3.60 UPS–uninterrupted power source

1004.1.3.61 VFD–variable frequency drive

1004.1.3.62 VMS–variable message sign

1004.1.3.63 VLAN–virtual local area network

1004.1.4 Definitions and Classifications

1004.1.4.1 BACnet: Building automation and control network communication protocol.

1004.1.4.2 Box: An enclosure provided with a cover secured by fasteners other than hinges.

1004.1.4.3 Building management system: The PLC based hardware and associated software which together integrate with various building systems for monitoring and control. Deployed at Link stations.

1004.1.4.4 Cabinet: An enclosure that is designed for either surface mounting or flush mounting and is provided with a frame, mat, or trim in which a swinging door or doors are or can be hung (NEC 2020).

1004.1.4.5 Cutout Box: An enclosure designed for surface mounting that has swinging doors or covers secured directly to and telescoping with the walls of the enclosure (NEC 2020).

1004.1.4.6 Enclosure: The case of housing or apparatus, or the fence or walls surrounding an installation to prevent personnel from accidentally contacting energized parts or to protect the equipment from physical damage (NEC 2020).

1004.1.4.7 Emergency response matrix: A cause-and-effect type matrix which details automated actions performed by various fire and life safety related systems in the event an emergency ventilation mode is activated.

1004.1.4.8 Facility building management system: Representative of more traditional building automation platforms, this system integrates with various building systems for monitoring and control. Deployed at all locations except Link stations.

1004.1.4.9 Emergency Ventilation System: This requirement set is meant to apply to the systems providing monitoring and control of specific fire and life safety functions and mechanical emergency ventilation systems covered under NFPA 130 Chapter 7. Deployed at Link stations.

1004.1.4.10 Fail-safe: Inherently responds in a way that will cause minimal or no harm to other equipment, to the environment, or to people.

1004.1.4.11 Field control system: A collective term including the PLC based building management system and emergency ventilation systems installed.

1004.1.4.12 Industrial control panel: See current NEC definition.

1004.1.4.13 Interface terminal cabinet: A wall-mounted, single door enclosure used for marshalling signals between controller I/O and field equipment.

1004.1.4.14 Local control: The point of control of a system which from a control perspective is the closest to the system from where full control of the system can be achieved.

1004.1.4.15 Modbus RTU: Open serial communication protocol, see RS-485.

1004.1.4.16 Modbus TCP/IP: Modbus communication over TCP/IP networks

1004.1.4.17 Packaged equipment (Unit): A single piece of equipment provided by a manufacturer in a substantially complete and operable condition, where the controls hardware is factory installed and equipment is sold and shipped as a single entity.

1004.1.4.17.1 RS-485: A widely used standard used in bi-directional serial communication systems.

1004.1.5 References (Not Used)

1004.2 STAKEHOLDER NEEDS

1004.2.1 Passenger Experience

1004.2.1.1 PSO Engineering's mission is to protect and uphold the integrity of the technical requirements to ensure passenger satisfaction and safe, quality, reliable and durable operations through establishing, integrating, and managing the needs of the agency through engineering, core systems and facility requirements.

1004.2.2 Operational Needs

1004.2.2.1 Common Operational Needs (BMS/EVS/FBMS)

1004.2.2.1.1 An operational needs assessment must be conducted with Sound Transit engineering and facilities maintenance representatives in early design stages to document a Concept of Operations in the Basis of Design.

Commentary: This assessment is meant to account for any atypical applications specific to the project scope. If an operational assessment has been performed prior to front-end engineering, the document should be revised to include more detailed analysis and reissued.

1004.2.2.1.2 Deliver a fully functioning system to operations.

1004.2.2.1.3 System designs must implement both local and remote means to control and monitor equipment. Designs must accommodate the remote operation philosophy of stations and parking garages.

Commentary: Sound Transit does not staff operations or maintenance technicians at stations or parking garages. Instead, several facilities (e.g., OMF) are continuously staffed to serve as central locations which support all operations and maintenance of Sound Transit assets.

1004.2.2.1.4 System graphics must be provided to remotely monitor and control interfacing equipment.

1004.2.2.1.5 Clear and intuitive commands must be provided for use by authorized operators.

1004.2.2.1.6 Support operations with the creation of procedures, or amendment of existing procedures, related to these systems.

1004.2.2.2 BMS Operational Needs

1004.2.2.2.1 An existing BMS CCS SCADA system must be expanded to visualize subsystems and interfaces in real-time. See Set 324 SCADA for more information.

1004.2.2.2.2 An existing BMS HMI interface must be expanded to visualize subsystems and interfaces in real-time.

Commentary: Designers should study the existing system graphics and interface. Currently, the BMS SCADA is based on a Wabtec proprietary AIM product. BMS HMI is meant to define the web-browser based interface to GE Digital's Cimplicity graphics. See Figure 1004-12 in appendix.

1004.2.2.2.3 Two dedicated BMS desktop workstations must be provided on-site for stations with an FCC room—one BMS SCADA which mirrors LCC and one HMI for local control of buildings. Reference Set 601 Fire-Life-Safety for additional requirements.

Commentary: These workstations should be co-located with other SCADA workstations, often in proximity to the fire alarm control panel.

1004.2.2.3 EVS Operational Needs

1004.2.2.3.1 An existing EVS SCADA system must be expanded to visualize subsystems and interfaces in real-time. See Set 324 SCADA for more information.

1004.2.2.3.2 At enclosed stations and tunnel adjacent facilities, provide the following:

1004.2.2.3.2.1 Panels for manual control of emergency ventilation equipment. At minimum, this includes an EVCP, but may also require FCP and FDCP as described in Sections 1004.4 and 1004.6.

1004.2.2.3.2.2 Local EVS SCADA workstation required at stations with an FCC room.

1004.2.3 Maintenance Needs

1004.2.3.1 Products provided must be new, currently manufactured, and have been applied in similar installations.

1004.2.3.2 Design Considerations

1004.2.3.2.1 Designs must be as functionally, mechanically, electrically, and electronically independent as practical to facilitate routine maintenance.

1004.2.3.2.2 Systems must be capable of undergoing maintenance without the interruption of revenue service.

Commentary: Maintenance at stations and garages is typically reserved for periods that do not impact passengers. Limit maintenance windows to non-revenue periods unless the scope can be performed without service impacts.

1004.2.3.3 Access Considerations

1004.2.3.3.1 Personnel access space provisions for equipment operation and maintenance must be evident on the drawings.

1004.2.3.3.2 Provide 1 meter (approximately 3.28 feet) or greater unobstructed space to maintain equipment mounted on walls, racks, cabinets, or enclosures. If equipment is housed in a telecommunications space, follow working clearances required for other cabinets as stated in Set 301 Network Infrastructure.

1004.2.3.3.3 Doors must be provided on all industrial control panels, communication cabinets, and interface termination cabinets. Doors must have adequate space to open at least 90 degrees.

1004.2.3.3.4 All enclosure doors must be lockable. Designers should specify panel/enclosure locks to minimize the number of unique keys required for access.

1004.2.3.4 Batteries provided with BMS/EVS systems for instruments or backup control power must be itemized on a replacement schedule for maintenance teams per Asset Management.

1004.2.3.5 Maintenance Documentation

1004.2.3.5.1 All control system and equipment, O&M, and as-built documentation must be provided in a readily searchable format.

1004.2.3.5.2 O&M documentation must include accurate, site-specific information, identifying features such as equipment tags and model numbers.

1004.2.3.6 Maintenance Features

1004.2.3.6.1 Make analysis and reporting tools available to system users. Design teams must specify requirements enabling convenient methods of exporting data for analysis.

1004.2.3.7 Software Maintenance

1004.2.3.7.1 Software maintenance and support must be specified for a minimum of one year following project completion.

1004.2.3.7.2 Anticipated software and licenses must be rigorously examined by design teams and documented in design specifications. The design team must carry out a software needs assessment with Sound Transit to assess existing software licensing limitations. Software requiring recurring service charges must be communicated to operations teams prior to acceptance.

1004.2.3.7.3 The software and licensing information must be documented, itemized, and turned over to Operations Technology.

1004.2.4 Safety Needs

1004.2.4.1 Passenger, operator, and maintainer safety for normal operations and emergency operations must be accounted for in designs.

1004.2.4.2 Electrical Safety

1004.2.4.2.1 Reference Set 1005 Electrical Power.

1004.2.4.2.2 Enclosure's housing control equipment must follow NEC Article 409 for Industrial Control Panels.

1004.2.4.2.3 Equipment that can be automatically started by BMS / FBMS or EVS must have permanent labels affixed to caution technicians to verify unit disconnects are properly switched to a safe position before servicing, per lockout/tagout procedures.

1004.2.4.2.4 Openings around electrical penetrations through fire-rated walls, floors, or ceilings must be fire stopped using approved methods defined in specifications and drawings, to maintain fire resistance ratings. Refer to Set 1006 Electrical Raceway for additional requirements.

1004.2.4.3 Mechanical emergency ventilation systems, including dampers and fans, must have functional manual controls from hardwired local panel switches or motor starters.

1004.2.4.4 All safety-related control circuits must be designed for fail-safe operation.

1004.2.4.5 System programming must implement logic interlocks to prioritize passenger and personnel safety. Interlocks must be clearly identified in a sequence of operation and control schematics.

1004.2.4.6 An ERM must be developed and provided for EVS deployments whenever NFPA 130 defined mechanical ventilation systems are provided.

Commentary: Sound Transit will provide an ERM template on request.

1004.2.5 Security Needs

1004.2.5.1 Physical Security

1004.2.5.1.1 Station and garage elements accessible to passengers must incorporate methods to prevent or deter theft and vandalism, including material selection and placement.

1004.2.5.1.2 Control panels and cabinets housing BMS / FBMS or EVS equipment are prohibited in public areas.

1004.2.5.2 Cybersecurity

1004.2.5.2.1 Employ control system designs with secure deployment strategies.

1004.2.5.2.2 Designed systems must be highly resistant to interception, intrusion, and unauthorized use and modification according to best practices identified in NIST Guide to Industrial Control System Security in specifications.

1004.2.5.2.3 Networked BMS, FBMS and EVS equipment must never be exposed to the Internet.

1004.2.5.2.4 The BMS/FBMS reside within the TCN, while the EVS resides within the EFN. The TCN and EFN are isolated from each other both physically and logically.

1004.2.5.2.5 Default IT configurations must be identified and implemented at the earliest opportunity.

Sound Transit typically provides pre-configured ethernet switches for all projects, which requires several months of lead time for procurement.

Coordinate with Operations System Admins when procuring new workstations and servers to ensure proper configuration of settings like active directory and domain control.

1004.2.5.2.6 Refer to Set 1201 Cybersecurity for further requirements.

1004.2.6 Reliability, Availability and Maintainability Needs

1004.2.6.1 Ensure that systems are designed, installed, and calibrated to operate efficiently and ensure reliability and ease of maintenance.

Equipment selection should consider the operating environment and small maintenance windows associated with public transportation. Designs should strive to keep downtime less than one working shift annually.

1004.2.6.2 Designs must support the development of routine maintenance procedures, such as firmware updates, to maintain equipment.

1004.2.6.3 Redundant PLC CPUs must be installed and configured as hot standby systems in all tunnel Link stations.

1004.2.6.4 EVS designers must consider EVS supervisory control and provide sufficient details for documentation in ventilation system reliability analysis when required by NFPA 130.

1004.2.6.5 All equipment must meet seismic needs according to applicable building codes as approved by AHJ.

1004.2.7 Environmental and Sustainability Needs

1004.2.7.1 Facility designs must promote stewardship of resources and utilities when selecting material, equipment, and applications with the goal of conservation and efficiency.

1004.2.7.2 Environmental and sustainability goals, such as LEED™ certification, with items fulfilled by BMS / FBMS must be identified per EP-03 milestones.

1004.3 SYSTEM REQUIREMENTS

1004.3.1 General Requirements

1004.3.1.1 Record documents including drawings and specifications must clearly indicate delineation of design and construction responsibilities.

1004.3.1.2 All components must be specified to optimally expand on existing Sound Transit investments.

1004.3.1.3 Material selection must incorporate standard, readily available, and industrialized products.

1004.3.1.4 BMS / FBMS must provide centralized management of building subsystems defined in further sections.

1004.3.1.5 EVS must provide centralized management of fire and life safety related systems defined in further sections.

1004.3.2 Functional Requirements

1004.3.2.1 Sound Transit does not operate facilities with on-site staff; therefore, the design must aim to reduce labor costs through remote operation, monitoring, and troubleshooting.

1004.3.2.2 Common Functional Requirements

1004.3.2.2.1 BMS / FBMS and EVS must be conservatively designed and incorporate system diagnostics to notify operators and technicians of fault conditions.

1004.3.2.2.2 Design teams must establish a priority between local and remote control, as well as provide indication of this status.

1004.3.2.2.3 Scheduling features must accommodate day types (weekday/weekend), daylight saving time, seasonal, and non-business days.

1004.3.2.3 EVS Specific Functional Requirements

1004.3.2.3.1 During an emergency, where tunnel ventilation is required, all interlocks for each tunnel ventilation motor/fan combination must be bypassed as these units must continue operate until fan destruction (failure) or the emergency is resolved.

1004.3.3 Performance Requirements

1004.3.3.1 Regular confidence testing must be performed to ensure all systems are operational, as verified in integrated testing. Implement software configuration management post installation.

1004.3.3.2 Determine project performance requirements in the design phase, plan the commissioning process, verify, and document compliance as needed.

1004.3.3.3 Assess energy saving and resource efficiencies strategies such as control of energy efficient fixtures, task lighting, occupancy sensors, and radiant, heating.

1004.3.3.4 System Modes and States Requirements

1004.3.3.4.1 BMS / FBMS and EVS must be designed to run as stand-alone systems.

1004.3.3.5 Information and Data Management Requirements

1004.3.3.5.1 Design teams must maintain immediate electronic access to master design documents throughout the life of the project.

1004.3.3.5.2 Program Revisions

1004.3.3.6 Adaptability and Expandability Requirements

1004.3.3.6.1 Design teams must consider atypical building applications for the project and design for future expansion.

1004.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

1004.4.1 System Breakdown Structure

1004.4.1.1 For retrofits or modification of existing BMS / FBMS or EVS services, the design team must survey potentially affected equipment and determine changes required to interface new control work. All software and hardware required to interface to existing systems must be provided.

1004.4.1.1.1 Reference Systems Standard Drawings, which include general BMS and EVS architectures.

1004.4.1.2 Common System Architecture (BMS / FBMS / EVS)

1004.4.1.2.1 Point Types

1004.4.1.2.1.1 Typical hardware point types, software point types, and trend parameters must be specified for each equipment level component. Similar components may be summarized by system.

Commentary: Hardware point types include wired I/O like analog inputs, analog outputs, digital inputs, and digital outputs. Software point types include object types, variables, deadband parameters, alarm, and event points.

1004.4.1.2.1.2 Hardware and software tags must be based off the equipment tags and labels per Sound Transit Equipment Naming and Numbering Standard.

1004.4.1.2.2 Each system must be allocated to the correct VLAN for network communication.

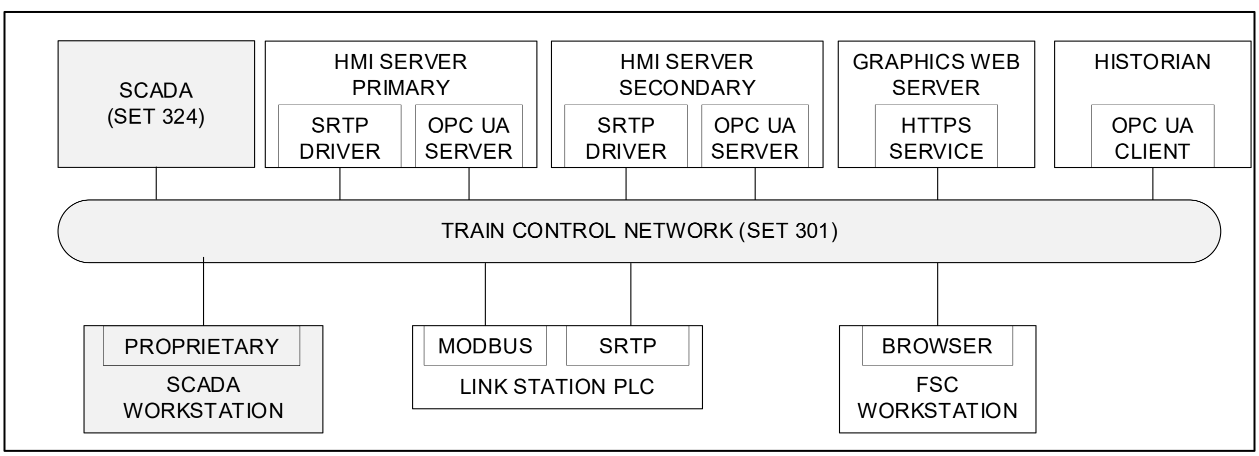
1004.4.1.2.3 All PLC based systems must utilize fault tolerant PROFINET I/O ring topology.

1004.4.1.3 BMS Architecture

1004.4.1.3.1 Apply the generic BMS architecture shown in Figure 1004-5 to EVS designs.

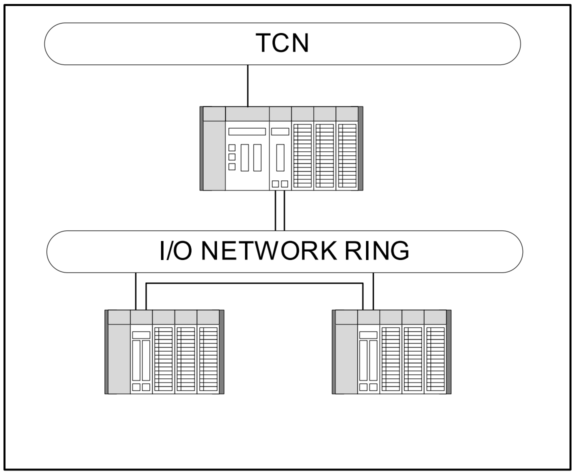
Commentary: High-level design includes SCADA servers and workstations. See Set 324 SCADA TCS Train Control, FCS servers (redundant HMI, web, historian), TCN elements, PLCs, and FCS workstations.

Figure 1004-4: High-Level BMS Architecture for Link Stations



1004.4.1.3.2 Elevated or at-grade stations must implement a simplex BMS architecture, noted by a single high-performance, standalone controller. See Figure 1004-5.

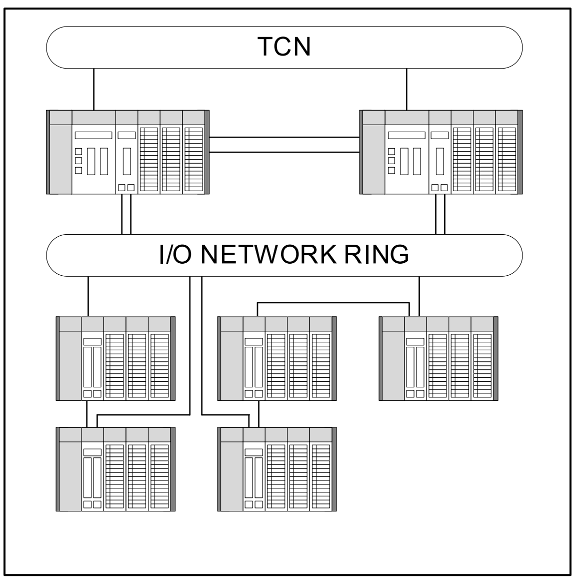
Figure 1004-5: Generic BMS Architecture for Elevated/At-Grade Stations



1004.4.1.3.3 Tunnels or enclosed stations must implement an advanced high availability system architecture, noted by a hot-standby controllers for “bumpless” failover. See Figure 1004-6.

Commentary: Reference PACSystems Guide Form Specification for examples of a simplex and advanced high availability architecture.

Figure 1004-6: Generic BMS Architecture for Tunnel Stations

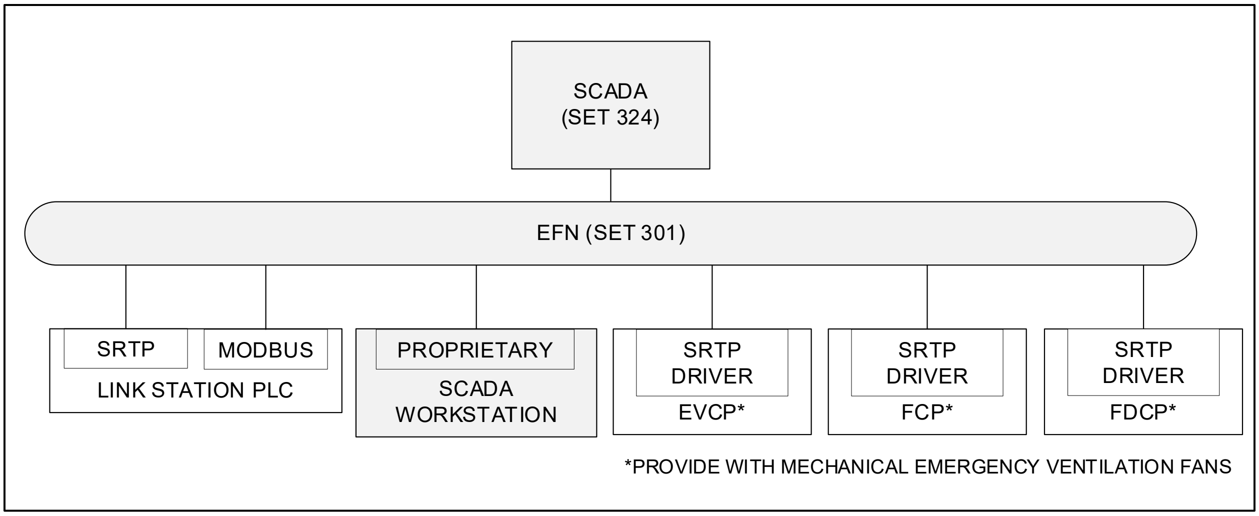


1004.4.1.4 EVS Architecture

1004.4.1.4.1 Apply the generic EVS architecture shown in Figure 1004-7 to EVS designs.

Commentary: High-level design features SCADA servers and workstations (see Set 324 SCADA), EFN elements, PLCs, and various control panels (EVCP, FCP, FDCP).

Figure 1004-7: High-Level EVS Architecture for Link Stations



1004.4.1.4.2 Generic EVS control architectures are similar to BMS shown in Figures 1004-5 and 1004-6, except all controllers connect to the EFN only (instead of TCN).

1004.4.1.4.3 Motor starters and any operating control devices must be located away from ventilation system airstreams.

1004.4.1.4.4 Where mechanical emergency ventilation systems are installed, an EVCP must be provided as the primary HMI for operations and emergency responders.

1004.4.1.4.5 FCPs must be provided to offer local control of emergency mechanical ventilation fan, typically jet fans installed along the tunnel segments.

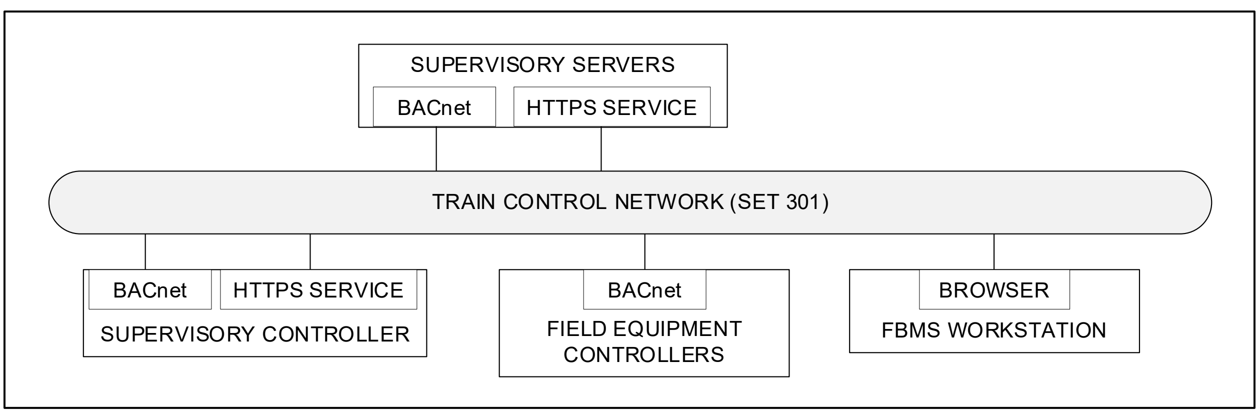
1004.4.1.4.6 FDCPs must be provided to offer local control of emergency mechanical ventilation fans and associated dampers, typically where reversible ventilation fans are installed in Link stations.

1004.4.1.5 FBMS Architecture

1004.4.1.5.1 Apply the generic FBMS architecture shown in Figure 1004-9 to FBMS designs.

Commentary: High-level design features supervisory servers, supervisory controllers, field equipment controllers, I/O modules, and workstations.

Figure 1004-8: High Level FBMS Architecture

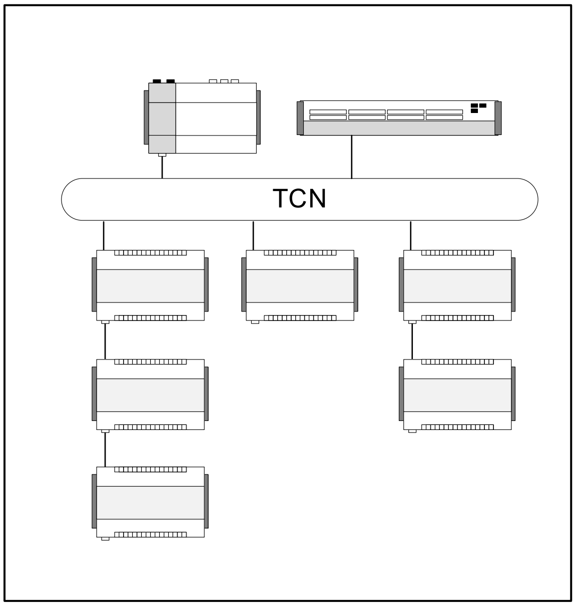


1004.4.1.5.2 All locations with FBMS installed must implement a peer-to-peer network of DDC controllers and modules. See Figure 1004-9.

1004.4.1.5.3 Locations with multiple supervisory controllers installed must integrate into a single server for a web-based graphical interface.

Commentary: Multiple supervisory controllers may be necessary for a functioning system. Consider the number of peer-to-peer devices and limitations of supervisory controllers.

Figure 1004-9: Generic FBMS Architecture



1004.4.2 System Sites and Locations

1004.4.2.1 All cabinets and enclosures installed indoors must be type 12 rated. Exception: For enclosures installed in communications or server rooms, type 1 ratings are acceptable.

1004.4.2.2 Enclosures housing BMS/EVS CPUs or I/O cards are not permitted outdoors.

1004.5 SYSTEM INTERFACE REQUIREMENTS

1004.5.1 System Interface General Information

1004.5.1.1 System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 1004-1: Interface Between Building Monitoring and Control and Other Disciplines

SET SERIES	SET NAMES	SET 1004 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	
300	Operational Communications	X
400	Vehicle	
500	Track	
600	Fire-Life Safety	X
700	Structures	
800	Architecture	X
900	Civil	
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

1004.5.1.2 BMS / FBMS and EVS designs are highly interdisciplinary topics that require coordination and collaboration. The BMS / FBMS and EVS design team must be involved in the development of each equipment level system sequence of operation for inclusion in record documents. Coordination with responsible disciplines must be demonstrated at all design milestones to define the system sequence of operation.

1004.5.1.3 Design teams must identify the interfaces with other systems including new or existing access control, mechanical HVAC, plumbing, power, and lighting systems. The design team must evaluate, identify, and document these interfaces based on facility needs.

1004.5.1.4 The BMS / FBMS designs must identify and communicate the limitations of design responsibility for interdisciplinary interfaces. HVAC, electrical, lighting, plumbing, and fire/life safety designers must continuously coordinate.

Commentary: In an HVAC example, the calculations and sizing may be the responsibility of mechanical designer, panel and wiring the responsibility of the electrical designer, and equipment control the responsibility of the BMS / FBMS designer. It is the responsibility of the prime contractor to meet all the requirements of the design.

1004.5.1.5 The design of major mechanical and electrical equipment must incorporate provisions for communication, control, and indication.

1004.5.1.6 Account for miscellaneous field device mounting and interconnecting wiring for all interface systems such as mechanical, electrical, and plumbing systems.

1004.5.2 Interface Groups

1004.5.2.1 Field control systems are interface intensive with multiple disciplines. The following establishes anticipated interfaces, coordination expectations, and requirements for those interfaces.

1004.5.2.2 Designers should consult with SME's regarding which data should be captured, in addition to points explicitly mentioned in this section.

Commentary: For example, UPS and Generator controllers often have many modbus registers for various diagnostic data. Recommend consulting with SMEs to determine which data would be useful.

1004.5.2.3 Radio

1004.5.2.3.1 Refer to Set 303 Radio.

1004.5.2.4 Fire/Life Safety

1004.5.2.4.1 Fire Alarm Systems

1004.5.2.4.1.1 Fire alarm control panels must be monitored by BMS / FBMS via hardwired connections.

Commentary: Typically, these include monitoring fire alarm panels for general conditions such as alarm, supervisory, and trouble status. Additional inputs include status of duct smoke detection and clean agent systems.

1004.5.2.4.1.2 Fire alarm system I/O must be identified on a sequence of operation.

1004.5.2.4.1.3 In Link stations, EVS must include supervised input from fire alarm panels for general alarm, supervisory and trouble conditions.

1004.5.2.4.1.4 When applicable in Link stations, fire alarm systems must include input for each ventilation mode from EVS.

1004.5.2.4.2 Fire/Smoke Dampers

1004.5.2.4.2.1 Fire/Smoke Dampers must be controlled directly by the fire alarm control panel, except as follows:

1004.5.2.4.2.1.1 The EVS must be used to control station emergency ventilation and stair/elevator smoke control, including associated dampers such as fire/smoke dampers. Refer to Set 601 for further details.

1004.5.2.4.2.1.2 Fire/smoke damper position must be monitored by BMS via hardwired connection to an auxiliary switch.

1004.5.2.4.3 Clean Agent Systems

1004.5.2.4.4 Clean agent systems must be monitored by BMS/FBMS via hardwired connection, typically accomplished by connection through the fire alarm control panel.

1004.5.2.4.5 Fire Suppression Systems

1004.5.2.4.5.1 EVS monitoring of fire protection must be as follows:

1004.5.2.4.5.1.1 Standpipe deluge valves must be monitored for open/closed position via supervised signals from the fire alarm panel. If these valves can be inhibited, this condition must also be monitored and alarmed.

1004.5.2.5 Gas Monitoring Systems

1004.5.2.5.1 Hydrogen Gas Detection

1004.5.2.5.1.1 Dedicated battery rooms must be equipped with a hydrogen gas detector. Additional rooms may require hydrogen detection if housing equipment is subject to hydrogen evolution, such as a UPS room.

1004.5.2.5.1.2 Detectors must interface with BMS or FBMS systems via relays to indicate both 1% and 2% concentration by volume. Audible and visual notification must be integrated with BMS/FBMS. See Set 601 Fire/Life Safety for additional requirements.

1004.5.2.5.1.3 Coordinate with mechanical designer to provide a sequence of operation for ventilation.

1004.5.2.5.2 Carbon Monoxide and Nitrogen Dioxide Detection

1004.5.2.5.2.1 Dual gas detectors to measure both carbon monoxide and nitrogen dioxide concentrations must be installed throughout enclosed parking garages. These devices must be UL2075 listed.

1004.5.2.5.2.2 All detectors must integrate with a central gas monitor. The central gas monitor must interface with the FBMS to indicate system faults and gas concentrations.

1004.5.2.5.2.3 Coordinate with mechanical designer to develop a sequence of operation for ventilation.

1004.5.2.5.2.4 Coordinate with electrical designer for necessary cable and conduit.

1004.5.2.6 Elevators

1004.5.2.6.1 Design teams must coordinate with Washington State Labor and Industries regarding installation locations of equipment.
Commentary: There exist deployments of BMS / FBMS at Sound Transit locations with connections to elevators and escalators. New installations do not require an interface with BMS / FBMS and will instead use an independent monitoring service.

1004.5.2.6.2 Elevator Pits – See 1004.5.2.8.2 Sump Pumps and Pits

1004.5.2.7 Escalators

1004.5.2.7.1 Design teams must coordinate with Washington State Labor and Industries regarding install locations of any equipment.
Commentary: There are deployments of BMS / FBMS at Sound Transit locations with connections to elevators and escalators. New installations do not require an interface with BMS / FBMS, and will instead use an independent monitoring service.

1004.5.2.7.2 Escalator Pits – See 1004.5.2.8.2 Sump Pumps and Pits

1004.5.2.8 Plumbing

1004.5.2.8.1 All heat trace controllers must interface with BMS / FBMS for monitoring faults. See Set 1002 regarding further heat trace design requirements.

1004.5.2.8.2 Sump Pumps and Pits

1004.5.2.8.2.1 Sump pumps must interface with BMS / FBMS for monitoring. Refer to Systems Standard Drawings for sump pump interface points.

1004.5.2.8.2.2 For units serving elevator shafts or escalator pits, all enclosures, conduit and wiring methods must be coordinated with Washington State Labor and Industries.

1004.5.2.8.3 Booster Pumps

1004.5.2.8.3.1 Booster pumps must interface with BMS / FBMS for monitoring. Provide same interface points as sump pumps at a minimum.

1004.5.2.8.4 Automated Valves

1004.5.2.8.4.1 Automated valves must interface with BMS / FBMS for control and monitoring.

1004.5.2.8.4.2 Actuation of automatic control valves and campers must be electric.

1004.5.2.9 Mechanical HVAC

1004.5.2.9.1 Exhaust and Supply Fans

1004.5.2.9.1.1 Exhaust/supply fans must interface with BMS / FBMS for monitoring and control. Refer to Systems Standard Drawings for interface points.

1004.5.2.9.2 Dampers

1004.5.2.9.2.1 Actuated dampers must interface with BMS / FBMS for monitoring and control. Refer to Systems Standard Drawings for interface points.

1004.5.2.9.3 Air Conditioning Units

1004.5.2.9.3.1 ACUs must interface with BMS / FBMS for monitoring and control. Refer to Systems Standard Drawings for interface points. Coordinate with mechanical designer to provide on-board controllers and all other control accessories to integrate with BMS / FBMS.

Commentary: Packaged control options will provide more diagnostics than necessary to integrate with BMS/FBMS graphics, however these should be available for troubleshooting purposes.

1004.5.2.9.4 Economizers

1004.5.2.9.4.1 If such spaces are provided with an air or water economizer, the economizer controls shall be configured with an override signal from the BMS / FBMS to disable economizer operation during heat recovery mode.

1004.5.2.9.4.2 Economizers must interface with BMS / FBMS for monitoring and control. Refer to Systems Standard Drawings for interface points. Coordinate with mechanical designer to provide on-board controllers and all other control accessories to integrate with BMS / FBMS.

Commentary: Packaged control options will provide more diagnostics than necessary to integrate with BMS/FBMS graphics, however these should be available for troubleshooting purposes.

1004.5.2.9.5 Heaters

1004.5.2.9.5.1 Heaters interfaces to BMS / FBMS for control must be identified. Refer to Systems Standard Drawings for interface points and coordinate with the mechanical designer as needed.

1004.5.2.9.6 Variable Air Volume (VAV) Controllers

1004.5.2.9.6.1 VAVs must interface with BMS / FBMS for monitoring and control. Refer to Systems Standard Drawings for interface points. Coordinate with mechanical designer to provide on-board controllers and all other control accessories to integrate with BMS / FBMS.

Commentary: Packaged control options will provide more diagnostics than necessary to integrate with BMS / FBMS graphics, however these should be available for troubleshooting purposes.

1004.5.2.9.7 Chillers

1004.5.2.9.7.1 When applicable, coordinate mechanical designs to ensure boiler basis of design and specifications call for control accessories to be provided for remote monitoring and control from BMS / FBMS.

1004.5.2.9.8 Boilers

1004.5.2.9.8.1 When applicable, coordinate mechanical designs to ensure boiler basis of design and specifications call for control accessories to be provided for remote monitoring and control from BMS / FBMS.

1004.5.2.9.9 Hydronic Heating and Cooling System

1004.5.2.9.9.1 When applicable, coordinate mechanical designs to ensure hydronic system basis of design and specifications call for control accessories to be provided for remote monitoring and control from BMS / FBMS.

1004.5.2.9.9.2 Room temperature measurement may be accomplished through several means:

i. Flush mount RTD devices with associated transmitters.
ii. Networked sensors certified with BTL.
iii. Thermostats installed with packaged HVAC units serving the same room.

1004.5.2.9.9.3 Room thermostat setpoints must be adjustable via BMS / FBMS HMI graphics.

1004.5.2.10 Lighting Control

1004.5.2.10.1 Refer to Set 1007 Electrical Lighting for more detailed requirements for lighting control.

1004.5.2.10.2 Lighting Control Panels must integrate with BMS / FBMS systems to provide the following:

1004.5.2.10.2.1 Override function to turn all lights on.

1004.5.2.10.2.2 Provide master 'revenue service' timeclock function.

1004.5.2.10.2.3 Provide system fault indications to BMS / FBMS.

1004.5.2.11 Electrical Power

1004.5.2.11.1 Uninterruptible Power Supplies

1004.5.2.11.1.1 UPS units must interface with BMS / FBMS for monitoring. Refer to Systems Standard Drawings for interface points. Coordinate with electrical designer to provide on-board controllers and all other control accessories to integrate with BMS / FBMS.

1004.5.2.11.2 Permanent Generators

1004.5.2.11.2.1 GEN units must interface with BMS / FBMS for monitoring. Coordinate with electrical designer to provide on-board controllers and all other control accessories to integrate with BMS / FBMS.

1004.5.2.11.3 AC Switchgear

Switchgear must interface with BMS / FBMS for monitoring. Refer to Systems Standard Drawings interface points. Coordinate with electrical designer to provide on-board controllers, and all other control accessories, to integrate with BMS / FBMS.

1004.5.2.11.4 Automatic Transfer Switches and Manual Transfer Switches

1004.5.2.11.4.1 ATS units must interface with BMS / FBMS for monitoring. Coordinate with electrical designer to provide on-board controllers and all other control accessories to integrate with BMS / FBMS.

1004.5.2.11.5 Utility Submeters

1004.5.2.11.5.1 Interface to WinPM.Net and Eaton Foreseer EPMS platforms. Design teams must work with Sound Transit engineering to identify integration requirements for any additional BMS or FBMS interface.

1004.5.2.11.6 Photovoltaic Systems

1004.5.2.11.6.1 PV systems and management systems must be specified for cellular and cloud-based monitoring options.

Commentary: PV equipment and monitoring system functions should operate outside of any ST networks such as TCN.

1004.5.2.11.7 EV Chargers

1004.5.2.11.7.1 EV charging stations and management systems must be specified for cellular and cloud-based monitoring options.

Commentary: EV equipment and monitoring system functions should operate outside of any Sound Transit networks, such as TCN.

1004.5.2.12 Access Control System

1004.5.2.12.1 Access Door Controllers must interface with BMS for monitoring and control. Refer to Systems Standard Drawing for interface points.

1004.5.2.12.2 Access controlled doors in egress paths must be unlocked by BMS in the event of emergencies such as a fire alarm.

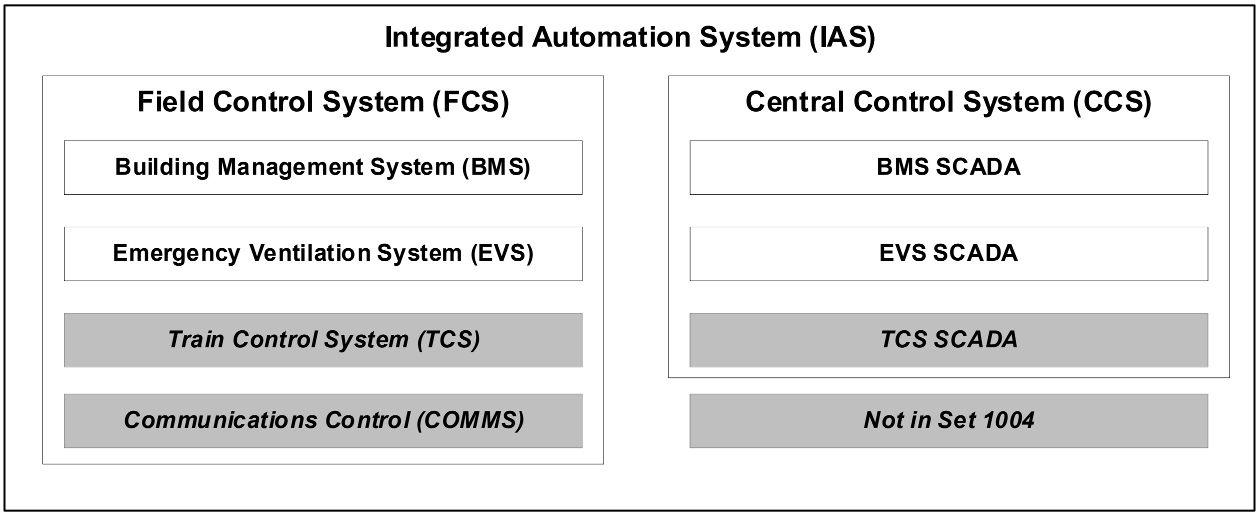
1004.5.2.12.3 Roll-up-grills, vertical lift gates, and other coiling doors must interface with BMS / FBMS for monitoring and control. Refer to Systems Standard Drawing for interface points.

1004.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

1004.6.1 System and Subsystem Elements General Information

Commentary: The following sections are intended to outline general building / facility management system requirements. The buildings and structures section to follow outline additional requirements specific to buildings, structures, and sites.

Figure 1004-10: Integrated Automation System Components



1004.6.1.1 Network access to BMS / FBMS and EVS controllers must be configured for remote troubleshooting and real-time communication with controllers.

1004.6.1.2 Ethernet network for I/O which is dedicated and physically separate from all other Ethernet networking.

1004.6.2 Central Control System (CCS) Elements

1004.6.2.1 The enterprise control environment includes system servers, networking, and workstations enabling the BMS / FBMS and EVS functionality. Servers in this environment run applications for supervisory control and monitoring, logging historical data, alarm/event indication, and clock synchronization.

1004.6.2.2 Web-based graphics are deployed at this level to enable access from dedicated workstations or remote access by authorized personnel trained to do so.

1004.6.2.3 Network access to controllers, HMIs, and intelligent devices must be configured for real-time communication and remote troubleshooting.

1004.6.2.4 Design teams must ensure the best practices for control system security are followed.

1004.6.3 Field Control System Elements

1004.6.3.1 Common FCS elements (BMS / EVS / FBMS)

1004.6.3.1.1 HMI and workstation elements

Commentary: Building / Facility control elements include most of the physical BMS / EVS equipment, such as panels and accompanying hardware, network cabling and I/O wiring.

1004.6.3.1.1.1 A minimum of four distinct roles must be configured in any HMI graphics package: Administrator, Engineer, Operator, and Guest (view only). Each role must have unique privileges defined based on level of responsibility.

1004.6.3.1.1.2 Unique credentials must be issued to individual users. Exception: EVS HMI for use by first responders may require shared credentials.

1004.6.3.1.1.3 Trends visualize data from control variables over distinct time intervals. Trends inform technicians and engineers of gradual system changes, change of state, and rates of change.

1004.6.3.1.1.4 Features

1004.6.3.1.1.4.1 Timeclock / scheduling functions.

1004.6.3.1.1.4.2 Operations (revenue) scheduling.

1004.6.3.1.1.4.3 Date / time stamps.

1004.6.3.1.1.4.4 Log activity reporting.

1004.6.3.1.1.4.5 Measurement and trends.

1004.6.3.1.1.4.6 Time delays.

1004.6.3.1.1.4.7 System and site optimization reports.

1004.6.3.1.1.4.8 Historian capacity.

1004.6.3.1.1.4.9 Memory for data retention.

1004.6.3.1.1.5 Alarms.

1004.6.3.1.1.5.1 An alarm philosophy document is mandatory for each deployment. This must specify detail setpoints, types/priorities, recommended operator responses, acknowledgement abilities, and archiving methods.

Commentary: Reference the applicable Sound Transit Control System Guidelines for more information.

1004.6.3.1.2 Networking Elements

1004.6.3.1.2.1 Workstations

1004.6.3.1.2.1.1 Provide telecommunications outlets in the fire command center for workstation connections to TCN or EFN.

1004.6.3.1.2.1.2 Dedicate a switch port and IP address for an engineering connection.

1004.6.3.1.2.2 I/O Network

1004.6.3.1.2.2.1 BMS and EVS PLC-based systems must utilize PROFINET ring network for CPU to remote I/O networking.

1004.6.3.1.2.2.2 BMS equipment interfaces must utilize BACnet/IP, BACnet MS/TP, Modbus TCP, Modbus RTU, or PROFINET standard protocols.

1004.6.3.1.2.2.3 Remote I/O (RIO) communication to main PLC must not to be routed through the TCN network.

1004.6.3.1.2.2.4 RIO to PLC communication requires geographically separated dedicated fiber or Cat6 cable.

1004.6.3.1.3 Panel Power

1004.6.3.1.3.1 Panel power distribution must be designed so that failure of any one feeder or branch overcurrent device, conductor, or raceway will not result in total disruption of electrical services required for safe operation of the facility.

1004.6.3.1.3.2 Circuit and feeder sizing shall account for all loads, voltage losses due to distance, and inrush associated with any end devices.

1004.6.3.1.3.3 Control panels containing multiple power circuits and sources must be permanently labelled identifying the location of disconnects for each circuit.

1004.6.3.1.3.4 Within each cabinet, each PLC must be supplied by a redundant pair of 24 volts DC power supplies.

1004.6.3.1.4 Control Power

1004.6.3.1.4.1 All control panels must be powered from UPS circuits.

1004.6.3.1.4.2 Control transformers must be rated for Class 2, 24 Vac / Vdc applications and rated at 125 percent of the connected load power consumption. These may be either fused or current-limiting type.

1004.6.3.1.4.3 Control power supplies must be monitored for power loss and alarmed to SCADA.

1004.6.3.1.5 Devices

1004.6.3.1.5.1 Relays

1004.6.3.1.5.1.1 All relays must be UL listed. Contact ratings, configuration, and coil voltage must be suitable for application.

1004.6.3.1.5.1.2 Specify control relays with LED indication when energized.

1004.6.3.1.5.1.3 Time delay relays must be solid-state plug-in type with adjustable delays.

1004.6.3.1.6 Cables

1004.6.3.1.6.1 Pathways

1004.6.3.1.6.1.1 Conduit material must follow the criteria in Set 1005 Electrical Power.

1004.6.3.1.6.1.2 Minimum conduit trade size is 1 inch.

1004.6.3.1.6.1.3 Conduit must never be used for fault current or as a safety ground return conductor.

1004.6.3.1.6.1.4 Wire splicing is permitted only in junction boxes or pull boxes.

1004.6.3.1.6.1.5 All cables and wiring must be labeled at each end with a point address, device served, or termination number per the Sound Transit Facility and Equipment Naming Standard.

1004.6.3.1.6.1.6 Terminal strips and control panels must be permanently labeled with descriptive identifiers.

1004.6.3.1.6.1.7 Routing of voice or data cables in the same conduit as power conductors is not allowed except in cases using class 2 power supply used with 24 volts nominal or less and load is less than 100 volt-amperes.

1004.6.3.1.6.2 Power

1004.6.3.1.6.2.1 115-volt power circuit wiring above 100 feet must use minimum 10 AWG conductors.

1004.6.3.1.6.2.2 24-volt control power wiring above 200 feet must use minimum 12 AWG conductors.

1004.6.3.1.6.2.3 Single conductor control cables must be specified.

Commentary: For example, #14 AWG, stranded tinned copper (ASTM B33), class B stranding (ASTM B8) with XHHW-2 XLPE insulation rated to 600V.

1004.6.3.1.6.2.4 Multi conductor control cables must be specified.

Commentary: For example, at least #16 AWG sized stranded copper conductors. XHHW-2 XLPE insulation rated to 600V.

1004.6.3.1.6.2.5 Instrumentation cables must be specified.

Commentary: For example, TC type cable, #18 AWG twisted shielded pair rated to 600V.

1004.6.3.1.6.3 Grounding

1004.6.3.1.6.3.1 System grounding must be installed per Set 1005 Electrical Power guidance drawing JCD-604.

1004.6.3.1.6.4 Communication

1004.6.3.1.6.4.1 Category Cable: Meet or exceed Category 6 performance requirements recognized in the active version of ANSI/TIA-568 standard. Jackets for these cables must be plenum (CMP) rated.

1004.6.3.1.6.4.2 Fiber Optic Cable: Provide single-mode fiber with a minimum of 12 strands when used for BMS and EVS applications. Must be plenum (OFNP) rated. Specify with LC connectors.

1004.6.3.1.7 Applications

1004.6.3.1.8 Safety Interlocks

1004.6.3.1.8.1 Control logic including interlocks must be initially defined for control system integrators. Integrators should expand on this logic through coordination during construction.

1004.6.3.1.8.2 Safety related control circuits must be hardwired, not dependent upon networked interfaces.

1004.6.3.1.9 Circuit Supervision

1004.6.3.1.9.1 All non-supervised alarm circuits must be connected such that the non-alarmed state is normally energized and drops out (opens) upon alarm unless there are special circumstances that would make that impractical.

1004.6.3.1.10 Spares

1004.6.3.1.10.1 A spare philosophy must be developed, documented, and demonstrated in engineering drawings.

1004.6.3.1.10.2 Cable not terminated to equipment must be identified for future use with wire markers.

1004.6.3.2 BMS Elements

1004.6.3.2.1 BMS servers, workstations, and network controllers must support and utilize communication over Ethernet local area network technology.

1004.6.3.2.2 The BMS controller must exchange a PLC status contact with the EVS controller for awareness and need to repair.

1004.6.3.3 EVS Elements

1004.6.3.3.1 Control Panels

1004.6.3.3.1.1 General

1004.6.3.3.1.1.1 EVS systems are integrated over Sound Transit's EFN. This network is isolated from all other networks, including Agency and Train Control Network (TCN).

1004.6.3.3.1.1.2 Tunnel EVS PLC CPUs are required to be configured for redundancy.

1004.6.3.3.1.1.3 EVS redundant PLCs must be in separate cabinet locations, each having separate power circuits to each cabinet.

1004.6.3.3.1.1.4 The EVS controller must exchange a PLC status contact with the BMS controller for awareness and need to repair.

1004.6.3.3.1.1.5 Local control panels at station and ventilation shafts must control fans and dampers located on the site.

1004.6.3.3.1.2 EVCP

Commentary: EVCPs are the primary means for local control of emergency mechanical ventilation systems and allow manual initiation of ventilation modes. These may be provided in Link stations adjacent to tunnel sections, or at surface entrances to enclosed stations.

1004.6.3.3.1.2.1 Tunnel stations must be equipped with an EVS SCADA workstation and an EVCP located in the FCC.

1004.6.3.3.1.2.2 The EVCP must operate as the local station supervisors control panel for the EVS at required Link stations.

1004.6.3.3.1.2.3 Fan and damper conditions in all operating modes shall be displayed at LCC and at the EVCP. All control functions available at related FCP/FDCPs must annunciate at the EVCP, for instance if a unit is taken out of AUTO.

1004.6.3.3.1.2.4 The EVCP must have capability to initiate a ventilation mode at neighboring stations where a multi-station response is required in the event of a communications failure.

1004.6.3.3.1.2.5 The EVCP must be capable to control equipment at other stations based on emergency ventilation modes specified in design.

1004.6.3.3.1.2.6 When stairwell / elevator pressurization systems are required, monitoring and control of this equipment must be fulfilled by the EVCP. AHJ concurrence for the EVCP to serve as the fire fighter's smoke control panel is required.

1004.6.3.3.1.2.7 EMP / EVS workstation must display the following functions (as applicable):

i. Schematic background of the station / tunnel layout.
ii. Active emergency mode.
iii. Fire Alarm system status.

1004.6.3.3.1.3 FCP / FDCP

1004.6.3.3.1.3.1 Install FCP / FDCPs near fan motor starting equipment.

1004.6.3.3.1.3.2 Each FCP / FDCP implements a touchscreen HMI, selector switches, and indicating lights for local control of equipment.

1004.6.3.3.2 Networking Elements

1004.6.3.3.2.1 The EFN must provide ability for remote control of ventilation equipment, including from LCC, from the emergency management panel for DSTT locations, and from the EVCP at station fire command centers.

1004.6.3.3.2.2 EVS servers, workstations, and network controllers must support and utilize communication over Ethernet local area network technology.

1004.6.3.3.3 Instrumentation

1004.6.3.3.3.1 An instrument index must be provided for all devices interfacing to EVS controllers from fan assemblies.

1004.6.3.3.3.2 Instrument specifications forms must be provided for all temperature, vibration, and flow elements.

1004.6.3.3.3.3 Template forms may be provided with clear indication of applicable devices shown in an instrument index.

1004.6.3.3.4 FBMS Elements

1004.6.3.3.4.1 All controllers must be BTL certified and listed and capable of supporting both industry-standard and vendor specific protocols.

1004.6.3.3.4.2 The FBMS utilizes Modbus over Ethernet and BACnet RS-485 serial I/O network standards.

1004.6.3.3.4.3 The local FBMS JACE integrates with the Sound Transit campus Niagara supervisory system.

1004.7 ENGINEERING MANAGEMENT REQUIREMENTS

1004.7.1 Design Management

1004.7.1.1 Interoperability with existing Enterprise level applications and designed equipment level devices.

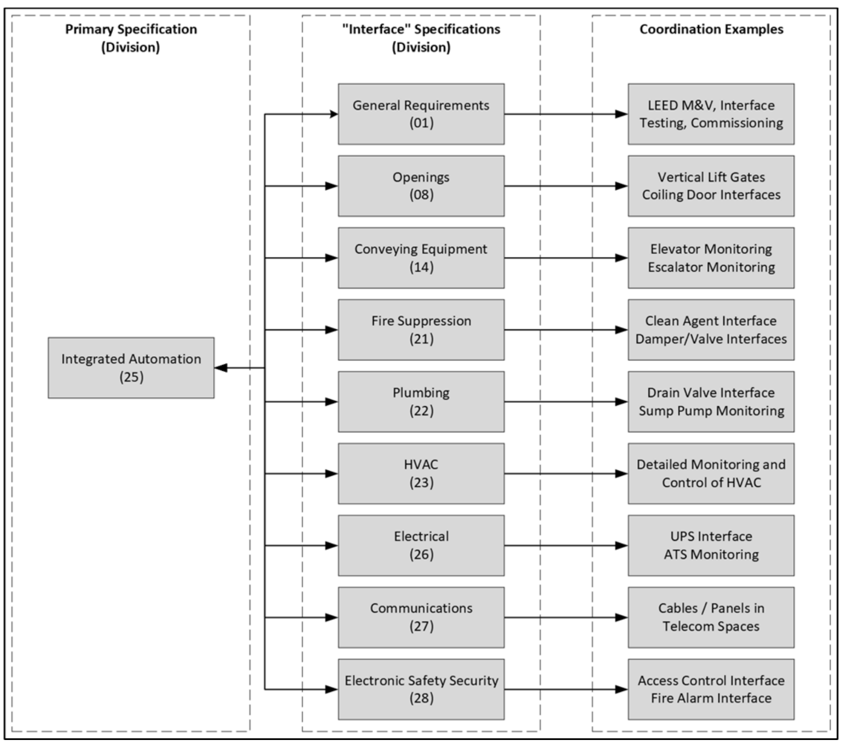
1004.7.1.2 Existing Systems or Retrofits

1004.7.1.2.1 Perform an assessment of existing BMS interfaces to identify system limitations during retrofit / upgrade projects, such as network bandwidth or software licensing. Any identified limitations will result in additional project scope to support the expansion of Sound Transit's existing BMS.

1004.7.2 Interface and Integration Management

1004.7.2.1 The design must consider and account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructable documentation and functional designs.

Figure 1004-11: Specification Coordination for Automation



1004.7.2.2 Ensure interface equipment provisions are made for required monitoring, control, and alarm functions to BMS / FBMS and EVS. This may require involvement in construction submittal reviews.

1004.7.2.3 Integrators must save backup copies of programs and configuration files prior to making any field changes.

1004.7.2.4 Integrators must provide a documented strategy for configuration management and version control.

1004.7.2.5 Building Layout / Plans

1004.7.2.5.1 Building layout drawings must show device layout and conduit. See Set 1006 Electrical Raceway.

1004.7.2.6 Riser Diagrams

1004.7.2.6.1 These should include wiring between building controllers, control panels, and all interfacing equipment.

1004.7.2.7 Drawings

1004.7.2.7.1 Typical installation details must be provided.

1004.7.2.7.2 Typical points lists must be provided.

1004.7.2.7.2.1 A representative points list must be produced for each type of equipment. A method to efficiently handle deviations from the designed points list should be documented.

Commentary: The purpose of this method should serve to reduce Sound Transit project risk and schedule, as well as Contractor exposure. For example, a Request for Information to modify individual point names is not an efficient means to handle deviations from the typical points list.

1004.7.2.7.3 Wiring Schematics

1004.7.2.7.4 Control schematics should be provided showing typical control, communication, and power wiring. These may be representations of systems or individual units. Sequences of operation and controller I/O must be supplemented by these schematics.

1004.7.2.7.5 Panel layout drawings housing EVS, BMS, or FBMS equipment must be provided.

1004.7.2.8 Narrative Documents

1004.7.2.8.1 Develop a design narrative during early design. This should describe the system and its functions at a high level. It is considered an evolving document, to be continually updated throughout the design.

1004.7.2.8.2 A control narrative must demonstrate sufficient coordination with other design disciplines has taken place.

1004.7.2.8.2.1 Control narratives must outline sequences of operation.

1004.7.2.8.2.2 Control narratives must include alarm rationalization, which identifies priority, threshold, and corrective action.

1004.7.2.9 Specifications

1004.7.2.10 Modeling and Simulations

1004.7.2.10.1 Design team must contribute and actively participate in building information modeling (BIM) activities which model BMS / FBMS or EVS and equipment interfaces.

1004.7.3 Manufacturing and Construction Management

1004.7.3.1 Design teams must identify fundamental bills of material in the basis of design document in specifications and drawings.

1004.7.3.2 Submittals

1004.7.3.2.1 Cut sheets of individual devices being submitted must accurately show the make and model number of each device.

1004.7.3.2.2 Where a submittal is comprised of multiple devices that makeup an overall system, a tabulated submittal should be provided with an overall description of the system and corresponding documents of devices along with interconnection diagrams of each devices showing the overall system.

1004.7.3.2.3 Motor starter/controller submittals must include EVS signals in control diagrams.

1004.7.3.3 Design teams must anticipate, document equipment, and provide assurance of construction teams application of small purchase waivers under 49 U.S.C. Section 5323(j) Buy America Clause or exceptions under 49 CFR Section 661.7, Appendix A.

1004.7.3.4 Designs must specify equipment from active product offerings to mitigate Sound Transit's maintainability and obsolescence risks.

1004.7.4 Installation Management

1004.7.4.1 Equipment and enclosure cabling must be installed in a neat and workmanlike manner.

1004.7.4.2 Post-installation modifications must undergo evaluation for impact and appropriate level of testing, including regression testing.

1004.7.5 Inspection and Testing Management

1004.7.5.1 Inspection

1004.7.5.1.1 Designs must adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

1004.7.5.1.2 Labeling requirements must follow Sound Transit's Naming and Numbering Standard.

1004.7.5.1.3 Deviations or labeling not covered in the Naming and Numbering Standard must be follow a clearly defined philosophy by the designer. In such instances, designs are encouraged to meet industry recognized standards, for example ANSI/TIA-606.

1004.7.5.2 Testing Management

1004.7.5.2.1 System checkout and testing requirements must be developed and incorporated in record documents, such as project specifications.

1004.7.5.2.2 Factory testing, site testing, final demonstration and operations acceptance activities must be detailed in commissioning specifications.

1004.7.5.2.3 All test plans must be written and submitted to Sound Transit prior to scheduled test dates.

1004.7.5.3 Factory Acceptance Tests

1004.7.5.3.1 FAT must be performed for both field control systems (BMS / FBMS and EVS).

1004.7.5.3.2 Factory testing must be performed for both field devices and central control systems.

1004.7.5.4 Field (Site) Acceptance Testing

1004.7.5.5 Field testing must be performed to demonstrate proper operation of systems including automatic, manual, local, and remote control.

1004.7.5.6 Field testing of equipment must be performed to demonstrate configuration, control, and operation at each station.

1004.7.5.7 Field testing of PLC program must be performed as part of level three interstation testing.

1004.7.5.8 Confidence and Proof Testing

1004.7.5.8.1 Provisions to force/disable/override control logic to bypass final control elements must be assessed for use during confidence and proof testing. When implemented, these must be identified on graphics and/or annunciated as an abnormal condition to operators.

Commentary: Bypasses for recurring system testing are typically only necessary for emergency ventilation systems.

1004.7.5.8.2 Periodic confidence testing to verify proper system function is required.

1004.7.6 Training, Pre-Revenue Operations

1004.7.6.1 Training procedures must ensure that operators and maintainers are able to thoroughly understand the delivered systems.

1004.7.6.2 Provide training to Sound Transit and all Sound Transit delegated personnel on the operation of building management, emergency ventilation, and facility building management systems. Formal training must take place following commissioning.

Commentary: Sound Transit encourages involvement throughout commissioning as this provides informal training opportunities.

1004.7.6.3 A training plan must be developed and include separate courses for operations, maintenance, and engineering staff, with potential of two subgroups each due to competing work schedules.

1004.7.6.4 All operation and maintenance manuals must be provided in digital format as part of training materials.

1004.7.6.5 Content in the training materials must be directly applicable to the constructed system and is required to identify specific equipment tags throughout the manual.

1004.7.6.6 Engineering training must include a comprehensive overview of programming and graphics functions, as well as transfer of all credentials and other information necessary for system administrators. Techniques covered in this course must include program backup, restoration, and system startup at minimum.

1004.7.6.7 Operations training must focus on monitoring and control tasks available to operators. The purpose of this training is for system familiarization as well as development and revision of operating procedures.

1004.7.6.8 Maintenance training must focus on standard troubleshooting procedures related to the delivered systems. This includes an overview of the system, equipment descriptions, preventative maintenance procedures, recommended maintenance intervals, and identification of hazards associated with maintenance tasks.

1004.7.6.9 Training must consist of a minimum of two days of classroom material, and two days field familiarization for each course.

1004.7.6.10 Structure training courses to accommodate up to 30 participants.

1004.7.6.11 As-built drawings must be provided for validation during pre-revenue service, prior to project closeout.

1004.7.6.12 System changes executed in pre-revenue operations, such as a modification to a program or graphic, must be regression tested at Sound Transit’s discretion.

1004.7.7 Certification Management

1004.7.7.1 For any reason NRTL certifications or listings are voided throughout construction, field re-certification must take place.

1004.8 APPENDICES

Figure 1004-12: Typical Link Station BMS / EVS Deployment

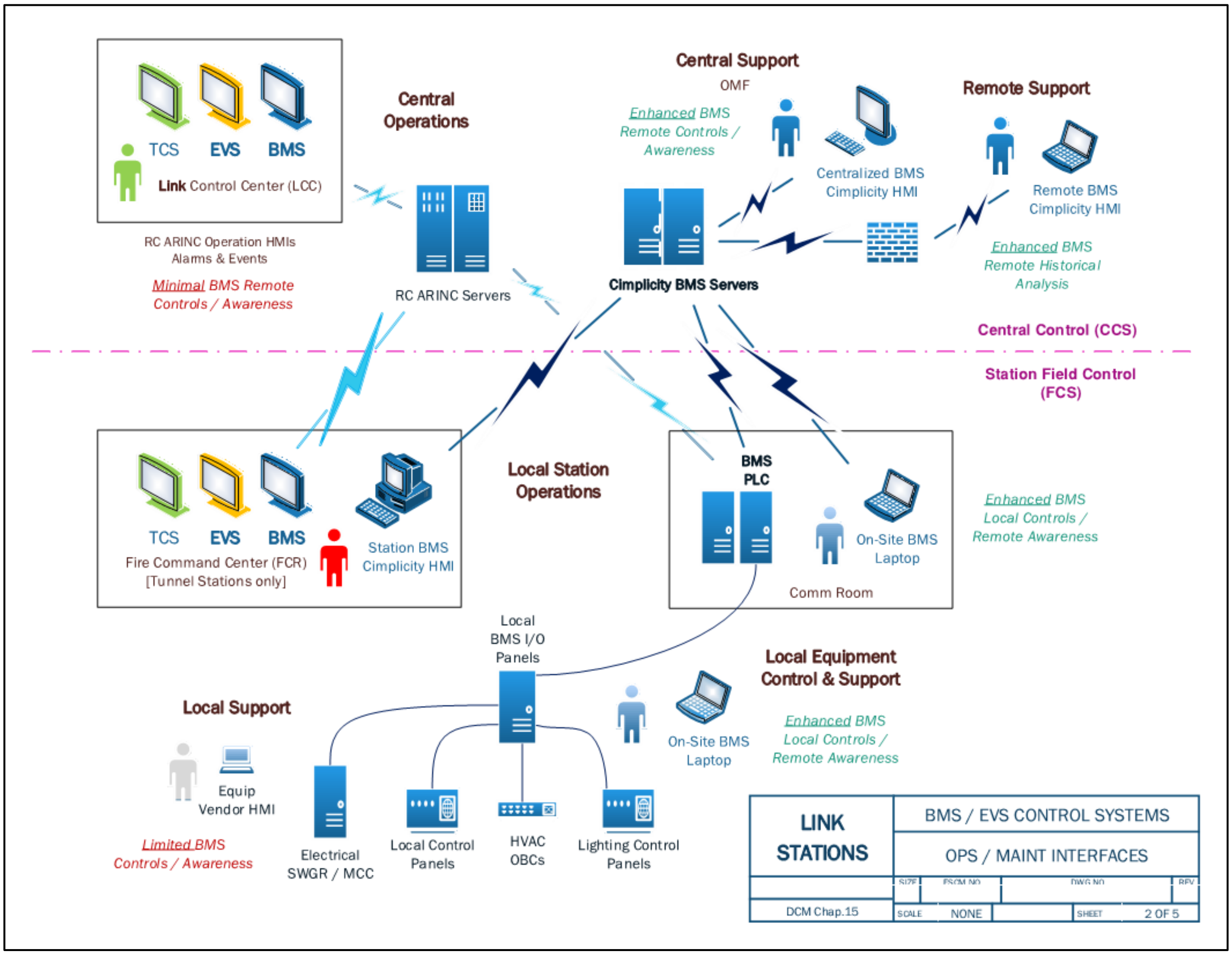


Figure 1004-13: Typical Sound Transit Facility FBMS Deployment

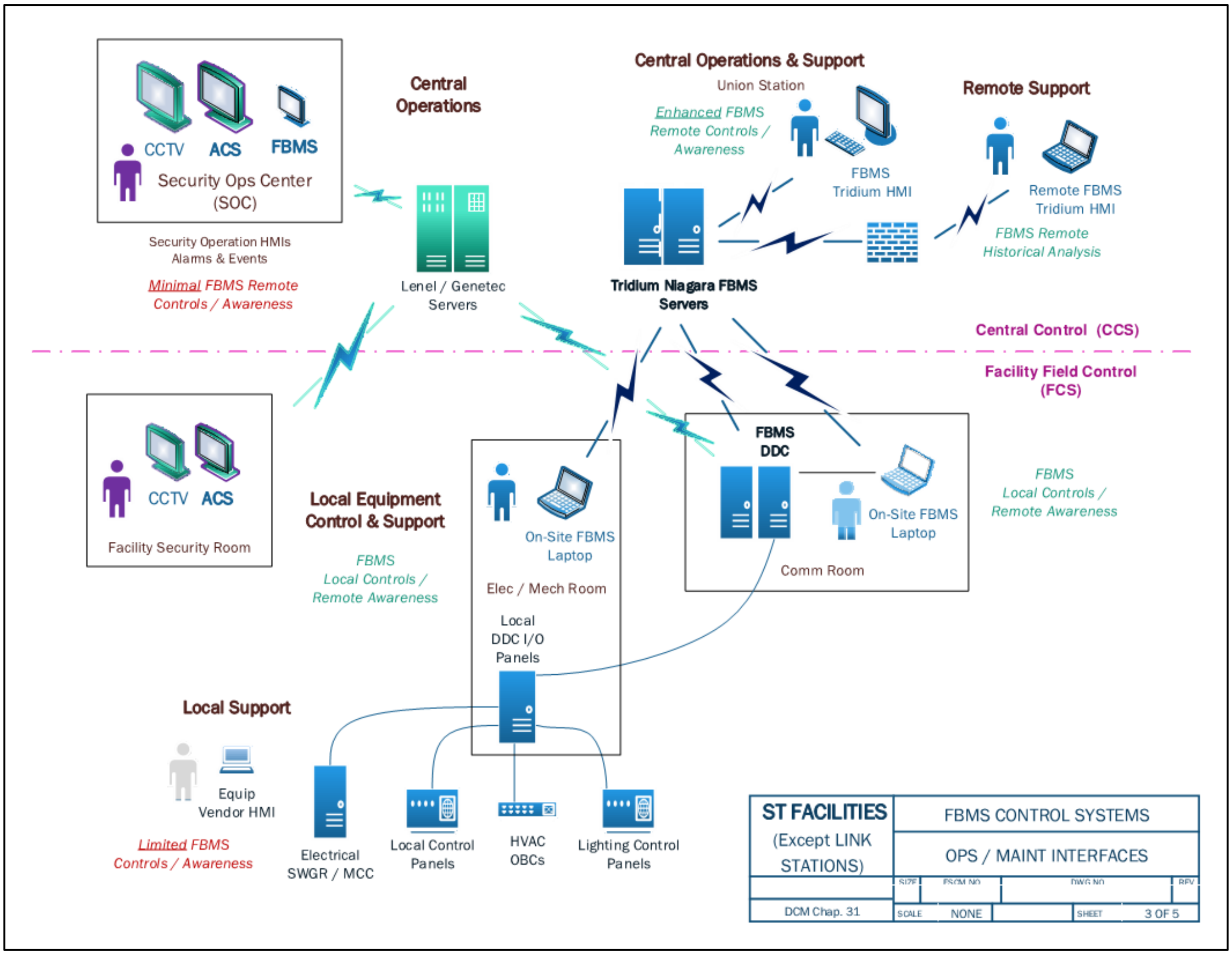
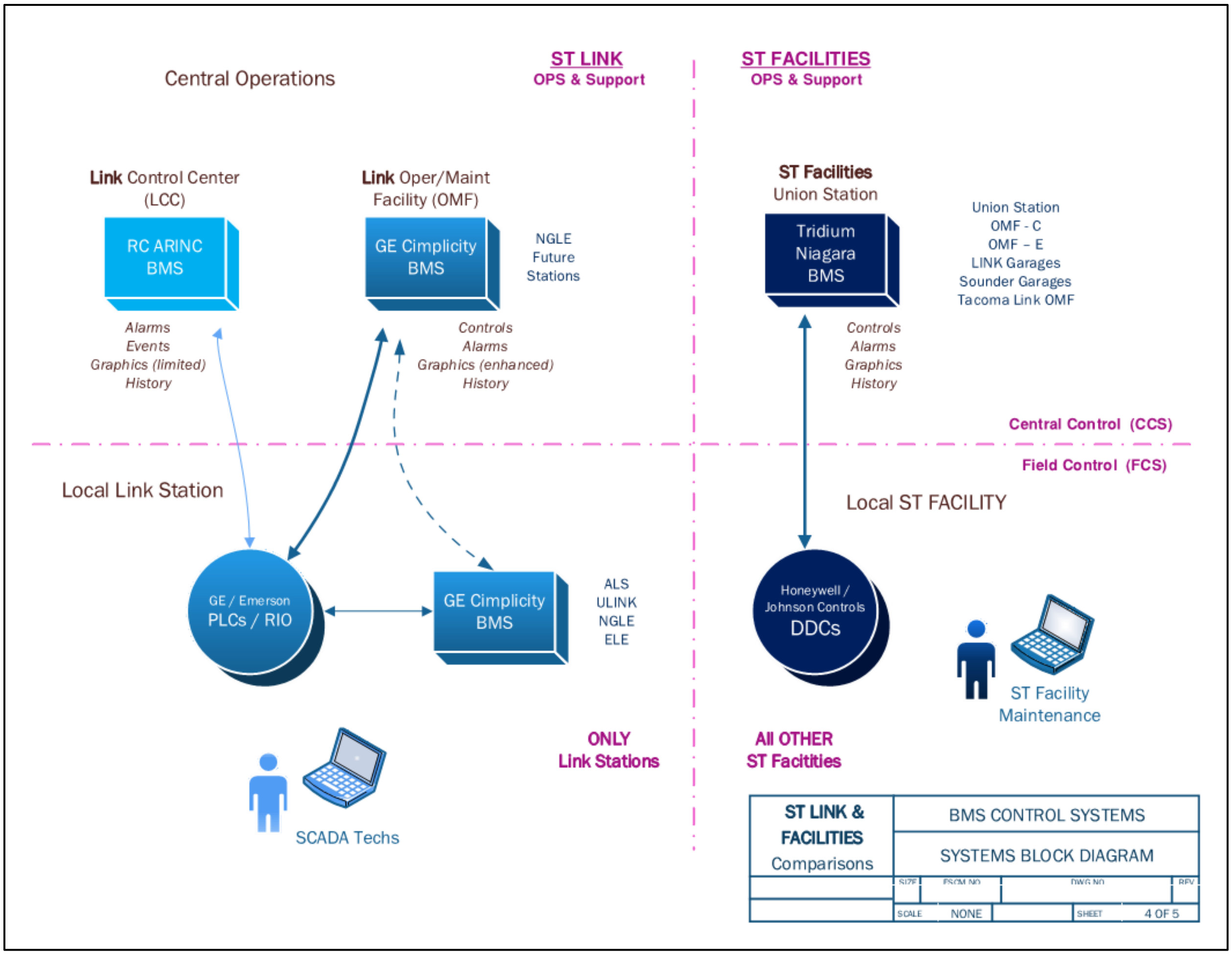


Figure 1004-14: Link Stations and Sound Transit Facility Comparison



END SET - 1004

1005 ELECTRICAL POWER

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SET - 1005 TABLE OF CONTENTS

TABLES

FIGURES

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SET - 1005 ELECTRICAL POWER

1005.1 INTRODUCTION

1005.1.1 Document Scope

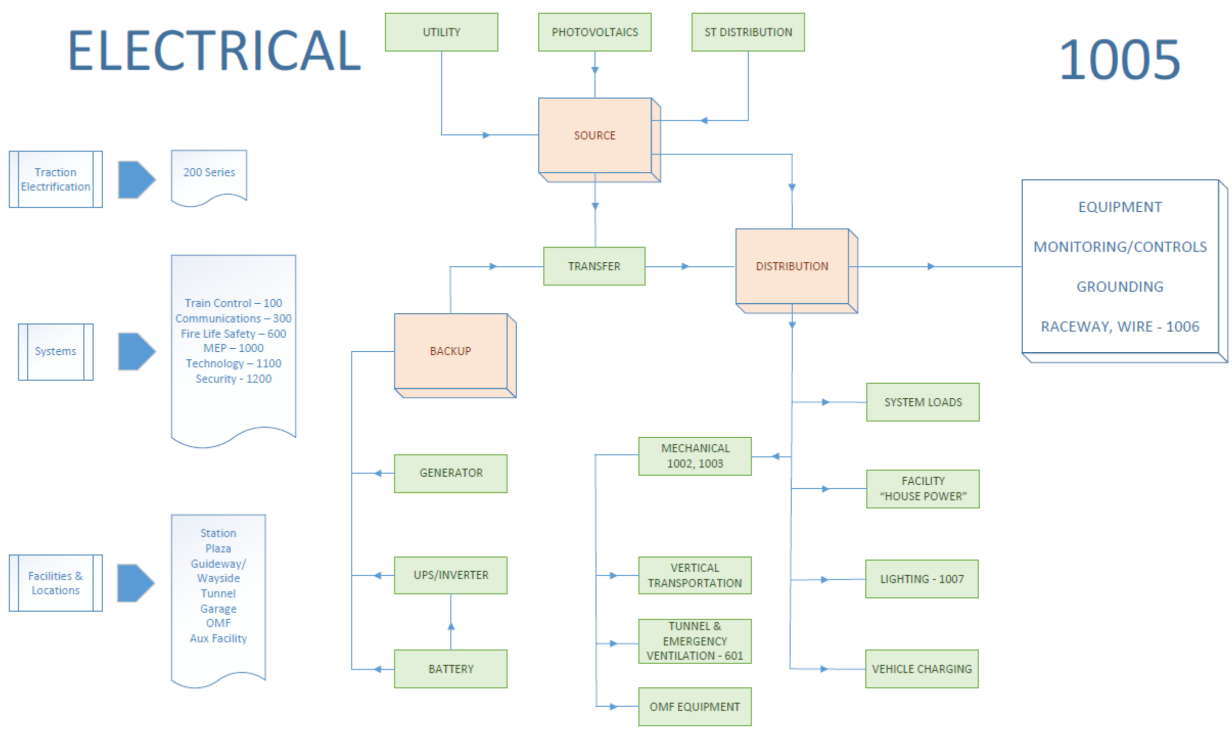
1005.1.1.1 The set establishes electrical systems criteria for all Sound Transit facilities and applies to all modes including Link, BRT, and Sounder. These criteria include requirements for the function and design of electrical and related systems. Refer to Set 220 Traction Power for electrical requirements specific to the DC traction power supply and distribution system.

1005.1.1.2 The requirements set establishes minimum requirements. If there is a conflict between these requirements and adopted codes and standards, the most restrictive will apply.

1005.1.1.3 This section contains specific code references. The code references herein are based on the 2020 NFPA 70 (NEC), 2021 NFPA 70E, and the 2020 version of NFPA 130. Those specific references may change under future editions of the codes and standards.

1005.1.1.4 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 1005 owner to determine the technical source for the design criteria.

Figure 1005-1: System Context Diagram



1005.1.2 Regulations, Codes, Standards, and Guidelines

1005.1.2.1 International Regulations, Codes, Standards, and Guidelines

1005.1.2.1.1 International Building Code Chapter 30 with local amendments.

1005.1.2.1.2 CSA Group.

1005.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

1005.1.2.2.1 National Electrical Code (NFPA 70).

1005.1.2.2.2 Standard for Electrical Safety in the Workplace (NFPA 70E).

1005.1.2.2.3 American National Standards Institute ANSI C37.

1005.1.2.2.4 National Electrical Installation Standards' Good Workmanship in Electrical Construction.

1005.1.2.2.5 Institute of Electrical and Electronics Engineers (IEEE) National Electrical Safety Code.

1005.1.2.2.6 IEEE Guide for Safety in AC Substation Grounding.

1005.1.2.2.7 National Electrical Manufacturers Association (NEMA).

1005.1.2.2.8 Code of Federal Regulations Energy Efficiency Program for Certain Commercial and Industrial Equipment.

1005.1.2.2.9 Washington Industrial Safety and Health Act General Safety Standard.

1005.1.2.2.10 NFPA 101 Life Safety Code.

1005.1.2.2.11 NFPA 110 Standard for Emergency and Standby Power Systems.

1005.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

1005.1.2.3.1 Washington Administrative Code Electrical Safety Standards, Administration and Installation.

1005.1.2.3.2 Seattle City Light Standards for Electrical Service.

1005.1.2.3.3 Puget Sound Energy Electric Service Handbook.

1005.1.2.3.4 Seattle Electrical Code.

1005.1.2.3.5 Washington Cities Electrical Code.

1005.1.2.3.6 Snohomish Public Utilities District Electric Service Requirements.

1005.1.2.3.7 Tacoma Public Utilities Electrical Construction Standards.

1005.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

1005.1.2.4.1 American National Standards Institute (ANSI).

1005.1.2.4.2 Underwriters Laboratory (UL).

1005.1.2.4.3 International Electrical Testing Association (NETA).

1005.1.2.4.4 Surface Vehicle Recommended Practice J1772.

1005.1.2.5 Other Jurisdictions

1005.1.2.5.1 Local municipal codes often amend the NEC and other electrical codes and standards. All local amendments apply including those adopted during design unless the design has been formally vested in writing with the Authority Having Jurisdiction.

1005.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

1005.1.2.6.1 Sound Transit Electrical Safety Program.

1005.1.2.6.2 Sound Transit Equipment and Facilities Numbering Standards.

1005.1.2.6.3 Sound Transit Design Technology Manual.

1005.1.2.6.4 Interface Coordination and Integration Plan.

1005.1.2.6.5 General Testing and Commissioning Plan.

1005.1.2.6.6 Sound Transit Systems Standard Drawings and Specifications.

1005.1.3 Abbreviations and Acronyms

1005.1.3.1 AHJ–authority having jurisdiction

1005.1.3.2 ATS–automatic transfer switch

1005.1.3.3 EPMS– electrical power management system

1005.1.3.4 MTS– manual transfer switch

1005.1.3.5 NEC – National Electrical Code

1005.1.3.6 NFPA – National Fire Protection AssociationPV–photovoltaic

1005.1.3.7 PSE–Puget Sound Energy

1005.1.3.8 SCL–Seattle City Light

1005.1.3.9 UPS–uninterruptible power supply

1005.1.3.10 VFD–variable frequency drive

1005.1.4 Definitions and Classifications

1005.1.4.1 Facility service transformer: The transformer supplying power to the facility.

1005.1.4.2 Indoor distribution transformer: The transformers in the facility after the facility service transformer.

1005.1.5 References (Not Used)

1005.2 STAKEHOLDER NEEDS

1005.2.1 Passenger Experience

1005.2.1.1 PSO Engineering's mission is to protect and uphold the integrity of the technical requirements to ensure passenger satisfaction and safe, quality, reliable, and durable operations through establishing, integrating, and managing the needs of the agency through engineering, core systems and facility requirements.

1005.2.2 Operational Needs

1005.2.2.1 Stations and garages are operated without a continual presence of operators or maintenance staff. Designs must account for unattended facilities.

1005.2.2.2 Maintenance facilities are operated 24 hours a day 7 days a week in support of operating transportation service and maintaining the associated systems, buildings, and infrastructure.

1005.2.2.3 The power distribution system must be designed so that failure of any one component does not result in an unsafe operating condition. See Section 1005.2.6 Reliability, Availability and Maintainability Needs in this set.

1005.2.2.4 Power redundancies must be provided where required to ensure reliability.

1005.2.3 Maintenance Needs

1005.2.3.1 Maintenance at stations and garages is typically reserved for periods that do not impact passengers, limiting maintenance windows to non-revenue periods unless scope can be performed without passenger impact. Designs must account for narrow maintenance windows.

1005.2.3.2 All components of the power distribution system must be accessible and maintainable and must be in locations that can be serviced during operations.

1005.2.3.3 Power distribution systems must be documented, and all components must be included in operations and maintenance manuals.

1005.2.4 Safety Needs

1005.2.4.1 Passenger, operator, and maintainer safety for normal operations and emergency operations must be accounted for in designs. Ensure power system can be operated safely and components can be maintained safely.

1005.2.4.2 Comply with arc flash study and labeling requirements in this section

1005.2.4.3 Design power distribution system to facilitate creation of lockout/tagout safety program. Components of the system must be able to be electrically isolated.

1005.2.5 Security Needs

1005.2.5.1 Station and garage elements accessible to passengers must incorporate consideration to prevent theft and vandalism, including material selection and placement.

1005.2.5.2 All components of the power distribution system must be installed in locations and in a manner that is safe for the public.

1005.2.5.3 All components of the power distribution system must be installed in a manner that discourages vandalism. Use vandal-resistant covers and components in public areas.

1005.2.6 Reliability, Availability and Maintainability Needs

1005.2.6.1 Material and equipment selection must consider the operating environment and small maintenance windows associated with public transportation. Power systems must be resilient, reliable, and maintainable.

1005.2.6.2 Ensure equipment is accessible and maintainable for its operational lifetime.

1005.2.7 Environmental and Sustainability Needs

1005.2.7.1 Facility designs must promote stewardship of resources and utilities when selecting material, equipment, and operational strategies with the goal of conservation and efficiency.

1005.2.7.2 Coordinate with Sound Transit sustainability personnel and provide products and systems that align with agency goals.

1005.3 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

1005.3.1 System Breakdown Structure

1005.3.1.1 Electrical Services

1005.3.1.2 Electrical Equipment

1005.3.1.3 Power Monitoring

1005.3.1.4 Backup Power

1005.3.1.5 Electric Vehicle Charging

1005.3.1.6 Photovoltaic System

1005.3.1.7 Grounding

1005.3.1.8 Calculations and Studies

1005.3.2 System Sites and Locations

1005.3.2.1 Facilities

1005.3.2.1.1 Stations

1005.3.2.1.2 Parking Garage

1005.3.2.1.3 Operations and Maintenance Facility

1005.3.2.2 Guideway: Tunnel & Above Ground

1005.3.2.3 Wayside Facilities

1005.3.2.4 Battery Electric Bus Charging Yards

1005.4 SYSTEM INTERFACE REQUIREMENTS

Table 1005-1: Interface Between Mechanical/Electrical and Building and Other Disciplines

SET SERIES	SET NAME	SET 1005 INTERFACE
100	Signals/Train Control	X
200	Traction Electrification	X
300	Communications/Technology	X
400	Vehicles/Noise and Vibration	
500	Track	
600	Fire/Life Safely	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical/Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

1005.4.1 Train Control and Signals

1005.4.1.1 Coordinate for utility service entrance requirements.

1005.4.2 Traction Electrification

1005.4.2.1 Coordinate for power monitoring and central EPMS connectivity.

1005.4.2.2 Coordinate service for TPSS fed from Sound Transit-owned power network.

1005.4.3 Operational Communications

1005.4.3.1 Coordinate for voltage ratings, power source locations, and load levels.

1005.4.4 Fire/Life Safety

1005.4.4.1 Coordinate for normal power source for applicable panels.

1005.4.5 Structures

1005.4.5.1 Coordinate for equipment weights, seismic requirements.

1005.4.6 Architecture

1005.4.6.1 Coordinate for room layouts, maintenance access.

1005.4.6.2 Coordinate power needs for the following unique applications: Bike lockers, trip planners and vending carts. Refer to set 820 Facility Area Planning for location criteria.

1005.4.6.3 Where required, food vending carts must be provided a 120 V/240V, single phase receptacle.

1005.4.7 Civil

1005.4.7.1 Coordinate for electrical equipment located outdoors.

1005.4.7.2 Coordinate with Set 902 Utilities for electrical power service.

1005.4.8 Mechanical/Electrical and Building Systems

1005.4.8.1 Coordinate for electrical power requirements for mechanical equipment.

1005.4.8.2 Tight coordination required for all building management system elements.

1005.4.8.3 Coordinate for built-in station signal rooms.

1005.4.9 Technology

1005.4.9.1 Coordinate for voltage ratings, power source locations and load levels.

1005.4.9.2 Coordinate for new systems and integrations, refer to Set 1101 Common Technology and Set 1105 Data Communications Integration for additional requirements.

Commentary: These requirements apply to new systems and new integrations. This is not a mandate to retrofit existing systems that do not add a new functionality.

1005.4.10 Security

1005.4.10.1 Coordinate for voltage ratings, power source locations and load levels.

1005.5 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

1005.5.1 Electrical Services

1005.5.1.1 Utility Interface

1005.5.1.1.1 Coordinate electrical system voltages with servicing utility.

1005.5.1.1.2 Conform utility metering to the requirements of the servicing utility.

1005.5.1.1.3 Coordinate electrical system protective devices with servicing utility.

1005.5.1.2 Service Transformer

1005.5.1.2.1 Size service transformers based on connected load. Service transformers must be able to independently power the entire facility.

Table 1005-2: Utilization Voltages

EQUIPMENT	UTILIZATION VOLTAGE
Luminaires	120, 277 Vac 1-Phase
Motors 350 HP and above	480 Vac 3-phase, 4160 Vac 3-phase
Motors 1 HP to 500 HP	480 Vac 3-phase
Motors ¾ HP and smaller	120 Vac volts AC 1-phase, 208 Vac 3-phase
Controls for switchgear	125 Vdc
Motor Controls	120 Vac
Fare Collection Equipment	120 Vac 1-phase
Communications and video equipment	120 Vac 1-phase, 120/240 Vac 1-phase, 208Y/120 Vac 3-phase
Food Vending Carts and receptacles	240 Vac 1-phase
Facilities	120/240 Vac 1-phase, 208Y/120 Vac 3-phase, 480Y/277 Vac 3-phase

1005.5.1.2.2 Where single phase power is taken from a three-phase source, the loads must be balanced among the three distribution phases.

1005.5.1.3 Capacity

1005.5.1.3.1 Electrical systems must have sufficient capacity to power all facility loads with 20 percent reserve. Maintenance facilities must have 40 percent reserve capacity.

1005.5.1.3.2 Specific requirements for UPS and Sound Transit owned facility service transformers appear in those sections.

Commentary: For example, if the facility has a calculated connected load of 2.1 mega volt amps, the 2.1 mega volt amps is used to size the utility transformer. The three branch panels that draw 0.7 mega volt amps would have feeders sized for 0.98 mega volta amps (0.7 + 40%) and the drop-down transformers sized appropriately. The 0.98 mega volt amps is not carried forward to the utility transformer. It is only used to size feeders and the indoor distribution transformer.

1005.5.1.3.3 Electrical system capacity must be calculated per NEC guidelines using a demand factor of 1.0, except for fare collection equipment where a demand factor of 0.5 is allowed.
All adjustment factors, including duty cycle and non-coincidental loads, must be documented in the approved load flow study prior to equipment approval.

1005.5.1.4 Reliability and Maintainability

1005.5.1.4.1 Failure of any one electrical system feeder or branch overcurrent device, conductor, or raceway must not result in total disruption of electrical services required for safe operation.

1005.5.1.4.2 Power system source selection must be based on reliability and total cost of ownership.

1005.5.1.4.3 Infrared windows are required for all substation, switchgear, and medium voltage switches.

1005.5.2 Electrical Equipment

1005.5.2.1 Electrical system components must be UL listed and labeled. If product listing is not available, equipment is to be factory or field inspected to ensure compliance with appropriate industry standards and certified for the intended use as required by the AHJ.

1005.5.2.2 Applicable electrical system components must accept lockout devices per NFPA 70E.

1005.5.2.3 Power distribution equipment enclosures must be NEMA 1 rated or better for all conditioned spaces.

1005.5.2.4 Power distribution equipment enclosures must be NEMA 3R rated or better for all outdoor applications.

1005.5.2.5 Power distribution equipment enclosures must be NEMA 4X rated in rail tunnels and in exposed areas subject to hose down and splashing water.

1005.5.2.6 Transformers

1005.5.2.6.1 Distribution transformers must be sized for 120 percent of connected load without addition of cooling means.

1005.5.2.6.2 Station transformer size must be based on the connected load with a single transformer independently powering the entire station. Each transformer of a main-tie-main architecture must be sized to independently power all loads.

1005.5.2.6.3 Power transformers are to be air-cooled vacuum-pressure impregnated with copper windings.

1005.5.2.6.4 Transformers must comply with Department of Energy 10 CFR Part 431 standard for energy efficiency.

1005.5.2.6.5 Use of transformer taps to compensate for voltage drop must be reviewed for overvoltage during light load periods.

1005.5.2.6.6 Transformers for systems servicing non-linear loads must be evaluated for consideration of oversizing and use of K-factor rated transformers.

1005.5.2.6.7 All Sound Transit owned medium voltage transformers must be provided with snubber protection integral to the equipment.

1005.5.2.6.8 Traction power transformer requirements are listed in Set 220 Traction Power.

1005.5.2.7 AC Switchgear

1005.5.2.7.1 Switchgear must be supplied with 125 Vdc control power with battery backup.

1005.5.2.7.2 AC Switchgear must be metal-clad, conform to ANSI C37 standards, and be rated for the utility supplied voltage and available fault current.

1005.5.2.7.3 AC Switchgear must be housed in dead-front enclosures containing draw-out circuit breakers, relaying, metering, and auxiliary power supply.

1005.5.2.7.4 Refer to 1004 Building Monitoring and Control for alarm and energy monitoring requirements.

1005.5.2.7.5 See Section 1005.4.8 Electrical Systems and Locations in this set for AC switchgear and backup power requirements for stations.

1005.5.2.7.6 Refer to 220 Traction Power for AC and DC switchgear for traction power.

1005.5.2.8 Panelboards and Switchboards

1005.5.2.8.1 Panelboards and switchboards must be supplied with a main circuit breaker and distribution or branch circuit breakers for each feeder or branch circuit. Main circuit breaker may be omitted when feeder overcurrent device is in the same room.

1005.5.2.8.2 All feeder, branch, and main breakers in panelboards and switchboards must be fully rated for the maximum available fault current at their respective locations in the power distribution system. Series rating is not allowed.

1005.5.2.8.3 Panelboard breakers must be bolt-on type only. Plug-in breakers are not allowed.

1005.5.2.8.4 Panelboard main breaker and incoming feeder must be 50 amps minimum. Upstream breakers feeding panels must be sized to match.

1005.5.2.8.5 Panelboard total circuit quantity must be sized to include spare circuit breakers and 20 percent spaces for future use.

1005.5.2.8.6 Provide panelboards and switchboards with factory installed surge protective devices rated for the application.

1005.5.2.9 Generators

1005.5.2.9.1 A connection for a mobile generator must be provided for all grade-separated stations and parking garages where an alternate power source is determined to be unnecessary by the basis of design.

1005.5.2.9.1.1 The generator and connection must provide backup power to critical loads, equipment on the communications UPS, and fire/life safety equipment.

1005.5.2.9.2 A mobile generator and connection must also provide power to garage exhaust fans and sump pumps and their related controls when an alternate source is not provided.

1005.5.2.9.3 Space, parking, and generator access must be provided where a mobile generator is required.

1005.5.2.9.4 The generator connection must be 40 feet or less from the proposed generator parking.

1005.5.2.9.5 Mobile generator and connection must be in an exterior space. Do not locate mobile generator and connection within a parking garage.

1005.5.2.9.6 Mobile generator space and access must provide for a standard industry sized truck and trailer, sized for the anticipated loads, to pull through and park.

1005.5.2.9.7 Mobile generator connections must include locking mechanism to remain in place while the generator is in use.

1005.5.2.9.8 Mobile generator connections are to be protected from the environment in accordance with NEMA 250.

1005.5.2.9.9 Basis of design as required by EP-03 must identify type of generator size, connector types, and physical size.

1005.5.2.9.10 Stationary generators must be rated for 125% of continuous loads, 100% of non-continuous load, and an additional 20% spare capacity

1005.5.2.9.11 Stationary generators must be sized to allow all motors to start and to minimize impact on other connected loads that are affected by voltage or frequency dips.

1005.5.2.9.11.1 Generator must be provided with voltage regulator.

1005.5.2.9.12 Generators must be sized for non-linear loads including but not limited to VFDs, UPS, HVAC, and lighting.

1005.5.2.9.13 Stationary generators must be permanently connected to the electrical distribution system.

1005.5.2.9.14 Stationary generators must be monitored by BMS. If a fire pump is serviced by a stationary generator, monitoring must include Fire Alarm System, as required by local jurisdiction and BMS. Coordinate with 1004 Building Monitoring and Control and 601 Fire/Life Safety.

1005.5.2.9.15 Stationary generators will not serve as a dedicated backup power supply in lieu of UPS backup power for critical loads.

1005.5.2.9.16 Stationary generators must be equipped with integral overcurrent and fault protection.

1005.5.2.9.17 When located indoors, generator controls must include a remote emergency-stop switch in the generator room by the door entrance.

1005.5.2.9.18 When located indoors, a separate indoor stationary generator room must be constructed with two-hour fire-resistant rated materials and following requirements in NFPA and local fire and building codes. Provide battery powered lighting within generator room.

1005.5.2.9.19 When located outdoors, the generator must be supplied with an appropriately rated enclosure.

1005.5.2.9.19.1 Provide a sound attenuating enclosure and intake on exhaust silencer that meets state and local noise pollution requirements and ordinances.

1005.5.2.9.20 Provide a stationary generator with a fuel tank sized for a minimum of twelve hours of runtime. Fuel tank must have leak detection.

1005.5.2.9.21 A diesel fuel system must be provided and designed per NFPA, WAC and local fire and building codes.

1005.5.2.9.22 Coordinate with Set 803 Sustainability for final fuel selection.

1005.5.2.10 Transfer Switches

1005.5.2.10.1 Where a mobile generator is required, an MTS must be provided. Non-automatic electrically operated switches are not allowed.

1005.5.2.10.1.1 The MTS must provide means to identify switch position during a power outage and must be manually operable without removing or opening covers.

1005.5.2.10.2 ATS must be double throw, non-fused with an open transition on loss of normal source power.

1005.5.2.10.3 ATS must be electrically operated and mechanically held. Provide switch with visual switch position indication.

1005.5.2.10.4 Provide ATS with a microprocessor-based controller. ATS must be monitored by BMS. Coordinate with 1004 Building Monitoring and Control for additional requirements.
ATS must be capable of monitoring the return of primary power and must have an adjustable duration of time from primary power outage to steady return of primary power.

1005.5.2.11 Lighting Inverters and UPS

1005.5.2.11.1 UPS and internal protective devices must have capacity for loads in all operating modes, including applicable starting and inrush currents.

1005.5.2.11.2 UPS systems must have an internal bypass switch that will automatically failover to normal power source in the event of UPS output failure.

1005.5.2.11.3 UPS systems must include Ethernet connection and display to indicate output voltage and inverter current. Provide status and alarm indication as required in Set 1004 Building Monitoring and Control.

1005.5.2.11.4 UPS and lighting inverters must be equipped with external maintenance bypass equipment to facilitate maintenance and replacement while continuing service.

1005.5.2.11.5 UPS and lighting inverters must not be connected directly to loads. All loads must be distributed from external panelboards or power distribution units.

1005.5.2.11.6 Lighting inverters must provide emergency power to lighting circuits only.

1005.5.2.11.7 Switching time must not exceed 50 milliseconds.

1005.5.2.11.8 UPS and inverters cannot be serviced from other UPS or inverters. Battery chargers can be serviced from UPS but must be approved for use by manufacturer.

1005.5.2.11.9 Power Distribution Units must be provided with all rack-mounted UPS systems.

1005.5.2.11.10 Rack-mounted UPS systems over 5 kilo-volt amperes must be designed in a rack dedicated to UPS equipment.

1005.5.2.11.11 UPS systems over 15 kilo-volt amperes and all three-phase units must be designed in a floor-mounted enclosure by a single manufacturer.

1005.5.2.11.12 Dedicated equipment space, as defined in NEC 110 for switchboards, switchgear, panelboards, and MCCs must be provided for all UPS systems over 15 kilo-volt amperes and all three-phase units.

1005.5.2.11.13 Systems that include motors or starters serviced from UPS must be listed for use.

1005.5.2.11.14 Batteries for control power, UPS, and inverters must be VRLE-type and installed in air-conditioned spaces only.

Commentary: Lithium-Ion type is not currently approved by Sound Transit. Consultants must obtain permission from ST before spending time on designs including Lithium-Ion or similar technologies. The batteries must be guaranteed for five years from the date of installation against defective parts and workmanship.

1005.5.2.11.15 Battery system must allow full calculated load with a runtime duration specified in Section 1005.4.3 Backup Power and based on load classification.

1005.5.2.11.16 UPS systems with combined load type classifications must default to the more stringent runtime requirements.

1005.5.2.11.17 UPS and lighting Inverters must conform to UL 924, UL 1779, NFPA 101, NEC and OSHA requirements.

1005.5.2.12 Protective Devices and Relays

1005.5.2.12.1 Low voltage overcurrent elements designed to protect emergency lighting and communications equipment must use thermal and magnetic properties for operation.

1005.5.2.12.2 Protective relays must be of microprocessor based IED type and capable of interconnecting with PLC supervisory devices

1005.5.2.12.3 Protective relays must be enclosed in rustproof, dust-proof, high-impact cases with test switches.

1005.5.2.12.4 Relays must be flush mounted with wiring connections on the back.

1005.5.2.12.5 Relays must be visible, accessible for maintenance, and grouped with devices of related functions.

1005.5.3 Power Monitoring

1005.5.3.1 Separate sub-metering for each electrical load type including lighting, HVAC, receptacles, and vertical transportation must be provided at a minimum.

1005.5.3.2 Sub-metering must be provided per the latest Seattle Energy Code requirements including for facilities outside the limits of the city.

1005.5.3.3 Sub-metering requires coordination across multiple disciplines and with ST PSO Engineering, Sustainability, Systems and Information Technology to develop communication configuration for integrating information with ST's existing EPMS. Basis of Design must identify configuration.

1005.5.3.4 Specify the additional metering, its communication protocol and network hardware, software, and licensing to incorporate new meters in the existing EPMS.

1005.5.3.5 Determine what is included in each subcontractor's scope of work. Coordinate with Set 1004 Building Monitoring and Control.

1005.5.3.6 See additional requirements for meter communications in Set 1004 Building Monitoring and Control.

1005.5.4 Backup Power

1005.5.4.1 All electrical loads must be classified as critical, essential, or nonessential. Essential Systems are described below and addressed as Backup Power for Tunnel Systems. Nonessential loads are loads not defined as Critical or Essential.

1005.5.4.2 Configuration and applicability of backup power must be identified in the Basis of Design identified in EP-03.

1005.5.4.3 Critical Systems

1005.5.4.3.1 Backup electrical system for critical loads must meet the requirements of NEC Article 700 with a minimum battery backup time of 90 minutes.

1005.5.4.3.2 Electrical service to critical loads must be from a normal source and must transfer to an alternate source within a quarter cycle.

1005.5.4.3.3 The following critical loads must be serviced from a UPS:

1005.5.4.3.3.1 Fire control room/fire command center.

1005.5.4.3.3.1.1 All control panels supporting functionality.

1005.5.4.3.3.1.2 Lighting.

1005.5.4.3.3.1.3 Receptacles.

1005.5.4.3.3.2 Emergency Lighting (Means of Egress Lighting)

1005.5.4.3.3.2.1 If station UPS load consists of only lighting, a central lighting inverter may be used.

1005.5.4.3.3.3 Tunnel and cross passage lighting.

1005.5.4.3.3.4 Control power for critical or essential systems.

1005.5.4.3.3.5 Security control and indicator systems.

1005.5.4.3.4 Service the following critical loads from the communications UPS:
Commentary: The backup power strategy for sensitive electronic equipment is fundamentally different than for lighting which necessitates a separate UPS dedicated to these loads.

1005.5.4.3.4.1 Emergency signage, to include any automated emergency messages such as VMS messages.

1005.5.4.3.4.2 Closed-circuit television.

1005.5.4.3.4.3 Public address.

1005.5.4.3.4.4 Radio.

1005.5.4.3.4.5 Emergency Communications as defined in Set 601 Fire/Life Safety and Set series 300 Operational Communications.

1005.5.4.3.4.6 Access card readers.

1005.5.4.3.4.7 Supervisory control, automation, and monitoring to support devices listed in items 1 through 6 above.

1005.5.4.3.5 Electrical power for critical loads must be from a UPS or a battery system directly supplying DC powered equipment. Service the UPS or battery charger from the essential power source where available.

1005.5.4.3.6 Fire detection and other critical systems that require low voltage DC for normal operation may utilize internal battery DC power supplies.

1005.5.4.4 Essential Systems

1005.5.4.4.1 Electrical service to essential loads must be from a normal source and must transfer automatically to an alternate source within 10 seconds.

1005.5.4.4.2 Alternate electrical system sources must consist of a stationary generator system or an alternate utility source. Alternate utility services are acceptable only if demonstrated to be substantially independent as defined in Chapter 7 of the NEC and meet with approval from the AHJ and Sound Transit.

1005.5.4.4.3 See parking garage and link tunnel specific requirements in Section 1005.5.9 Electrical Systems and Locations.

1005.5.5 Electric Passenger Vehicle Charging

Commentary: Coordinate EV design with Sound Transit Sustainability's design requirements memorandum.

1005.5.5.1 When electrical vehicle charging stations are required, install level 2 and level 3 chargers per the Washington State Energy Code and as specified in each project.

1005.5.5.2 Level 2 charging distribution panel or panels are to be circuited with 208 volts. If three-phase power is not available, 240-volt service may be used. Coordinate with Set 803 Sustainability.

1005.5.5.3 Level 3 charging distribution panels are to be circuited with 480-volt three-phase service. Coordinate with Set 803 Sustainability.

1005.5.5.4 Non-revenue vehicle and public-facing chargers must be metered separately. See Section 1005.4.3 Power Monitoring in this set.

1005.5.5.5 For level 2 chargers, conform car connector to SAE J1772.

1005.5.5.6 All charging stations must be equipped with charge management capability or must integrate to centralized charge management software.

1005.5.5.7 All charging stations must be compatible with Sound Transit's enterprise electrical vehicle charge management system.

1005.5.6 Photovoltaic Systems

1005.5.6.1 Facility designs must incorporate any solar readiness requirements in place within the facility's jurisdiction.

1005.5.6.2 The solar PV system must be designed for rooftop applications to collect and manage energy produced by solar panels as a grid-tied system.

1005.5.6.3 The PV system must be interconnected to the local utility provider power grid as well as to the facility service distribution equipment.

1005.5.6.4 Each PV system must be designed with utility production metering and, if allowed, a utility net meter to return excess energy to the power grid.

1005.5.6.5 The PV system must consist of traditional opaque-back sheeted monofacial panels, inverter, DC disconnect to solar arrays, AC disconnect to utility production meter from distribution equipment, utility production meter, utility net meter, external rapid shutdown, and appropriate signage.

1005.5.6.6 All equipment must be UL listed and labelled.

1005.5.6.7 Cable and conduit must be designed for rooftop applications and wet weather conditions.

1005.5.6.8 PV system components must be in a secure area, concealed from public reach and view, and protected from weather.

1005.5.6.9 Utility production meter, utility net meter and associated AC disconnects must be accessible to the utility and not located behind access-controlled doors, gates, or fences.

1005.5.6.10 Utility production meter, utility net meter, associated disconnects, and interconnections must be as required by the local utility.

1005.5.6.11 Utility production meter must be specified as revenue grade quality.

1005.5.6.12 The PV system must be designed for no more than 100 kilowatts AC unless approved by Sound Transit and meet minimum size requirements specified in local energy codes.

1005.5.6.13 Designs must indicate maximum power provided at the production meter in AC kilowatts.

1005.5.6.14 Maximum voltage must be calculated according to NEC 690 and adjusted for voltage correction factors as necessary per WAC.

1005.5.6.15 Inverters must be located so that all maintenance will occur at grade level or in easily accessible locations.

1005.5.6.16 Inverters must include RS-485 or Ethernet communication features. Reference 1004 Building Monitoring and Control Systems for additional monitoring requirements.

1005.5.6.17 Solar panel placement must be designed to be south facing and to adhere to access way requirement. Coordinate with Set series 700 Structures and Set series 800 Architecture.

1005.5.6.18 Solar panels must incorporate a rapid shutdown separate from the inverter as required in NEC and local codes.

1005.5.6.19 Solar array panels must be in easily accessible locations for maintenance personnel and maintenance equipment. Top of array heights must be determined by designer and coordinated with Sound Transit.

1005.5.6.20 Solar array panels must be located within 75 feet of a hose bibb.

1005.5.6.21 Solar array panels and associated fire sprinkler system (if applicable) must be designed above 9 feet, out of the touch zone.

1005.5.6.22 Shape and size of solar array must allow maintenance personnel to reach each component without climbing on panels or using equipment over the panels.

1005.5.6.23 PV system design must be coordinated with lighting design. Reference Set 1007 Electrical Lighting.

1005.5.6.24 PV system design must be coordinated with building structural design to accommodate system loads as well as any equipment required for maintenance.

1005.5.7 Grounding
Electrical raceways, fittings, and equipment must be grounded as required by the NEC.

Commentary: See Link specific requirements in Section 1005.5.9 Electrical Systems and Locations.

1005.5.8 Calculations and Studies

1005.5.8.1 Provide all documentation and calculations required for obtaining an electrical permit. Research electrical and energy use requirements for each municipality.

1005.5.8.2 Designs for new facilities must include a lightning risk assessment performed in accordance with NFPA 780. Provide lightning protection system if required by the assessment. Electrical system requirements must be based on load calculations.

1005.5.8.3 Perform calculations for backup power system including all mode scenarios and demonstrating that UPS sizing can meet anticipated nominal, peak, and emergency load conditions.

1005.5.8.4 Electrical system calculations must be stamped and sealed by a Washington State licensed electrical engineer.

1005.5.8.5 Provide preliminary short circuit, coordination, load flow and voltage drop studies with electrical system designs.

1005.5.8.6 Studies analyzing proposed equipment must be performed and made available to Sound Transit prior to equipment approval.

1005.5.8.7 Short circuit study must demonstrate that all equipment is rated for the available fault current at its respective location in the power distribution system. Series-ratings are not allowed.

1005.5.8.8 Coordination study must demonstrate that, to the extent possible, phase overcurrent and ground fault devices are coordinated such that ground faults, short circuits, or overloads trip only the immediate upstream protective device from the point of fault or overload.

1005.5.8.9 Perform arc flash calculations for normal and backup power sources. Coordinate with Sound Transit for mode scenarios.

1005.5.8.10 Provide as-built short circuit, coordination, arc flash, load flow and voltage drop studies performed by the equipment manufacturer or a third-party entity primarily engaged in power system analyses.

1005.5.8.11 After final study approval, install arc flash labels conforming to NFPA 70E on electrical distribution equipment. Labels to be durable and weather resistant.

1005.5.8.12 Maintenance facility design must include hazardous area classification analysis per NEC 500.

1005.5.8.13 Complex Analyses

1005.5.8.13.1 Perform motor starting, transient switching, and harmonic analyses for electrical systems with significant motor loads, variable frequency drives or Sound Transit-owned medium voltage transformers.

1005.5.8.13.2 Perform transient switching study and submit to Sound Transit to support snubber sizing. Calculations to be performed specifying the transformer using the most conservative information available at the time.

1005.5.8.13.3 The designer and Sound Transit must determine which systems have a large enough quantity of nonlinear loads (e.g., VFDs and soft starts) to require a harmonic/IEEE 519 study. Tunnel stations would typically fall under this requirement.

1005.5.8.13.4 Tunnel ventilation system designers must provide an analysis of the effect of starting all tunnel emergency fans within the time prescribed by NFPA 130 on the electrical system. Reference Set 601 Fire-Life Safety and coordinate starting timing and sequences with Sound Transit.

1005.5.9 Electrical Systems and Locations

1005.5.9.1 Grounding

1005.5.9.1.1 Major metal components within 15 feet of centerline of track including platform structures, shelters, fences, poles, guardrails at platforms and along the guideway, handrails, doors, art and bollards that are susceptible to contact by patrons and/or operating and maintenance personnel and likely to become energized by a fallen overhead contact wire must be electrically bonded to the ground electrode.

Commentary: Incidental metallic objects separated in their entirety by a station structure are not required to be grounded as they are protected from a falling OCS by the structure.

1005.5.9.1.2 Conductive fencing within 15 feet of the centerline of track must be grounded. Where a fence is interrupted by gates, ground each side of the gate, and use a flexible ground strap to bond the gate to the fence.

1005.5.9.1.3 Fences at or near the location of a DC supply line or lines crossing them and at distances not exceeding 150 feet on either side must be grounded.

1005.5.9.1.4 Rail and equipment in contact with rail including switch machine, signal devices, train communication systems and other devices or systems that may contact the rail are specifically excluded from the requirements above and are to be isolated from ground.

1005.5.9.1.5 Tunnel handrails do not need to be grounded.

1005.5.9.1.6 Exposed conductive surfaces within 6 feet of the train body for the length of the platform are prohibited.

Commentary: Per IEEE 2720, directly grounded conductive infrastructure must not be permitted within reach of trains.

Commentary: Reference Grounding section of Set 1006 Raceway.

1005.5.9.2 Operations and Maintenance Facilities

1005.5.9.2.1 Sound Transit owned medium voltage service transformers for maintenance facilities must include 40 percent spare capacity.

1005.5.9.3 Parking Garages

1005.5.9.3.1 Underground garage ventilation and sump pumps must include circuiting to an alternate power source.

1005.5.9.4 Guideway: Tunnel & Above Ground

1005.5.9.4.1 Use NEMA 4X enclosures for all electrical distribution equipment.

1005.5.9.4.2 Backup Power for Tunnel Systems

Commentary: Existing Sound Transit tunnel stations are serviced by SCL in Seattle and PSE in Bellevue and are provided with power from multiple substations along the alignment. Except for some downtown Seattle locations, stations are connected at the medium voltage level via switchgear and cabling routed through the tunnel bores. Each station is always guaranteed power from more than one utility substation.

1005.5.9.4.2.1 Redundant power sources adhering to NEC 700 are required for designated loads, per NFPA 130.

Commentary: An interconnected Sound Transit owned medium voltage electrical distribution system is the preferred method if servicing utility cannot supply two substantially independent sources. A stationary generator can be considered if approved by Sound Transit.

Commentary: It is not the intention of this requirement to imply or require that traction electrification be tied to the interconnected system discussed herein.

1005.5.9.4.2.1.1 Redundant electrical distribution system must be physically separated.

1005.5.9.4.2.1.2 Tunnel cabling must be protected from damage resulting from a train derailment or other accident.

1005.5.9.4.2.1.3 Cabling must be protected from the effects of fire. Reference Set 601 Fire-Life Safety.

1005.5.9.4.2.1.4 Documented Sound Transit and AHJ approval must be provided for tunnel backup power system architecture.

1005.5.9.4.2.2 A Sound Transit owned interconnected medium voltage electrical distribution system must include a monitoring and control system that securely communicates with the Link control center.

1005.5.9.4.2.2.1 The control system must include capability to manually and safely open and close circuit breakers.

1005.5.9.4.2.2.2 The control system must include local HMI at each AC switchgear location as well as a fully operational HMI located at the Link control center.

1005.5.9.4.2.3 Critical loads as described in Section 1005.5.4 Backup Power must be provided with a backup power source.

1005.5.9.4.2.4 Essential loads include:

1005.5.9.4.2.4.1 Tunnel ventilation fans and dampers.

1005.5.9.4.2.4.2 Tunnel sump pumps.

1005.5.9.4.2.4.3 Tunnel station ventilation and pressurization fans and dampers.

1005.5.9.4.2.4.4 Tunnel stair and elevator hoistway pressurization fans.

1005.5.9.4.2.4.5 Tunnel track isolation dampers.

1005.5.9.4.2.4.6 Tunnel station loads.

1005.5.9.4.2.4.7 Tunnel communications room ventilation fans, dampers, and cooling equipment.

1005.5.9.4.2.4.8 Tunnel mechanical controls.

1005.6 ENGINEERING MANAGEMENT REQUIREMENTS

1005.6.1 Interface and Integration Management

1005.6.1.1 The design must consider and account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructable documentation, and functional designs.

1005.6.1.2 A power single-line diagram must be created for each electrical service.

1005.6.1.3 The single-line includes all power distribution equipment to the panelboard level and depicts backup power circuiting if applicable.

1005.6.2 Design Management

1005.6.2.1 For additions to existing systems, an assessment must be performed to identify system limitations. Remaining spare capacity must be documented.

1005.6.3 Manufacturing and Construction Management

1005.6.3.1 Power single-line diagrams must be kept current during construction and made available for Sound Transit's review upon request.

1005.6.3.2 Equipment submittals must include sufficient power system calculations, including preliminary short circuit and device coordination, to ensure equipment adequacy in the equipment's location in the distribution system.

1005.6.4 Installation Management

1005.6.4.1 Adhere to NECA installation standards including the Standard Practice of Good Workmanship in Electrical Contracting.

1005.6.4.2 Develop Energy Control Program (lockout/tagout) for each power distribution system. Conform to NFPA 70E and WAC safety standards for lockout/tagout.

1005.6.5 Inspection and Testing Management

1005.6.5.1 The design must adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

1005.6.5.2 Device configuration records and software setpoint files must be maintained during installation and startup and finalized versions must be delivered to Sound Transit following commissioning.

1005.6.6 Training, Pre-Revenue Operations

1005.6.6.1 Provide and document training for Sound Transit and partner agency maintainers on the energy control program (lockout/tagout). Coordinate with Sets 1002 Mechanical and 1003 Plumbing.

1005.6.7 Certification Management

1005.6.7.1 Electrical permits that have been signed off by the AHJ must be delivered to Sound Transit.

1005.7 APPENDICES (NOT USED)

END SET - 1005

1006 ELECTRICAL RACEWAY

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SET - 1006 TABLE OF CONTENTS

TABLES

FIGURES

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SET - 1006 ELECTRICAL RACEWAY

1006.1 INTRODUCTION

1006.1.1 Document Scope

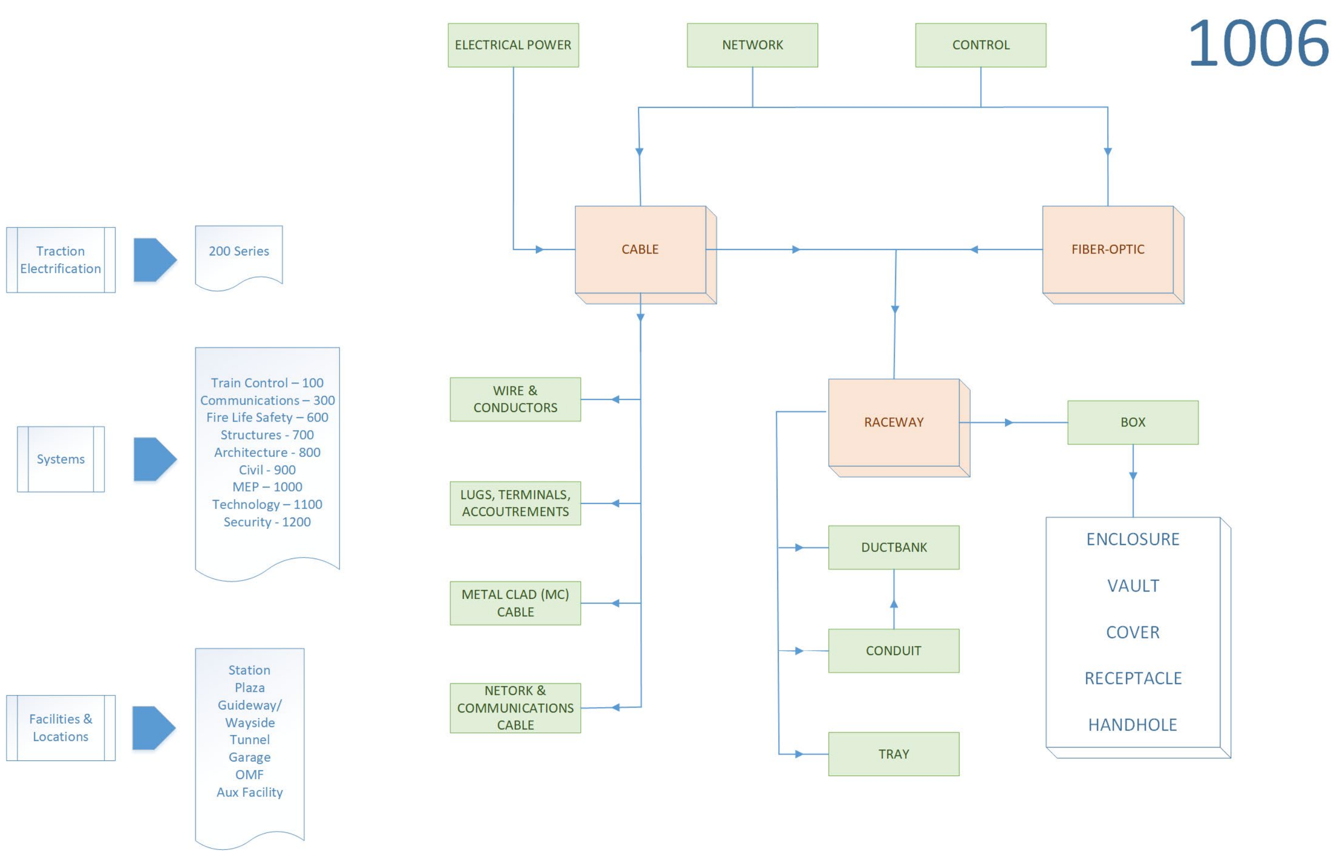
1006.1.1.1 The set establishes electrical raceway, cables, conductors, and enclosure design criteria for Sound Transit facilities including, but not limited to, passenger stations, park and ride facilities, operations and maintenance facilities, parking garages, systems buildings, and signal, communications, and power duct banks. These criteria apply to all modes including Sounder and BRT and include requirements for the function and design of electrical and related systems raceway, cable tray, conductors, and cable.

1006.1.1.2 Refer to 200 Traction Electrification for electrical requirements specific to the DC traction power supply and distribution system.

1006.1.1.3 This section contains specific code references. The code references herein are based on the 2020 NFPA 70 (NEC), the 2021 NFPA 70E and the 2020 version of NFPA 130. Those specific references may change under future editions of the codes and standards.

1006.1.1.4 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 1006 owner to determine the technical source for the design criteria.

Figure 1006-1: System Context Diagram



1006.1.2 Regulations, Codes, Standards, and Guidelines

1006.1.2.1 International Regulations, Codes, Standards, and Guidelines

1006.1.2.1.1 International Building Code Chapter 30 with local amendments.

1006.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

1006.1.2.2.1 National Electrical Code (NFPA 70).

1006.1.2.2.2 Standard for Electrical Safety in the Workplace (NFPA 70E).

1006.1.2.2.3 Code of Federal Regulations Energy Efficiency Program for Certain Commercial and Industrial Equipment.

1006.1.2.2.4 NFPA 101 Life Safety Code.

1006.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

1006.1.2.3.1 Washington Administrative Code Electrical Safety Standards, Administration and Installation.

1006.1.2.3.2 Washington Industrial Safety and Health Act General Safety Standard.

1006.1.2.3.3 Seattle City Light Standards for Electrical Service.

1006.1.2.3.4 Puget Sound Energy Electric Service Handbook.

1006.1.2.3.5 Seattle Electrical Code.

1006.1.2.3.6 Snohomish Public Utilities District Electric Service Requirements.

1006.1.2.3.7 Tacoma Public Utilities Electrical Construction Standards.

1006.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

1006.1.2.4.1 American National Standards Institute (ANSI).

1006.1.2.4.2 Underwriters Laboratory (UL).

1006.1.2.4.3 UL 1072 Standard for Medium Voltage Power Cables.

1006.1.2.4.4 UL 2420, 2515, 2515A.

1006.1.2.4.5 International Electrical Testing Association (NETA).

1006.1.2.4.6 National Electrical Manufacturers Association (NEMA).

1006.1.2.4.7 NEMA WC 74 Shielded Power Cable for Use in the Distribution and Transmission of Electric Energy.

1006.1.2.4.8 National Electrical Installation Standards' Good Workmanship in Electrical Construction.

1006.1.2.4.9 Institute of Electrical and Electronics Engineers (IEEE) National Electrical Safety Code.

1006.1.2.4.10 IEEE Guide for Safety in AC Substation Grounding.

1006.1.2.5 Other Jurisdictions

1006.1.2.5.1 Local municipal codes often amend the NEC and other electrical codes and standards. All local amendments apply including those adopted during design unless the design has been formally vested in writing with the AHJ.

1006.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

1006.1.2.6.1 Sound Transit Electrical Safety Program.

1006.1.2.6.2 Sound Transit Equipment and Facilities Numbering Standards.

1006.1.2.6.3 Sound Transit Design Technology Manual.

1006.1.2.6.4 Interface Coordination and Integration Plan.

1006.1.2.6.5 General Testing and Commissioning Plan.

1006.1.2.6.6 Sound Transit Systems Standard Drawings and Specifications.

1006.1.3 Abbreviations and Acronyms

1006.1.3.1 AWG– American wire gauge

1006.1.3.2 AHJ–authority having jurisdiction

1006.1.3.3 BMS–building management system

1006.1.3.4 EMT-electrical metallic tubing

1006.1.3.5 ENT-electrical non-metallic tubing

1006.1.3.6 EPR–ethylene propylene rubber

1006.1.3.7 FHIT-Electrical Circuit Integrity System of the UL Fire Resistive Directory

1006.1.3.8 GRS–galvanized rigid steel conduit

1006.1.3.9 HVAC–heating, ventilation, and air conditioning

1006.1.3.10 I/O–input/output

1006.1.3.11 NEC-National Electrical Code

1006.1.3.12 PSO–portfolio services office

1006.1.3.13 TPSS–traction power substation

1006.1.3.14 TVM–ticket vending machine

1006.1.3.15 WSDOT–Washington State Department of Transportation

1006.1.4 Definitions and Classifications

1006.1.4.1 Box: Any enclosure measuring fewer than 12 square inches.

1006.1.4.2 Cable Tray: mechanical support systems that provide a rigid structural system for electrical cables, raceways, and insulated conductors used for electric power distribution, control, signal instrumentation and communication,

1006.1.4.3 Duct bank: Group of conduits designed to protect and consolidate cabling to and from buildings. In a duct bank, data and electrical cables are laid out within conduits that are bundled together. These groupings of conduit are protected by concrete and metal casings.

1006.1.4.4 Electrical metallic tubing: An unthreaded thinwall raceway of circular cross section designed for the physical protection and routing of conductors and cables.

1006.1.4.5 Enclosure: Any box measuring equal to or greater than 12 square inches.

1006.1.4.6 Facility service transformer: The transformer supplying power to the facility.

1006.1.4.7 Galvanized rigid steel conduit: Galvanized steel tubing with a wall that is thick enough to allow it to be threaded.

1006.1.4.8 Indoor distribution transformer: The transformers in the facility after the facility service transformer.

1006.1.4.9 Liquidtight flexible metal conduit: A metallic flexible conduit covered by a waterproof plastic coating.

1006.1.4.10 Raceway: An enclosed channel designed expressly for holding wires, cables, or busbars.

1006.1.5 References (Not Used)

1006.2 STAKEHOLDER NEEDS

1006.2.1 Passenger Experience

1006.2.1.1 PSO Engineering's mission is to protect and uphold the integrity of the technical requirements to ensure passenger satisfaction and safe, quality, reliable and durable operations through establishing, integrating, and managing the needs of the agency through engineering, core systems and facility requirements.

1006.2.2 Operational Needs

1006.2.2.1 Stations and garages are operated without a continual presence of operators or maintenance people. Designs must account for unattended facilities.

1006.2.2.2 Maintenance facilities are operated 24 hours a day 7 days a week in support of operating transportation service and maintaining the associated systems, buildings, and infrastructure

1006.2.3 Maintenance Needs

1006.2.3.1 Maintenance at stations and garages is typically reserved for periods that do not impact passengers, limiting maintenance windows to non-revenue periods unless scope can be performed without passenger impact. Designs must account for narrow maintenance windows.

1006.2.3.2 Ensure raceways are useable and maintainable for their expected lifetimes.

1006.2.4 Safety Needs

1006.2.4.1 Passenger, operator, and maintainer safety for normal operations and emergency operations must be accounted for in designs.

1006.2.5 Security Needs

1006.2.5.1 Station and garage elements accessible to passengers must incorporate consideration to prevent theft and vandalism, including material selection and placement. Ensure raceways are secured from the public.

1006.2.6 Reliability, Availability and Maintainability Needs

1006.2.6.1 Material and equipment selection must consider the operating environment and small maintenance windows associated with public transportation.

1006.2.6.2 Raceway systems must be protected and maintainable.

1006.2.6.3 Where exposed or surface mounted, raceway must be readily accessible for inspection and maintenance.

1006.2.6.4 Pull boxes, junction boxes, gutters, and other accessible raceway components must not be obstructed.

1006.2.6.5 Coordinate with all applicable power, control, and networking users to ensure raceways are integrated as needed.

1006.2.7 Environmental and Sustainability Needs

1006.2.7.1 Facility designs must promote stewardship of resources and utilities when selecting material, equipment selection, and operational strategies with the goal of conservation and efficiency.

1006.3 SYSTEM REQUIREMENTS

1006.3.1 General Requirements (Not Used)

1006.3.2 Functional Requirements

1006.3.2.1 Electrical conduits, junction boxes, and appurtenances required to support wiring systems must be hidden from public view by locating them in an organized manner within raceways, cable trays, or chases.

1006.3.2.2 Raceways and chases must provide reasonable access and must accommodate future conduit.

1006.3.2.3 Where conduit must be exposed to public view to connect to equipment or fixtures, install conduit, boxes, and appurtenances in an organized manner, tight to adjacent surfaces, and painted to match those surfaces.

1006.3.2.4 Design raceway and chases to deter bird roosting. Where conduit is exposed in public or non-public areas outside of closed rooms, provide bird deterrent devices. Coordinate with Set series 800 Architecture.

1006.3.2.5 Expansion fittings must be used where raceway passes through structural expansion joints.

1006.3.2.6 When raceway is installed through a floor or wall penetration, a sealing compound with fire retardant rating that is specifically manufactured for the electrical system must be used to finish the surface to architectural requirements.

1006.3.2.7 Conductors, conduits, pull boxes, and materials must be properly identified, tagged, and labeled.

1006.3.2.8 Conduits must be used between non-public ancillary rooms.

1006.3.2.9 Cable tray must not be used in public spaces.

1006.3.2.10 Cable tray must be located away from obstructions and maintain appropriate clearance from signal racks, doors, HVAC equipment, and other equipment that requires a maintained space.

1006.3.2.11 Coordinate with Set series 800 Architecture and Sets 1002 Mechanical–Plumbing and 1003 Mechanical-HVAC.

Commentary: Horizontal cable tray should be located at least 36 inches from walls except at entrance and exit points.

1006.3.2.12 Conductors for emergency lighting, communications, and other systems required during emergency operations must be protected from physical damage from transit vehicles or other normal transit system operations and from fires.

1006.3.2.13 All emergency lighting branch circuits must be carried in separate conduits running from the emergency lighting power supply to the emergency lighting fixture.

1006.3.3 Performance Requirements

1006.3.3.1 All conduit in contact with soil must be non-metallic unless metallic materials are required for specific engineering purposes.

1006.3.3.2 Conduits leading from facility walls or roofs must be routed to avoid rainwater.

1006.3.3.3 Conduits must be insulated and routed to prevent water running in or along the conduit to equipment.

1006.3.3.4 Corrosion control measures must be provided as appropriate for the application and in accordance with industry standards. Refer to Set 902 Utilities and Set 222 Stray Current Corrosion Control.

1006.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

1006.4.1 System Breakdown Structure

The Electrical Raceway Set can be broken down into the following elements:

1006.4.1.1 Raceway

1006.4.1.1.1 Materials

1006.4.1.1.2 Duct bank Construction

1006.4.1.1.3 Conduit

1006.4.1.2 Wire and Wiring Devices

1006.4.1.2.1 Public and Non-Secure Spaces

1006.4.1.2.2 Cover Fasteners

1006.4.1.2.3 Receptacles

1006.4.1.2.4 Enclosures

1006.4.1.2.5 Wire

1006.4.1.2.6 Coordination with Subsystems

1006.4.1.3 Grounding

1006.4.1.4 Calculations and Studies

1006.4.1.5 System Sites and Locations

1006.4.1.5.1 Facilities

1006.4.1.5.1.1 Stations

1006.4.1.5.1.2 Parking Garage

1006.4.1.5.1.3 Operations and Maintenance Facility

1006.4.1.5.2 Guideway: Tunnel & Above Ground

1006.4.1.5.3 Wayside Facilities

1006.5 SYSTEM INTERFACE REQUIREMENTS

Table 1006-1: Interface Between Mechanical/Electrical and Building Systems and Other Disciplines

SET SERIES	SET NAMES	SET 1006 INTERFACE
100	Signals/Train Control	X
200	Traction Electrification	X
300	Communications / Technology	X
400	Vehicles / Noise and Vibration	
500	Track	X
600	Fire/Life Safely	X
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical/Electrical and Building Systems	X
1100	Technology	X
1200	Security	X

1006.5.1 Train Control and Signals

1006.5.1.1.1 Coordinate raceway/pathway for service entrance and any sharing of raceway with non-signals elements.

1006.5.1.2 Traction Electrification

1006.5.1.2.1 Coordinate raceway/pathway for service entrance.

1006.5.1.2.2 Coordinate raceway/pathway for TPSS fed from Sound Transit owned power network.

1006.5.1.2.3 Refer to Set 200 Traction Electrification for conduit requirements

1006.5.2 Operational Communications

1006.5.2.1 Coordinate for raceway/pathway, cables and conduit for facilities, wayside, and guideway services.

1006.5.3 Track

1006.5.3.1 Coordinate for raceway/pathway, conduit for power, signals, communications to and on guideway.

1006.5.4 Fire/Life Safety

1006.5.4.1 Coordinate for raceway/pathway, boxes, cables, and conduit for facilities.

1006.5.5 Structures

1006.5.5.1 Coordinate for embedded raceway, conduit.

1006.5.6 Architecture

1006.5.6.1 Coordinate for visible and embedded raceway, conduit.

1006.5.7 Civil

1006.5.7.1 Coordinate for manhole/handhole and buried raceway.

1006.5.8 Mech/Electrical and Building Systems (MEP)

1006.5.8.1 Coordination required for raceway, cable, and conduit for multiple MEP elements.

1006.5.9 Technology

1006.5.9.1 Coordinate for raceway, cable, conduit, and tray requirements.

1006.5.10 Security

1006.5.10.1 Coordinate for raceway, cable, and conduit.

1006.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

1006.6.1 Raceway

1006.6.1.1 Wires and cables must be protected by raceway except for low voltage signal or communications wiring routed from cable tray to rack or medium voltage MC cable where protected from physical damage.

1006.6.1.2 Provide 20 percent spare raceway fill capacity. At the completion of the project, space utilized plus spare capacity must not exceed the NEC allowable limit.

1006.6.1.3 Spare empty conduit must be provided for embedded raceway. Deviation requests must include tabulated quantities per location and be submitted for approval.

1006.6.1.4 Spare conduit must be installed with pull strings.

1006.6.1.5 Materials

1006.6.1.5.1 All raceway materials including conduit, ducts, boxes, cabinets, and enclosures must be constructed of non-combustible materials in accordance with NFPA 130 where required.

1006.6.1.5.2 Direct buried PVC Conduits used in heavy traffic areas, vehicular traffic areas, and heavy pedestrian traffic areas must be schedule 80. Direct buried schedule 40 conduits may be used in landscaping areas or light traffic areas.

1006.6.1.6 Duct bank construction requirements

1006.6.1.6.1 Duct banks must be constructed in accordance with Sound Transit standard drawings.

1006.6.1.6.2 Duct banks must be constructed per AHJ requirements. Should standards conflict, the more restrictive one will apply.

1006.6.1.6.3 Raceways passing under roadways must be protected from damage from passing vehicles. Duct banks will be located longitudinally along the length of the track and between the tracks.

1006.6.1.6.4 Lateral crossings underneath the tracks are not allowed without approval from Sound Transit. Where necessary, duct bank may be located directly under the tracks longitudinally, but in no case may a manhole or handhole be located between the rails.

1006.6.1.6.5 Where obstacles such as pole bases are encountered, the duct bank must be gradually offset around the structure and always retain the minimum dimensions of the envelope and structural integrity.

1006.6.1.6.6 Manholes, handholes, and vaults must be constructed in accordance with Sound Transit standard drawings and AHJ construction service guides. If the AHJ has no vault requirement, Seattle City Light electrical service guide must be followed.

1006.6.1.6.7 Locate manholes, handholes, and vaults out of areas of water accumulation and drainage paths. Water accumulation in manholes, handholes, and vaults must be prevented.

1006.6.1.6.8 Medium voltage feeders must be routed in GRS or concrete-encased RTRC and PVC. FRE applications must be approved on a case-by-case basis.

1006.6.1.6.9 Medium voltage conductors must be separated from other systems.

1006.6.1.6.10 If required because of electromagnetic interference, medium voltage AC conductors must be routed in GRS conduit.

1006.6.1.6.11 The effects of electromagnetic interference must be mitigated.

1006.6.1.6.12 Concrete used for medium voltage duct bank encasement must be dyed substantially red in color. Provide marking tape appropriate for high voltage electrical circuits and install tape 12 inches above the top of the duct bank or conduit run.

1006.6.1.6.13 Duct bank must be sloped to drain to manholes, vaults, or handholes and located to avoid interference with existing utilities.

1006.6.1.6.14 Where no manholes, vaults, or handholes exist, duct bank must be sloped away from buildings.

1006.6.1.7 Conduit

1006.6.1.7.1 Where multiple conduits or ducts are run as a duct bank, plastic spacers must be used to support the rows.

1006.6.1.7.2 Where multiple conduits or ducts are run as a duct bank, a two-inch minimum separation must be maintained.

1006.6.1.7.3 Rigid non-metallic conduit must not be used for the support of lighting fixtures.

1006.6.1.7.4 Conduit must be no smaller than ¾ inch.

1006.6.1.7.5 Conduit Bends

1006.6.1.7.5.1 No more than 270 degrees of conduit bend is permitted between pull points.

1006.6.1.7.5.2 Bend radii (measured to the inside curvature of the raceway) must be per NEC Chapter 9 Table 2.

1006.6.1.7.5.3 Minimum bend radius for medium voltage power conduits is given in the following table:

Table 1006-2: Minimum Conduit Bend Radius

Nominal Conduit Size (inches)	Conduit Bend Radius (inches)
2	24
2-1/2	27
3	30
3-1/2	33
4	36
5	60 for 26 kV 3C cable 42 for other
6	48

1006.6.1.7.5.4 If conduit segment length (between pull points) is greater than 200 feet, bend radius in Schedule 40 PVC conduit must be limited to no less than six feet.

1006.6.1.7.5.5 For installation of three-conductor type MC power cable, the minimum conduit bend radius must be limited to 60 inches.

1006.6.1.7.5.6 Field bends must be made using bending equipment and procedures acceptable to the conduit manufacturer.

1006.6.1.7.6 Conduit Types and Applications

Table 1006-3: Conduit Types and Applications

Location	Application (Note 5)	Raceway
Below grade or embedded in slabs or walls per NEC (Note 1)	Encased in concrete or direct buried	Corrosion wrapped GRS
		PVC
		RTRC/Epoxy Fiberglass-XW
Underground structures including tunnels	Conforming to NFPA 130	GRS
		Phenolic Fiberglass
Above grade (Note 2)	RTRC/Epoxy Fiberglass-XW conduit is prohibited for use in the S/C raceway and locations with direct sun exposure.	Corrosion wrapped GRS
		GRS
		RTRC/Epoxy Fiberglass-XW
10 feet above finished floor in non-underground stations or buildings, or in interior walls between conditioned spaces (Note 3)	Not exposed to corrosive chemicals or wet environments	RTRC/Epoxy Fiberglass
		EMT
Parking structures (Note 4)	Embedded in parking deck ONLY	ENT
Note 1: All stubs above grade must be GRS, or, where protected from physical damage, epoxy or phenolic fiberglass conduit. RTRC/Epoxy must conform to UL 2420, 2515 & 2515A. Where conduits enter the building below grade, provisions must be made to seal the interior of conduit to prevent water from traveling along cables to the interior of electrical equipment or boxes. Duct banks must conform to the local codes for construction and protection.		
Note 2: Corrosion wrapped GRS is required in corrosive environments. RTRC/Epoxy must conform to UL 2420, 2515 & 2515A.		
Note 3: Galvanized EMT conduit may be used with the following conditions: Strict adherence to NFPA 70 and with compression fittings only. Galvanized EMT is not allowed for use in parking decks or on the underside of the deck where it can be exposed to salt or other corrosive chemicals. EMT is not permitted for use in substations or for Link station and garage communications applications. RTRC/Epoxy must conform to UL 2420, 2515 & 2515A.		
Note 4: All stubs above grade must be GRS, or, where protected from physical damage, epoxy or phenolic fiberglass. Where the conduit exits the parking deck slab, only GRS is allowed. Exposed ENT is prohibited. Boxes must be metal, and fittings must be suitable for ENT. Boxes must be capable of supporting 50 lbs.		
Note 5: All fire-rated circuits, where required, must conform to UL 2196 as a rated FHIT system of raceways, conductors, and supports per UL 2196.		

1006.6.2 Wire and Wiring Devices

1006.6.2.1 Include nametags for conduit, junction boxes, and other raceway appurtenances adhering to Sound Transit's naming and numbering standards.

1006.6.2.2 Public and Non-Secure Spaces

1006.6.2.2.1 In public and/or nonsecure spaces, security must be integrated into pull boxes, hand holes, manholes, vaults, light pole covers, and all other applicable raceway components.

Commentary: Generally applicable for installations below 10 feet above finished floor in public areas that are secure in non-revenue hours.

1006.6.2.2.1.1 Enclose external electrical equipment with non-scalable barriers of suitable height which will also deter hurling objects into the enclosure.

1006.6.2.2.1.2 All boxes and vaults must have hardware and/or threading to accommodate the appropriate tamperproof, uniquely keyed fastener.

1006.6.2.2.1.3 Cover Fasteners

1006.6.2.2.1.3.1 Fasteners must be tamperproof and uniquely keyed.

1006.6.2.2.1.3.2 The fastener must be stainless steel and be able to repel locking pliers.

1006.6.2.2.1.3.3 The key must be nonsymmetrical, custom, and unique to Sound Transit.

1006.6.2.2.1.3.4 Fastener key heads are to match existing Sound Transit keyed fasteners.

1006.6.2.2.1.3.5 Sound Transit must be provided with ten ¼-inch hex drive key bits (Bryce Key-Rex Fastener with Raptor Claw option or approved equal).

1006.6.2.2.1.3.6 Covers must include two tamperproof fasteners, or more as required.

1006.6.2.2.1.3.7 Covers for boxes and vaults in pedestrian areas must have a recessed area for tamperproof fasteners.

1006.6.2.3 Receptacles

1006.6.2.3.1 Connection for a mobile generator, where required, must be limited to no more than 40 feet from the designated mobile generator parking area.

1006.6.2.3.2 In exterior, embedded and/or wet locations, receptacle boxes must be cast (galvanized) FS/FD type.

1006.6.2.3.3 In non-public spaces where receptacle is subject to spray or to weather, cover plates must be die-cast, copper-free aluminum with self-closing spring door and rubber gasket. Provide rain cover as needed.

1006.6.2.3.4 In public spaces, receptacles must be in recessed enclosures with flush lockable covers above the touch zone. Ceiling mount is preferred. Plastic covers are not allowed.

1006.6.2.3.5 Receptacles must be located to allow full coverage of all areas of all facilities, including vertical circulation elements, with a 75-foot electrical cord.

1006.6.2.3.6 Concession receptacles are to be 14-60R configuration as defined in NEMA WD6. Utilize a 240 Vac 60 amps circuit breaker, maximum.

1006.6.2.3.7 Weatherproof receptacle cover plates must be listed for wet locations.

1006.6.2.4 Enclosures

Commentary: Requirements of this section are not intended for enclosures that house any active device or that require heating or cooling. Refer to Set 1005 Electrical Power for power distribution equipment enclosures.

1006.6.2.4.1 Enclosure types must adhere to NFPA 70 and NFPA 130 based on applicability and environmental conditions.

1006.6.2.4.2 Enclosure type must adhere to NEMA 4X where subject to hose down and splashing.

1006.6.2.4.3 Enclosures for indoor use in non-public areas, other than for power distribution equipment specified in Set 1005 Electrical Power, must be NEMA 12 rated, minimum.

1006.6.2.4.4 Stainless steel and plastic enclosures are allowed. Plastic enclosures must be UV stabilized polycarbonate and used only in locations allowed by NFPA 130.

1006.6.2.5 Conductors and Cable

1006.6.2.5.1 Wiring in passenger facilities, garages, and maintenance facilities must be thermoset (XHHW, RHW or XHHW-2, RHW-2).

1006.6.2.5.2 Medium voltage conductor insulation must be EPR and conform to Sound Transit standard specifications.

1006.6.2.5.3 Coordinate with sets specific to communications and controls for networking, optical fiber, and I/O wiring.

1006.6.2.5.4 Coordinate with Set 601 Fire/Life Safety for fire alarm wiring requirements.

1006.6.2.5.5 Cables must be rated for the raceway or tray in which they are installed.

1006.6.2.5.6 Neutral conductors must be sized for 100 percent of the conductor load.

1006.6.2.5.7 Splicing must be minimized and approved by the resident engineer on a case-by-case basis. All underground or exterior splices must be epoxy sealed per WSDOT specification for 3M 82-F1 or 82-B1 Scotchcast Wye Resin Splice Kits or approved equal.

1006.6.2.5.8 Wiring internal to electrical switchgear and switchboards must be XLPE and sized per NEC Chapter 3.

1006.6.2.6 Coordination with Subsystems

1006.6.2.6.1 Coordinate raceway requirements with all other subsystems which require or provide electrical power to operate.

1006.6.2.6.2 Coordinate raceway requirements with all other subsystems that have a network connection.

1006.6.2.6.3 Dedicated raceway must be provided from an emergency lighting source to escalators to comply with emergency lighting requirement.

1006.6.2.6.4 Designer must coordinate with the escalator's manufacturer during design.

1006.6.2.6.5 Electrical Vehicle Charging stations must be provided with one 1-inch conduit minimum, routed from the electrical room to the charger.

1006.6.2.6.6 Coordinate with Set 902 Utilities on incoming service cable, conduit, and routing.

1006.6.2.6.7 One 1-inch conduit for power and one 1-inch conduit for data must be provided and connected to the communications equipment at each fare vending area for trip planners (dynamic rider information sign). Terminate conduit in a locking hand hole for future use in the TVM area.

1006.6.2.6.8 Shared Raceway

Commentary: Refer to BICSI TDDM and TIA-569-C for separation recommendations for EMI interference for all signal, controls, data, and power cables at all voltages.

1006.6.2.6.8.1 Conductors from different subsystems must not be mixed in the same raceway.

1006.6.2.6.8.1.1 Voltage levels in common raceway must adhere to NEC 300 and NEC 725 requirements.

1006.6.2.6.8.1.2 Power cables cannot share the same raceway as data, signal, and control cables unless allowed by other requirement sets.

1006.6.2.6.8.1.3 Medium voltage cables cannot share the same raceway, tray, or manhole as data, signal, control cables, and 600 volts and below cables.

1006.6.2.6.8.1.4 Medium voltage cables can only be in the same raceway, tray, or manhole with other medium voltage cables of the same voltage.

1006.6.2.6.8.1.5 120 Vac control cables must not be combined in the same raceway, tray, or manhole as 480 Vac and 120 Vac power cables.

1006.6.2.6.8.1.6 Lighting power cables must not be combined with lighting control cables in the same raceway.

1006.6.2.6.8.1.7 Do not combine 480/277 Vac cables in the same conduit as 120 Vac power cables.

1006.6.2.6.8.1.8 A 5-inch separation must be maintained between fluorescent lighting cables and Data, Signal, and Control cables.

1006.6.3 Grounding

1006.6.3.1 An equipment grounding conductor must be included with all power raceways.

1006.6.3.2 A separate wire for the bonding connection is required.

1006.6.3.3 Use of conduit or conduit bodies for bonding is not allowed.

1006.6.3.4 Grounding connections on mechanical and utility pipes, including water pipes, on the service side of dielectric couplings are prohibited.

1006.6.3.5 Ground wires must not be visible.

1006.6.3.6 Equipment grounding conductors must be sized per the NEC.

Commentary: Refer to Section 1005.5.7 Grounding in Set 1005 Electrical Power, and Section 1005.5.9 Electrical Systems and Locations.

1006.6.4 Calculations and Studies

1006.6.4.1 Electrical System calculations must be stamped and sealed by a Washington State licensed electrical engineer.

1006.6.4.2 Submit conduit fill and cable pulling calculations for Sound Transit approval. Calculations must be provided in sufficient detail to permit evaluation of the basis of design for the electrical distribution system.

1006.6.5 System Sites and Locations

1006.6.5.1 Facilities

1006.6.5.1.1 For raceway grouped in vertical risers and between rooms, 20 percent spare (empty) conduit for power and 20 percent spare (empty) conduit for data must be included. A minimum of one each of the same size already incorporated at the applicable location is required.

1006.6.5.1.2 For buried raceway grouped between manholes, handholes, and vaults, incorporate 20 percent spare (empty) conduit for power and 20 percent spare (empty) conduit for data. A minimum of one each of the same size already incorporated at the applicable location is required.

1006.6.5.1.3 Stations

1006.6.5.1.3.1 For canopies, designs must include a minimum of one spare (empty) conduit for power and one spare (empty) conduit for data of the same size already incorporated.

1006.6.5.1.3.2 Wiring in enclosed stations and trainways must conform to NFPA 130.

1006.6.5.1.3.3 Fire command centers must be equipped with quad receptacles located on each wall.

1006.6.5.1.4 Parking Garages (Not Used)

1006.6.5.1.5 Operations and Maintenance Facilities (Not used)

1006.6.5.2 Guideway: Tunnel and Above Ground

1006.6.5.2.1 Tunnel 26 kilovolt feeders must be metal clad type, 3C, #4/0 AWG 35kV rated.

1006.6.5.2.2 Conduits serving tunnels and stations must be routed inside the structure or embedded in concrete.

1006.6.5.2.3 Boxes in rail tunnels must be stainless steel.

1006.6.5.2.4 Enclosures in rail tunnels must be NEMA 4X.

1006.6.5.2.5 Coordinate with Set 220 Traction Power

1006.6.5.3 Wayside Facilities

1006.6.5.3.1 For signals system, room-to-room, and room-to-wayside equipment, signal wires must not be combined with power wires in the same cable.

1006.6.5.3.2 For signals system, signal cable, power cable, and communications cable must not be routed in the same conduit.

1006.7 ENGINEERING MANAGEMENT REQUIREMENTS

1006.7.1 Interface and Integration Management

1006.7.1.1.1 The design must consider and account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructible documentation and functional designs.

1006.7.2 Design Management

1006.7.2.1 Designs must include cable and conduit schedules submitted per Sound Transit Engineering Procedure 03.

1006.7.2.2 For additions to existing systems, an assessment must be performed to identify system limitations. Remaining spare capacity must be documented.

1006.7.3 Manufacturing and Construction Management (Not Used)

1006.7.4 Installation Management (Not Used)

1006.7.5 Inspection and Testing Management

1006.7.5.1.1 The design must adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

1006.7.6 Training, Pre-Revenue Operations (Not Used)

1006.7.7 Certification Management (Not Used)

1006.8 APPENDICES (NOT USED)

END SET - 1006

1007 ELECTRICAL LIGHTING

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SET - 1007 TABLE OF CONTENTS

TABLES

FIGURES

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SET - 1007 ELECTRICAL LIGHTING

1007.1 INTRODUCTION

1007.1.1 Document Scope

1007.1.1.1 The set establishes electrical lighting systems criteria for Sound Transit facilities including, passenger stations, parking garage, park and ride facilities, plaza, pedestrian bridge walkway, operations and maintenance facilities, artwork, vertical transportation, sustainability, signage, bike program, prefabricated buildings such as signal bungalow, communication bungalow and traction power substation, and emergency lighting. These criteria include requirements for the function and design of lighting and related systems.

1007.1.1.2 This section contains specific code references. The code references herein are based on the most current NFPA 70 (NEC), Seattle Energy Code, and Washington State Energy Code. Those specific references may change under future editions of the codes and standards.

1007.1.1.3 This section contains specific lighting levels for specific area or space in Sound Transit facilities. If the area or space specified in the design is not available in this section, then follow the recommended lighting level specified in Illuminating Engineering Society that meets the requirements of the AHJ adopted energy code.

1007.1.1.4 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 1007 owner to determine the technical source for the design criteria.

1007.1.2 Regulations, Codes, Standards, and Guidelines

1007.1.2.1 International Regulations, Codes, Standards, and Guidelines

1007.1.2.1.1 International Building Code with local amendments.

1007.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

1007.1.2.2.1 Americans with Disabilities Act (ADA).

1007.1.2.2.2 American Society of Mechanical Engineers (ASME) A17.1 Safety Code for Elevators and Escalators and as amended by the State of Washington Administration Code.

1007.1.2.2.3 2009 ICC A117.1 Accessible and Usable Buildings and Facilities – Chapter 5.

1007.1.2.2.4 IES G-1-16 Guide for Security Lighting for People, Property, and Critical Infrastructure.

1007.1.2.2.5 IES RP-8-18 Recommended Practice for Design and Maintenance of Roadway and Parking Facility Lighting.

1007.1.2.2.6 ANSI/IES TM-15-20 – Technical Memorandum: Luminaire Classification System for Outdoor Luminaires.

1007.1.2.2.7 ANSI/IES LP-7-20 – Lighting Practice: The Lighting Design and Construction Process
IEEE C62.41.2 Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and less) AC Power Circuits.

1007.1.2.2.8 National Fire Protection Association (NFPA).

1007.1.2.2.8.1 National Fire Protection Association (NFPA) 70 National Electrical Code (NEC) with local amendments.

1007.1.2.2.8.2 National Fire Protection Association (NFPA) 130 Standard for Fixed Guideway Transit and Passenger Rail Systems.

1007.1.2.2.9 UL 924 Emergency Lighting and Power Equipment.

1007.1.2.2.10 ANSI/UL 1598 Luminaires.

1007.1.2.2.11 UL 8750 Light Emitting Diode (LED) Equipment for Use in Lighting Products.

1007.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines

1007.1.2.3.1 Seattle Energy Code for Seattle area only.

1007.1.2.3.2 Washington Administrative Code (WAC).

1007.1.2.3.3 Washington State Energy Code (WSEC) for outside Seattle area.

1007.1.2.3.4 Washington Utilities and Transportation Commission.

1007.1.2.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

1007.1.2.5 Other Jurisdictions

1007.1.2.5.1 Authority Having Jurisdiction.

1007.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

1007.1.2.6.1.1 Sound Transit Equipment and Facilities Numbering Standard.

1007.1.2.6.1.2 Sound Transit Signage Design Manual.

1007.1.2.6.1.3 Architectural Standard Drawings.

1007.1.2.6.1.4 System Directive Drawings.

1007.1.2.6.1.5 Sound Transit Design Technology Manual.

1007.1.2.6.1.6 Sound Transit Station Experience Design Guidelines.

1007.1.2.6.1.7 Interface Coordination and Integration Plan.

1007.1.3 Abbreviations and Acronyms

1007.1.3.1 A–amperage, amps

1007.1.3.2 AASHTO–American Association of State Highway and Transportation Officials

1007.1.3.3 Avg–average

1007.1.3.4 AFF–above finished floor

1007.1.3.5 AFG–above finished ground

1007.1.3.6 AHJ– authority having jurisdiction

1007.1.3.7 BMS–building management system

1007.1.3.8 CCT–correlated color temperature

1007.1.3.9 CR – commuter rail

1007.1.3.10 CRI–color rendering index

1007.1.3.11 FC–foot-candle

1007.1.3.12 IES–Illuminating Engineering Society

1007.1.3.13 IBC–International Building Code

1007.1.3.14 LCP–lighting control panel

1007.1.3.15 LLF–light loss factor

1007.1.3.16 LLD–lamp lumen depreciation

1007.1.3.17 LDD–luminaire dirt depreciation

1007.1.3.18 LPD–lighting power density

1007.1.3.19 Max–maximum

1007.1.3.20 Min–minimum

1007.1.3.21 OCS–overhead contact system

1007.1.3.22 SME–subject matter expert

1007.1.3.23 TPS–traction power station

1007.1.3.24 TVM–ticket vending machine

1007.1.3.25 UPS–uninterruptable power supply

1007.1.3.26 V–volts

1007.1.3.27 Vdc–voltage direct current

1007.1.4 Definitions and Classifications

1007.1.4.1 Refer to ANSI / IES LS-1-21 – Lighting Science Nomenclature and Definitions for Illuminating Engineering and NFPA 70 (NEC) for definitions and classifications.

1007.1.4.2 Dark spot: An area of the surface that shows uneven result of light level or does not have uniform light level.

1007.1.4.3 Shadow: The effect of unbalanced uniformity ratio of the distribution of light on a surface.

1007.1.4.4 Continuously lighted: An area or location that requires lights to be on for more than three hours.

1007.1.5 References (Not Used)

1007.2 STAKEHOLDER NEEDS

1007.2.1 Passenger Experience

PSO Engineering's mission is to protect and uphold the integrity of the technical requirements to guarantee the passenger satisfaction, safe, quality, reliable, durable operations through establishing and managing the needs of the agency through engineering, core systems and facility requirements.

1007.2.2 Operational Needs

1007.2.2.1 Stations and garages must be operated without a continual presence of operators or maintenance personnel. Designs must account for unattended facilities.

1007.2.2.2 Maintenance facilities are operated 24 hours a day 7 days a week in support of operating transportation service and maintaining the associated systems, buildings, and infrastructure.

1007.2.2.3 Review the operational costs when specifying light systems products including the light fixtures and lighting control and choose products that are economical to construct and operate given the performance required.

1007.2.3 Maintenance Needs

1007.2.3.1 Maintenance at stations and garages are typically reserved for periods that do not impact passengers, limiting maintenance windows to non-revenue periods unless scope can be performed without passenger impact.

1007.2.3.1.1 Account for narrow window for maintenance during revenue periods without impacting operation.

1007.2.3.1.2 Account for tools or equipment that facility maintenance personnel need to use to access the light fixtures.

1007.2.3.1.3 The light fixture's installation and location must be convenient for facility maintenance personnel to remove existing light fixture, existing LED drivers, or existing integral or external sensor, and install new light fixture, new LED drivers, or new integral or external sensor.

1007.2.3.1.3.1 Provide additional fall protection to access the light fixture. See Set 804 Fall Protection for additional requirement for fall protection.

1007.2.3.2 Facility maintenance personnel must open the circuit breaker of the lighting circuit when they need to replace the lamp, LED driver, or sensor devices integral or external to the light fixture.

1007.2.3.2.1 Provide an internal quick disconnect device through the manufacturer.

1007.2.3.2.2 An external quick disconnect must be UL listed.

1007.2.3.3 Luminaires must reduce the collection of dirt and debris.

1007.2.3.3.1 Luminaires must prevent bird roosting. If luminaires provide opportunity for roosting, then provide bird deterrent devices. See Set 801 Architectural Materials, Elements, and Furnishings for additional requirements of the bird deterrent.

1007.2.3.4 Each project must have a minimum number of different types of the light fixture, and these types must be efficient and function according to the application of the light fixture type.

1007.2.3.4.1 Facility maintenance personnel must stock light fixture spares onsite and will perform quarterly audit of fixture and battery condition of exit signs and emergency egress circuited lights.

1007.2.4 Safety Needs

1007.2.4.1 Account for passenger, operator, and maintainer safety for normal operations in designs, including areas with potential trip hazards and the fluctuation of passenger movement when transferring or deboarding vehicles.

1007.2.5 Security Needs

1007.2.5.1 Station, garage, and facility lighting elements accessible to the public or in the touch zone area must provide additional material to prevent theft and vandalism.

1007.2.5.1.1 Materials for theft and vandal devices must be included. See Set 801 Architectural Materials, Elements, and Furnishings for additional touch zone information.

1007.2.5.2 The lighting system must support the ability for CCTV to provide a clear facial identification.

1007.2.5.3 Luminaire’s location must provide an environment that is secure, discourages crime, and able to do surveillance of facilities by crime prevention authorities.

1007.2.5.3.1 The lighting designer must consider areas and neighborhoods adjacent to the protected property or illuminated outdoor space.

1007.2.5.4 Perimeter fence lighting must comply with IES G-1-16 Guide for Security Lighting for People, Property, and Critical Infrastructure.

1007.2.6 Reliability, Availability and Maintainability Needs

1007.2.6.1 Material and equipment selection must consider the operating environment and small maintenance windows associated with public transportation.

1007.2.6.2 Evaluate the life cycle costs of the lighting system for over a 25-year cycle. The two major consideration for life cycle cost as follows:

1007.2.6.2.1 Capital cost is known as construction cost. Capital cost must include wiring, boxes, and conduit between the power source, lighting control panel, and light fixtures.

1007.2.6.2.2 Operating cost must include preventive maintenance (lamp replacement and associated cleaning of luminaires) and energy cost.

1007.2.6.3 The operating cost must establish per luminaire cost for power and maintenance.

1007.2.6.3.1 The actual cost per luminaire must be calculated using the formula: *kW x R = cost per hour*. Where kW is the rating of the luminaire, R is the cost per kilowatt-hour ($/kWh) charged by the utility.

1007.2.6.4 The lighting designer must evaluate the life cycle cost basis of luminaires.

1007.2.6.5 The lighting designer must verify that the luminaire products selected will be available to avoid construction schedule impacts.

1007.2.6.6 The lighting designer must confirm that parts or complete replacement units will be available following installation.

1007.2.6.7 Table 1007-1 shows the acceptable criteria for selecting light fixture.

Table 1007-1: General Energy Efficient Luminaire Criteria

Detail	Acceptance Criteria
Maintenance	Quick disconnects inside fixture, Tool entry, Stainless steel fasteners.
Driver	Replaceable.
Energy Efficient board	Replaceable. Proprietary is acceptable if business has at least 10-year history of making luminaires.
Warranty	At least 5 years, preferably 10 years.

1007.2.7 Environmental and Sustainability Needs

1007.2.7.1 Facility designs must promote stewardship of resources and utilities when selecting material, equipment selection, and operational strategies with the goal of conservation and efficiency.

1007.2.7.2 For environmental needs, the lighting designer must follow the BUG rating requirements in this section.

1007.2.7.3 For sustainability needs, check additional requirement specified in Set 803 Sustainability.

1007.3 SYSTEM REQUIREMENTS

1007.3.1 General Requirements

1007.3.1.1 Means of egress must comply with IBC and municipal code.

1007.3.1.2 Light rail stations and tunnels must comply with NFPA 130 requirement.

1007.3.1.3 Luminaires

1007.3.1.3.1 The luminaire type must include the material finish, control function, CRI, CCT, and/or distribution type.

1007.3.1.3.2 The luminaire must use at least five instances throughout the project to reduce the number of fixtures use.

1007.3.1.3.3 The luminaire type for back of house's rooms must be identical throughout the room and be appropriate for the room environment.

1007.3.1.3.4 All luminaires, including the exit sign, must be mounted above the touch zone in public areas, non-public space, and maintenance facilities. See Set 801 Architectural Materials, Elements, and Furnishings for touch zone.

1007.3.1.3.5 All luminaires accessible to public or in open, unsecured areas must be selected with material and components that prevent vandalism and corrosion.

1007.3.1.4 Lamps

1007.3.1.4.1 Lamps must be the latest energy efficient light source.

Commentary: LEDs are the preferred lamp to use while fluorescent is an option to use if LED is not available for the application and environment.

1007.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

1007.4.1 System Breakdown Structure

Set 1007 Electrical Lighting is broken down into the following elements:

1007.4.1.1 Location / Environment

1007.4.1.2 Lighting Strategy and Layout

1007.4.1.3 Circuiting

1007.4.1.4 Calculations

1007.4.1.5 Illuminance Levels

1007.4.1.6 Installation and Mounting

1007.4.1.7 Lamp Type

1007.4.1.8 Lighting Control

1007.4.1.9 Voltage Requirement

1007.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 1007-2: Interface Between Electrical Lighting and Other Disciplines

SET SERIES	SET NAMES	SET 1007 INTERFACE
100	Train Control and Signals	x
200	Traction Electrification	x
300	Operational Communications	x
400	Vehicles	
500	Track	x
600	Fire/ Life Safely	x
700	Structures	x
800	Architecture	x
900	Civil	x
1000	Mechanical/Electrical and Building Systems	x
1100	Technology	x
1200	Security	x

1007.5.1 Train Control and Signals

1007.5.1.1 Coordinate with Train Control and Signals for signal rooms located inside stations or facilities. This section does not address lighting provided as part of a prefabricated signal building.

1007.5.1.2 Coordinate at-grade railway crossings with Train Control and Signals

1007.5.2 Traction Electrification

1007.5.2.1 Coordinate with Traction Power for the traction power substations located inside stations or facilities. This section does not address lighting provided as part of a prefabricated substation.

1007.5.2.2 Coordinate with Traction Power and Overhead Centenary design for tunnel installations and light fixture installations.

1007.5.3 Operational Communication

1007.5.3.1 See Set 301 Network Infrastructure for additional lighting requirements at the point of cable termination.

1007.5.4 Track

1007.5.4.1 Installation of the light fixture in the tunnel, and light pole placement must coordinate with Track for Vehicle Clearance Envelope.

1007.5.4.2 Light for the maintenance walkway must coordinate with Track.

1007.5.5 Fire/ Life Safety

1007.5.5.1 Coordinate with Set 601 Fire/ Life Safety for exit sign requirements.

1007.5.5.2 Coordinate with Set 601 Fire/ Life Safety for means of egress (emergency) lighting requirements.

1007.5.5.3 Coordinate with Set 601 Fire/ Life Safety for location of sprinkler and standpipes, avoiding interference with light spill and effectiveness

1007.5.6 Structures

1007.5.6.1 Coordinate with Structural design the detail for light pole, location, base type, mounting details, seismic ratings, pole heights and wind loads.

1007.5.7 Architecture

1007.5.7.1 Coordinate with Architecture:

1007.5.7.1.1 Light fixture locations, fixture finishes and installation details.

1007.5.7.1.2 Ceiling, wall, and floor surface reflectance.

1007.5.7.1.3 Bird deterrent requirements for exterior fixtures.

1007.5.7.1.4 Light pole locations, materials, shapes, and finishes

1007.5.7.1.5 Signage locations

1007.5.7.1.6 Landscape architecture for site layout and vegetation.

1007.5.7.1.7 Art location

1007.5.7.1.8 Flagpole location

1007.5.7.1.9 Travel egress pathway to locate the egress emergency light fixtures and exit sign.

1007.5.8 Civil

1007.5.8.1 Coordinate with Civil for underground conduit routing and site layout.

1007.5.9 Mechanical / Plumbing

1007.5.9.1 Coordinate overhead pipe locations with Mechanical. If light fixtures will be mounted next to overhead pipes, make sure that the light fixtures meet the rating or listing section specified in this document.

1007.5.9.2 Overhead pipes must not block the light fixture for access or light spill and effectiveness.

1007.5.9.3 Coordinate the location of HVAC Systems. Make sure that HVAC systems will not block any light spill to the ground.

1007.5.10 Building Monitoring and Control

1007.5.10.1 Coordinate with Building Monitoring and Control for system interface with lighting control.

1007.5.11 Electrical Power

1007.5.11.1 Coordinate with Electrical Power designer for circuiting of normal and emergency power and supporting equipment.

1007.5.11.2 Coordinate luminaires and light pole locations with any Photovoltaic installations to prevent interference.

1007.5.12 Security CCTV

1007.5.12.1 Coordinate with Security CCTV design for location of the cameras.

1007.5.13 Technology

1007.5.13.1 Coordinate with Technology for the location of the following:

1007.5.13.1.1 Fare vending or TVM.

1007.5.13.1.2 Passenger information management system.

1007.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

1007.6.1 Location / Environment

1007.6.1.1 Exterior

1007.6.1.1.1 Exterior is the rating for an outdoor space exposed to ambient conditions, or indoor wet spaces. The luminaire rating for Exterior must have UL listing for wet rated or IP (Ingress Protection) ratings of IP65, IP66, or IP67.

1007.6.1.1.2 The following rooms must have exterior rated luminaires: restrooms, shower rooms.

1007.6.1.1.3 The following uses or areas must have exterior rated luminaires: elevator pits, escalator pits, shop pits, bike cages, parking areas, garage parking areas and garage ramps, tunnels, cross passages, all station platforms, all station and garage stairwells, all station escalator areas, pedestrian bridges and trash enclosures.

1007.6.1.2 Interior

1007.6.1.2.1 Interior luminaires must be UL rated for the functionality of the space, with a damp rating or dry rating.

1007.6.1.2.1.1 Damp rated luminaires must be used in enclosed, unconditioned or minimally conditioned spaces with no direct exposure to water and must be shielded from precipitation.

Commentary: Examples of damp locations include unconditioned closets in parking garages, shop areas with minimum ventilation, maintenance facility stairwells.

1007.6.1.2.1.2 Dry rated luminaires must be used in interior areas that are conditioned.

Commentary: Interior conditioned spaces include office spaces and communication rooms.

1007.6.1.2.2 Glare rating for interior use must have a glare rating of G = 0 or G = 1. When glare rating is not available, the interior light fixture must have a diffuser or lens that will reduce glare.

1007.6.1.3 Hazardous

1007.6.1.3.1 Hazardous is for hazardous location and the rating must comply with requirement specified in NFPA 70 (NEC) Article 500.

1007.6.1.3.2 Luminaires in sump pump area must comply with the Hazardous rating unless the lighting designer determines that the materials inside the sump pump are not hazardous. Then, the luminaires must have an Exterior rating.

1007.6.1.3.3 The designer must determine if hazard prevention materials are required at facility maintenance areas that receive a Hazardous rating.

1007.6.2 Lighting Strategy and Layout

1007.6.2.1 All facilities and platforms must be designed with normal and means of egress luminaires in a layout to satisfy code requirements and meet illuminance levels contained in illuminance level tables, unless noted otherwise.

1007.6.2.2 The lighting designer must ensure there is diversity in the layout, so that if a single light fixture fails or when facility maintenance personnel replace a luminaire, the area or space will not be left in total darkness.

1007.6.2.3 When designing the layout for the normal, means of egress, and exit sign luminaires, the lighting designer must consider the location of the building structures, such as columns and beams, as well as the location of equipment or trees in the plaza that could obstruct the light distribution and produce an uneven light level.

1007.6.2.4 All luminaires, including exit signs serving all light rail locations must be located a minimum of 10 feet from the OCS.

1007.6.2.5 Exit Signs

1007.6.2.5.1 See Set 601 Fire/Life Safety for code requirements.

1007.6.2.5.2 Exit signs must be green lettering with white background.

Commentary: The lighting designer must follow the requirements of AHJ regarding the exit sign's color lettering and background color, if different than the requirement above.

1007.6.2.5.3 Exit signs must have a test button or self-diagnostics for a quarterly condition assessment and illumination test.

1007.6.2.5.4 Exit signs must be installed in a location that guarantees visibility and readability to provide direction.

1007.6.2.5.5 Exit sign must have directional chevron inserts to provide direction as required by code and as reflected in the municipal code sheets developed by the architect.

1007.6.2.5.6 Exit sign product must be specified based on the environmental rating of the space.

1007.6.2.5.7 Exit sign must meet the UL 924 requirement.

1007.6.2.5.8 Exit signs must be compliant with the Washington State Building Code Amendment of the IBC for being on all the time.

1007.6.2.5.9 Exit signs must be readily visible within 100 feet from any location on the station platform.

1007.6.2.5.9.1 For parking garages, exit signs must be readily visible within 100 feet from any direction of egress travel, when required by the AHJ.

1007.6.2.6 Means of Egress Illumination (Emergency Lighting)

1007.6.2.6.1 See applicable code and municipal code sheets developed by the architect to determine means of egress pathways. Set 601 Fire/Life Safety.

1007.6.2.6.2 The means of egress illumination to all building structures must extend to the public way or safe dispersal area.

1007.6.2.6.3 The lighting designer must provide a convenient way for maintenance to assess the condition of the means of egress luminaires, quarterly.

1007.6.2.6.4 Means of Egress luminaires must meet the UL 924 requirements.

1007.6.2.6.4.1 When UL 924 devices are grouped for means of egress luminaire, then locate UL 924 devices next to the Means of Egress Lighting Control Panel, inside the Electrical Room. UL 924 devices must be installed in a junction box or arranged on a backboard with equipment labels that list the location or zone that UL 924 device serves.

1007.6.2.6.4.2 When UL 924 devices serve a single room or space, then install the UL 924 device in the same room that the UL 924 device serves. The UL 924 device must be installed inside a junction box next to the room light switch that is accessible for facility maintenance personnel from an even surface level.

1007.6.2.6.4.2.1 When UL 924 devices are factory installed as integral to the light fixture care must be taken to maintain warranty during installation.

1007.6.2.6.4.2.2 If the test switch is used to check egress luminaires, then the lighting designer must make the test switch accessible from an even surface level for facility maintenance personnel.

1007.6.2.6.5 A building exterior door must have a Means of Egress luminaire mounted above the exterior side of the exit doorway if the exit door is designated for Means of Egress.

1007.6.2.6.6 All back of house rooms must have a minimum of one means of egress luminaire inside the room, located near the door.

Commentary: The IBC may not require means of egress luminaires in all rooms. The requirement above is to ensure we have means of egress lighting for worker safety.

1007.6.2.6.7 A standalone exit sign is not considered a means of egress light fixture.

Commentary: If an exit sign is a combination unit that includes two emergency lights, then the combination unit can be used in lieu of means of egress light fixture next to the exit door. The combination units must meet the light level requirement for the means of egress.

1007.6.2.6.8 For office areas, the lighting designer must provide at least one means of egress light fixture next to the interior side of the exit door.

1007.6.2.6.9 For secure areas that contain outdoor equipment that requires service at least one means of egress light fixture must be provided within the space.

1007.6.2.6.10 The lighting designer must provide means of egress luminaires for publicly accessible stairs and escalators.

1007.6.2.6.11 When a public access stair and escalator are adjacent to each other, then the lighting designer must provide means of egress luminaire in the combined space.

1007.6.2.6.11.1 The escalator's luminaires must coordinate with Set 805 Vertical Transportation and the requirement specified in ASME A17.01 for walking surface.

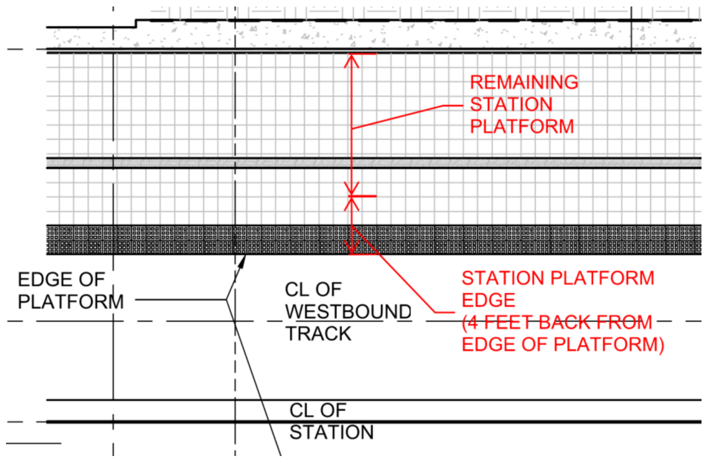
1007.6.2.6.12 Means of egress luminaires must be provided for tunnels in compliance with NFPA 130.

1007.6.2.7 Station Platform (Light Rail and Commuter Rail).

1007.6.2.7.1 Luminaire for normal, means of egress, and exit sign must be mounted on the underside of the canopy structure and above the touch zone.

1007.6.2.7.2 Station platforms must be designed with two sections of the light levels, the station platform edge (4 feet from the edge of platform) and the remaining station platform. See Figure 1007-1, Station Platform.

Figure 1007-1: Station Platform



1007.6.2.7.2.1 For Terminus Link Stations, the designer must provide luminaires at the end of the track that extends beyond the platform for vehicle operators at night.

1007.6.2.7.3 Open Plaza

1007.6.2.7.3.1 Outdoor stairs or stairs located in the plaza or open plaza are to be considered part of the open plaza and must be designed to the same illuminance levels in Table 1007-4

1007.6.2.7.3.2 Lighting designer must consider the transition of the light level between properties and property lines when placing light pole fixtures.

1007.6.2.8 Maintenance Facility Yard Luminaires

1007.6.2.8.1 The lighting designer must design the lighting layout in the yard as equivalent to Crew Change Walkways so that the light rail operators or commuter rail operators can see the walking surface.

1007.6.2.8.2 Luminaires for Light Rail Yards must not be installed on OCS poles and location must be at least ten feet away from the OCS.

1007.6.2.8.3 Guardhouse lighting must comply with IES G-1-16 Guide for Security Lighting for People, Property, and Critical Infrastructure.

1007.6.2.9 At- Grade Railway Crossings

1007.6.2.9.1 The placement of the pole and luminaire for an at-grade crossing must comply with the recommendation in IES RP-8-18.

1007.6.2.10 Maintenance Facilities Shop Areas

1007.6.2.10.1 Luminaires and mounting structure hardware for light rail and commuter rail must locate and coordinate with other equipment such as motorized cranes.

1007.6.2.11 Ticket Vending Machine Area

1007.6.2.11.1 When locating luminaires in the TVM area, evaluate and eliminate the glare produced on the TVM touch-screen display.

1007.6.2.11.2 The luminaire in the TVM area must have a horizontal coverage of at least ten feet from the front of the TVM.

1007.6.2.12 Variable Message Signs or Passenger Information Management System

1007.6.2.12.1 Luminaires must not block the view of the VMS or PIMS signs.

1007.6.2.12.2 When locating luminaires near VMS or PIMS signs, evaluate and eliminate the glare produced on VMS or PIMS signs.

1007.6.3 Circuiting

1007.6.3.1 The lighting designer must ensure diversity in circuiting to match diversity in layout strategy, alternating circuits as necessary for functional areas, in order to ensure that failure of a circuit does not leave a room or functional area in total darkness.

1007.6.3.2 Lighting circuits must be segregated to allow maintenance without impacting entire functional areas or between floors.

1007.6.3.3 Provide separate conduit for normal lighting and emergency lighting. See Set 1006 Electrical Raceway for additional information.

Commentary: Follow the requirement specified in Sound Transit Equipment and Facilities Numbering Standard for conduit tag.

1007.6.3.4 Provide at least 20 percent spare capacity for each circuit breaker for the normal lighting or emergency lighting. See Set 1005 Electrical Power for spare capacity.

1007.6.3.4.1 Account for the high inrush of the LED technology when selecting circuit breakers for normal and means of egress luminaires.

1007.6.3.4.2 Account for the voltage drop requirement in all lighting circuits. See Set 1005 Electrical Power for voltage drop.

1007.6.3.4.3 Minimum wire size for both normal and emergency lighting circuits must be #12 AWG.

1007.6.3.5 Exit Signs

1007.6.3.5.1 The Exit sign must have a dedicated emergency (critical) circuit, and the dedicated circuit must not be connected to the lighting control sequence. The Exit sign must be illuminated at all times.

1007.6.3.5.2 Use an inverter or UPS to power the eExit sign. See Set 1005 Electrical Power for emergency (critical) power requirement.

1007.6.3.5.3 Provide a UL rated integral battery pack for the Eexit sign for remote or practically difficult locations that are not practical to provide a central inverter/UPS. The integral battery pack in the Exit sign must be identified and approved in the Basis of Design.

1007.6.3.6 Means of Egress (Emergency Lighting)

1007.6.3.6.1 Use inverter or UPS for means of egress (emergency/critical) power. See Set 1005 Electrical power for emergency (critical) power requirement.

1007.6.3.6.2 Provide a UL rated integral battery pack for means of egress luminaires in remote locations or that are practically difficult to circuit to a central inverter/UPS.

1007.6.3.6.3 Limit the number of integral battery pack luminaires in an installation to three. When more than three integral battery pack luminaires are provided in an area of close proximity, provide a central inverter/UPS.

1007.6.3.6.4 Egress public stair, public access stair, or combination of public access stair and elevator must have at least two emergency (critical) circuits for the means of egress luminaire.

1007.6.3.7 Station Platform

1007.6.3.7.1 Cables and conduit must comply with NFPA 130 requirement. See Set 1005 Electrical Power and Set 1006 Electrical Raceway.

1007.6.3.7.2 Station platforms must have the following:

1007.6.3.7.2.1 At least two normal circuits for normal luminaires.

1007.6.3.7.2.2 At least two emergency (critical) circuits for means of egress luminaires.

1007.6.3.7.3 For Link Terminus Stations, the track extending beyond the platform for the end of the line must have the following:

1007.6.3.7.3.1 At least two normal circuits for normal luminaire.

1007.6.3.7.3.2 At least two emergency (critical) circuits for means of egress luminaire.

1007.6.3.7.3.3 Ensure the lighting circuit system at the end of the track of the terminus station will not require any changes for future line extension, by having a dedicated circuit breaker.

1007.6.3.8 Tunnel

1007.6.3.8.1 The circuiting for tunnel lighting, including cross passages and support spaces, must comply with NFPA 130 as emergency lighting and as defined by critical loads within Set 1005 Electrical Power.

1007.6.3.8.2 The cables and conduit for tunnel lighting must comply with NFPA 130 requirement as an emergency (critical) lighting. See Set 1006 Electrical Raceway.

1007.6.3.8.3 Tunnel lighting must have the following circuit requirements:

1007.6.3.8.3.1 Provide a minimum of two critical power circuits per tunnel bore.

1007.6.3.8.3.2 Alternate tunnel luminaires fed from separate circuit in separate lighting panelboards.

1007.6.3.8.3.3 Provide local disconnect means at each tunnel luminaire and include a fuse for each tunnel luminaire.

1007.6.3.8.3.4 The tunnel cross-passage luminaires must be connected to different tunnel lighting circuits.

1007.6.3.9 Open Plaza or Plaza Area must have at least two normal power circuits.

1007.6.3.10 Mezzanine and Maintenance Facility Shop

1007.6.3.10.1 Mezzanine and maintenance facility shop must meet the following circuit requirements:

1007.6.3.10.1.1 At least two normal power circuits for normal luminaires.

1007.6.3.10.1.2 At least two emergency (critical) circuits for exit sign and means of egress luminaires.

1007.6.3.10.1.3 Alternate normal luminaires fed from normal power circuits.

1007.6.4 Calculations

1007.6.4.1 Voltage Drop

1007.6.4.1.1 See Calculations and Studies in Set 1005 Electrical Power.

1007.6.4.2 Lighting Calculations

1007.6.4.2.1 The luminaires must be approved as part of the Basis of Design prior to being included in the design and lighting calculation. See Figure 1007-6 Lighting and Lighting System Design Process, and Figure 1007-7 Lighting and Lighting System Construction Process.

1007.6.4.2.2 The lighting calculation must demonstrate all lighting meet the levels in the Tables 1007-4, 1007-5 and 1007-6.

1007.6.4.2.2.1 For functional areas that are not in the illuminance tables noted, follow IES recommendations for comparable areas.

1007.6.4.2.2.2 For undesignated outdoor areas or locations not included in the illuminance level tables, provide a light level of 5.0 foot-candle average, with 3:1 average-to-minimum uniformity ratio.

1007.6.4.2.2.3 At-grade railway crossing lighting calculation must follow IES G-1-16 Guide for Security Lighting for People, Property, and Critical Infrastructure.

1007.6.4.2.3 Lighting Calculation Software

1007.6.4.2.3.1 The lighting designer must use the latest version of AGI32 or Elum Tools.

1007.6.4.2.3.2 The lighting designer must submit the lighting calculations in PDF format (11x17), with the information from the source file and the manufacturer cut sheet to Sound Transit Electrical SME for review.

1007.6.4.2.3.3 The lighting calculations must include the room number(s) or area number(s), calculation points, luminaire, luminaire's unique identification with mounting height, and include architectural backgrounds and structural elements.

1007.6.4.2.4 Lighting Calculation Tables

1007.6.4.2.4.1 Calculation summary must have the following:

i. Label
ii. Calculation type
iii. Units
iv. Average, maximum, minimum, average/minimum and maximum/minimum values

1007.6.4.2.4.2 Luminaire schedule as part of the calculations must have the following:

i. Symbol
ii. Quantity
iii. Label
iv. Tag (luminaire identification tag)
v. Description
vi. LLF
vii. Luminaire lumens
viii. Luminaire watts
ix. Total watts
x. LPD area summary
xi. Label
xii. Area

1007.6.4.2.5 Initial lighting calculations must be prepared and submitted during 60 percent design with approved Basis of Design light fixture selection.

1007.6.4.2.5.1 Once the Sound Transit Electrical SME has reviewed and approved the lighting calculation, the lighting calculation must be considered the final design.

1007.6.4.2.5.2 If there are changes between 60 percent design and 90 or 100 percent design, the lighting designer must update the lighting calculation with approved light fixture selection in the Basis of Design and resubmit for another approval from Sound Transit Electrical SME.

1007.6.4.2.6 The lighting points below 0.05 foot-candle for means of egress lighting calculation must be removed.

1007.6.4.2.7 The unit for both normal and means of egress lighting calculation must be in foot-candles, and the lighting calculation must be depicted at 0 feet high from the floor unless noted otherwise.

1007.6.4.2.8 Lighting calculation points for each set of stairs and/or escalator must be depicted from the walking surface, must be spaced to cover the entire walking surface and be readable.

1007.6.4.2.9 The lighting calculation points' spacing for stair or combination of stair and escalator area must have 1 foot from left to right and from top to bottom of the center points relative to polygon boundaries.

1007.6.4.2.10 All lighting calculation points must be readable.

1007.6.4.2.11 The lighting calculation points' spacing excluding stair and/or escalator must have 5 feet from left to right and from top to bottom of the center points relative to polygon boundaries.

1007.6.4.2.12 The lighting calculation must include glare rating.

1007.6.4.2.13 The lighting designer must use the value in the Light Loss Factors table for lighting calculation.

Table 1007-3: Light Loss Factors

Light Loss Factors for LED			
	Lamp Lumen Depreciation	Luminaire Dirt Depreciation	Total LLF
Exterior			
Light Poles, Tunnel	0.95	0.85	0.808
Other exterior	0.95	0.9	0.855
Interior			
Equipment Room (Elec, Mech, Comm, Sprinker, Shop, Shop Pit, and etc.)	0.9	0.9	0.810
Office Areas	0.9	0.95	0.855
Hazardous Location	0.9	0.8	0.720

1007.6.5 Illuminance Levels

1007.6.5.1 Illuminance levels must have uniform distribution and meet the requirements of the following tables.

Table 1007-4: Maintained Illuminance of Public Areas at Station and Garage

AREA	**Units of light level at height[1] (FC at FT)**	**Min / Avg / Max**	**Uniformity Ratio**
Station Platform Edge (Up to Four Feet Back), Remaining Station, and Mezzanine	10 at 0	Avg	Avg-to-min uniformity ratio of 3:1
Public Access Stairs, Elevator Lobbies including Elevator Landing Sills, Escalators and Escalator Landings (Includes approach areas to stairs/escalator/elevator)	10 at 0	Min	
Entry approaches to stations	7 at 0	Avg	
Means of Egress Lighting[5]	1.0 at 0 0.1 at 0	Avg Min	Max-to-min uniformity ratio not exceeded 40:1
Public Restrooms	20 at 0	Avg	

AREA	Units of light level at height[1] (FC at FT)	Min / Avg / Max	Uniformity Ratio
Bicycle Parking, Bike Cage (Covered or uncovered)	5 at 0	Avg	Avg-to-min uniformity ratio not greater than 3:1
Open Plaza, Plaza, and Plaza's Stair	5 at 0	Avg	Avg-to-min uniformity ratio not greater than 3:1
Pedestrian Walkways, Pedestrian Bridge Deck (Covered or Uncovered)	3 at 0	Avg	Avg-to-min uniformity ratio not greater than 3:1
Passenger Drop-off and Bus Loading Zones/Lanes	4 at 0	Avg	
Parking Lots, Garage Roof Parking	3 at 0	Avg	Avg-to-min uniformity ratio not greater than 3:1
Parking Garage Level, Ramps	6 at 0	Avg	Avg-to-min uniformity ratio of 4:1
Parking Garage Entrance (Daytime with transition lights)	50 at 0	Avg	Avg-to-min uniformity ratio of 4:1
Parking Garage Entrance (Nighttime without transition lights)	15 at 0	Avg	Avg-to-min uniformity ratio of 4:1
Face of Static Signs (vertical)			
At Station, Mezzanine, Stair Landings, Elevator Lobby and Bicycle Parking[4]	10 at center of the signage	Avg	
At Parking Garage and Ramps[4]	6 at center of the signage	Avg	
At Open Plaza[4]	5 at center of the signage	Avg	
At the Passenger Drop-off, Bus Loading Zones,[4]	4 at center of the signage	Avg	
Face of Fare Vending Machine (vertical)	10 at 5	Min	Avg-to-min ratio of 3:1
Fare vending areas[3] or kiosk[3]	20 at 0	Avg	
Perimeter Fences and Barriers	2 at 0	Min	Max-to-min ratio does not exceed 6:1
[1] horizontal foot-candle above finished floor or finished ground, unless noted otherwise			
[2] lighting at elevator lobbies must address the lobby proper or, if undefined, 10 feet to each side of the outside edge of the outermost elevator doors or to structure, whichever is less.			
[3] lighting at vending area or kiosk must cover at least 10 feet in front of the vending machine or kiosk.			
[4] light levels indicated for signage reflect the light levels required for the area served as a minimum. Light levels on the vertical surface of signage will result in a higher foot-candle, due to proximity to luminaires.			
[5] Measured along the path of egress at floor levels.			

Table 1007-5: Maintained Illuminance of Non-Public Areas (Back-of-House and areas only accessible by Sound Transit or authorize personnel) in Station and Garage

AREA	Units of light level at height[1] (FC at FT)	Min / Avg / Max	Uniformity Ratio
Covered or Interior Stairs' Landing and Steps	10 at 0	Min	Avg-to-min uniformity ratio of 3:1
Elevator Machine Rooms	20 at 0	Min	

AREA	Units of light level at height[1] (FC at FT)	Min / Avg / Max	Uniformity Ratio
Elevator Pit	10 at 0	Min	
Service Elevators Lobby[2], Service Elevator Landing Sill	10 at 0	Min	
Mechanical, Electrical, Communication Rooms, System Rooms	50 at 0	Avg	
Signal Room, TPSS Room	70 at 3	Min	
Corridors	10 at 0	Avg	
Office, Conference Room	30 at 3'-0" above finished floor	Avg	
Office Computer areas	15 at 3'-0" above finished floor	Avg	
Tunnel Ventilation Fan Rooms and associated air way shafts near dampers	15 at 0	Avg	
Staff Restrooms	20 at 0	Avg	
Staff Crew Rooms, Lunchroom	30 at 3'-0" above finished floor	Avg	
Storage Rooms	5 at 0	Avg	
Custodial Rooms, Trash Rooms	10 at 0	Avg	
Tunnels: trackway and walkway	2 at 0	Min	Max-to-min uniformity ratio of 10:1
Cross Passages	15 at 0		
Crew Change Walkways	2 at 0	Min	Max-to-min uniformity ratio of 10:1
Non-covered, Open Stairs, Landings and Steps	5 at 0	Avg	Avg-to-min uniformity ratio not greater than 3:1
Non-Revenue Track Sections[3]	2 at 0	Min	Max-to-min uniformity ratio of 10:1
Perimeter Fences and Barriers	2 at 0	Min	Max-to-min ratio does not exceed 6:1
Means of Egress Lighting[4]	1.0 at 0 0.1 at 0	Min Avg	Max-to-min uniformity ratio not exceeded 40:1
[1] horizontal foot-candle unless noted otherwise			
[2] lighting at elevator lobbies must address the lobby proper or, if undefined, 10 feet to each side of the outside edge of the outermost elevator doors or to structure, whichever is less, and extending to 10 feet in front of the elevator doors or to structure, whichever is less.			
[3] Non-Revenue track sections are sections where trains include tail tracks at terminus stations, pocket track, turn back tracks, siding tracks and hi-rail access tracks where operators will have to leave the vehicle in order to perform responsibilities.			
[4] Measured along the path of egress at floor levels.			

Table 1007-6: Maintained Illuminance of Maintenance Facilities

AREA	Units of light level at height[1] (FC at FT)	Min / Avg / Max	Uniformity Ratio
Mechanical, Electrical, Communication Rooms	50 at 0	Avg	
Storage / Custodial Rooms	10 at 0	Avg	
Office, Conference Room	30 at 3'-0" above finished floor	Avg	
Office Computer areas	15 #at 3'-0" above finished floor	Avg	
Corridors and Approaches to Elevators	10 at 0	Avg	
Staff Crew Rooms, Lunchroom	30 at 3'-0" above finished floor	Avg	
Elevator Machine Rooms	20 at 0	Min	
Elevator Pit	10 at 0	Min	
Elevators Lobby[2] , Elevator Landing Sill	10 at 0	Min	
Restrooms, Lockers	20 at 0	Avg	
Maintenance Stairs	10 at 0	Min	
Yard with tracks	2 at 0	Min	Avg-to-min uniformity ratio not greater than 6:1
Crew Change Walkways	2 at 0	Avg	
Shop Area	50 at 0	Avg	
Shop Pit Area	100 at 0	Avg	
Building Stair's Steps and Landing (inside the building)	10 at 0	Min	
Means of Egress Lighting[3]	1.0 at 0 0.1 at 0	Avg Min	Max-to-min uniformity ratio not exceeded 40:1
Pedestrian Walkways, Pedestrian Bridge Walkways (Covered or Uncovered)	3 at 0	Avg	Avg-to-min uniformity ratio not greater than 3:1
Parking Lots	3 at 0	Avg	Avg-to-min uniformity ratio not greater than 3:1
Perimeter Lighting	2 at 0	Min	Max-to-min ratio does not exceed 6:1

[1] horizontal foot-candle unless noted otherwise

[2] lighting at elevator lobbies must address the lobby proper or, if undefined, 10 feet to each side of the outside edge of the outermost elevator doors or to structure, whichever is less.

[3] Measured along the path of egress at floor levels.

1007.6.6 Installation and Mounting

1007.6.6.1 Installation

1007.6.6.1.1 Luminaires' installation must coordinate with other disciplines regarding installation support or mounting requirements.

1007.6.6.1.2 Luminaires must be installed per manufacturer's recommendation.

1007.6.6.1.3 The lighting designer must provide details on how the luminaires, conduits, and junction box connect to the architecture or structure elements.

1007.6.6.1.4 Nonlight pole luminaires must be installed above touch zone, and the maximum height of the luminaire from above the finished floor is 16 feet. See Set 801 Architectural Materials, Elements, and Furnishings for touch zone and Set 804 for Fall Protection requirements.

1007.6.6.1.5 Parking Garage

1007.6.6.1.5.1 Parking garage interior (except the back-of-house rooms) luminaires must be surface mount.

1007.6.6.1.5.2 The lighting designer must locate the surface mount luminaire above the drive aisle at the end of the parking stall markers, as shown in Figure 1007-2 Parking Garage Luminaire Location, or areas that accessible at all times. Lighting must not be located above parking stall in order to avoid conflicts with transit users and allow daytime maintenance.

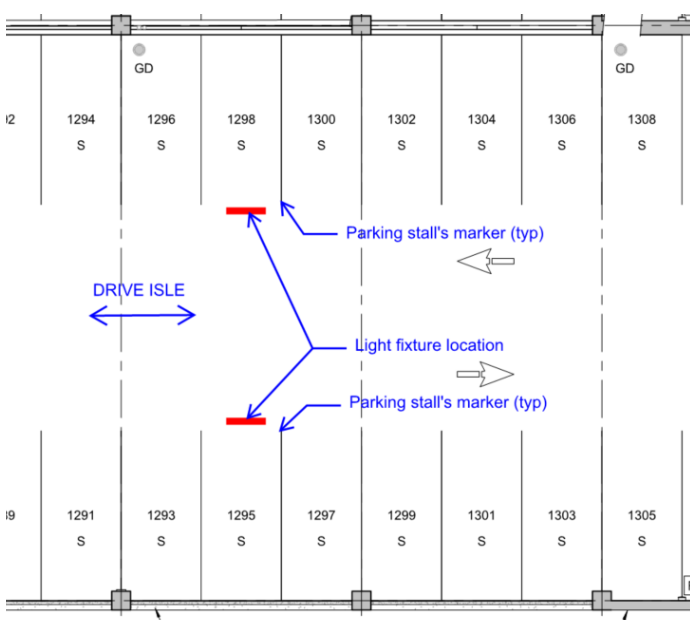
1007.6.6.1.5.3 Handhole opening must be 18 inches from above finished floor or top of light pole base or column barrier in the garage roof top.

1007.6.6.1.5.4 Parking garage rooftop, light pole handhole openings must be accessible from the flat surface.

1007.6.6.1.5.5 Locate parking garage rooftop light poles in the center of the structure. If parking garage rooftop light poles are located on the perimeter, they must have an exposed base with an equal height of the perimeter barriers.

1007.6.6.1.5.6 The lighting designer must locate parking garage rooftop light poles to safely accommodate lift access from a flat surface for the inspection and maintenance of overhead pole elements. Access from a ramp is prohibited.

Figure 1007-2: Parking Garage Luminaire Location



1007.6.6.1.6 Light Poles

1007.6.6.1.6.1 Location or placement of the light pole must not obstruct the movement of vehicles.

1007.6.6.1.6.2 The location and height of the light pole must not interfere with the guideway structure.

1007.6.6.1.6.3 The height of the light pole fixture must include the height of the exposed light pole base plus the length of the light pole. See Figure 1007-3 for details.

1007.6.6.1.6.4 The light pole structure must have a handhole opening with removable cover and tampered resistance fastener. Supporting embedded handholes, flush with walking or parking surface, must be traffic rated. For fastener, see Set 1005 Electrical Power and Set 1006 Electrical Raceway for additional requirements for public areas.

1007.6.6.1.6.4.1 Handholes must be grounded.

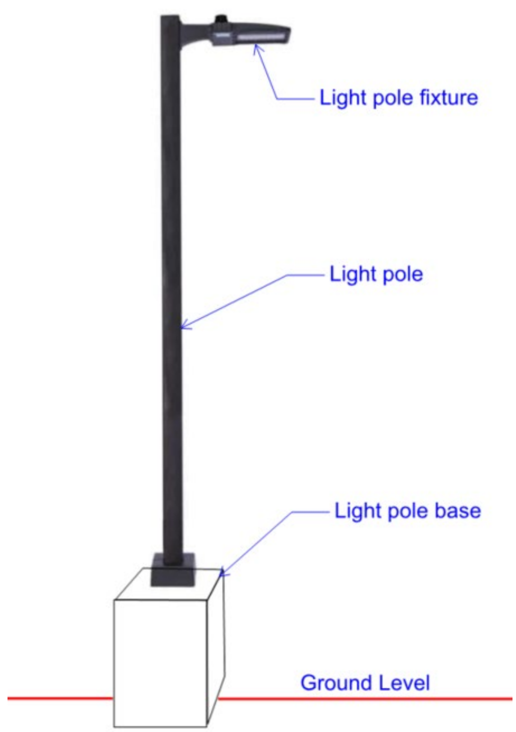
1007.6.6.1.6.5 The wiring inside the light pole must have a metal divider inside the handhole to separate the power conductors of the light fixture from other communication device(s) mounted on the light pole.

1007.6.6.1.6.6 Facility maintenance personnel must access the wiring inside the light pole from top of the light pole and through the handhole opening.

1007.6.6.1.6.7 Provide integral surge and overcurrent protection for light pole fixtures.

1007.6.6.1.6.8 Street and roadway luminaires must conform to the criteria and standards of the AHJ. If the AHJ's standard is not available, then use Sound Transit's standard.

Figure 1007-3: Light Pole Detail



1007.6.6.1.6.9 The light pole height must follow the requirements specified in Table 1007-7.

Table 1007-7: Light Pole Height

Light Pole Location	Height of the Light Pole Fixture from The Above Finished Ground	*Commentary*
Station Platform	12 feet min to 16 feet max	*Applies to all station platform* *For LR and URV – light pole and/or light pole fixture must have 10 feet clearance from OCS line. Also, metallic objects must be 6 feet from the vehicle body.*
Garage Roof Top and Surface Parking	12 feet min to 25 feet max	*Garage roof top light pole fixture height is subject to the following:* *1) AHJ limitation.* *2) Sound Transit Maintenance vehicle for maneuvering from entrance level to the roof top. See Set 830 Parking Facilities.*
Open Plaza	12 feet min to 25 feet max	
Roadway / Street	16 feet min to 25 feet	*Light pole height is subject to AHJ limitation.*
Yard Light Pole	Varies	*The yard light pole and light pole fixture must have 10 feet clearance from OCS.*

1007.6.6.1.6.10 The lighting designer must specify the devices or accessories mounted on the light pole.

1007.6.6.1.6.11 The devices and device's height from finished floor to the bottom of the device must be included in the light pole schedule.

1007.6.6.1.6.12 If the light pole requires a single or duplex receptacle, then the receptacle must have a ground-fault circuit interrupter and have a weatherproof cover.

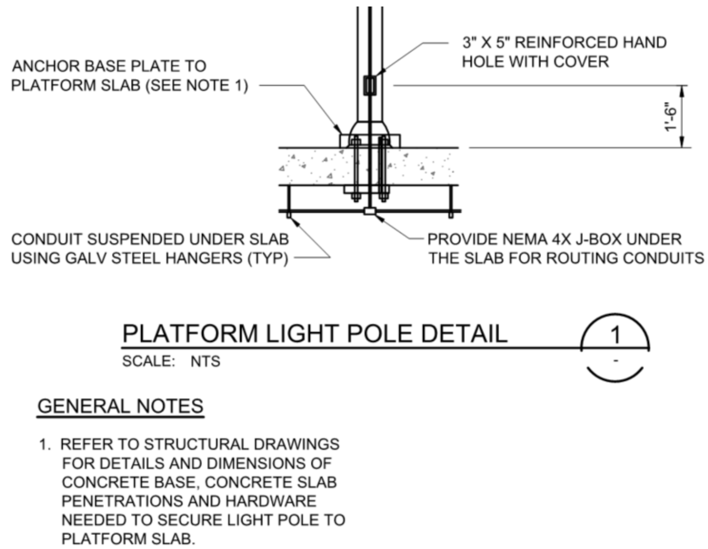
1007.6.6.1.6.13 The weatherproof cover must be tamperproof uniquely keyed for Sound Transit fasteners and located above the touch zone. See Set 1005 Electrical Power and Set 1006 Electrical Raceway for additional requirements for public area.

1007.6.6.1.6.14 The lighting designer must select a light pole mounting base and structure that withstands wind loads, per ASHTO standards.

1007.6.6.1.6.15 Light poles taller than 20 feet must have a pendulum vibration damper and be specified to match pole finish.

1007.6.6.1.6.16 When light poles are required on elevated stations, installation and mounting details of the pole and conduit routing must be closely coordinated with structural design. The following figure is provided as an example to illustrate complexity.

Figure 1007-4: Platform Light Pole for Elevated Platform Station

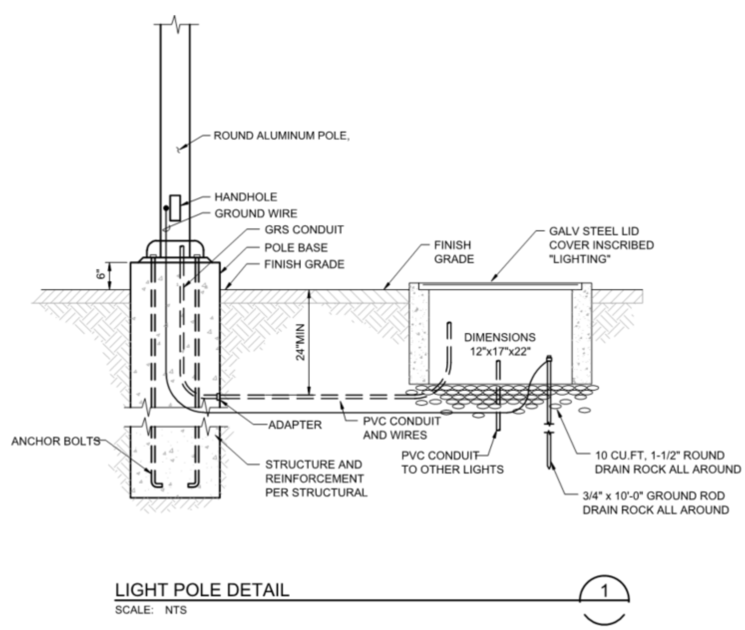


1007.6.6.1.6.17 Light pole locations in parking areas (surface lot or rooftop) must accommodate designated parking stall width and length.

1007.6.6.1.6.18 Light poles in parking areas or subject to vehicle movement, must have at least 36 inches base height from finished surface to protect the light pole from vehicle.

1007.6.6.1.6.19 Light poles located in hardscape and landscaped areas require installation and mounting details of the pole and conduit routing to be closely coordinated with structural, architecture and landscape architect. The following figure is provided as an example to illustrate complexity.

Figure 1007-5: Light Pole Base Typical



1007.6.6.1.7 Stairs

1007.6.6.1.7.1 Provide luminaire installation in enclosed and open stairs that meet required lighting level and are located to allow access by a ladder on a flat surface or provide fall protection elements for maintenance access.

Commentary: Luminaires installed directly overhead of steps creates issues with accessing fixtures for maintenance. For wide public access stairs or when combined with escalators, where it is difficult to meet light levels, it is acceptable to provide a continuous housing that is installed over the steps in order to meet lighting requirements.

1007.6.6.1.7.2 When a continuous housing is used for public access stairs or stair and escalator combinations, it must provide coverage from the top landing to the bottom landing.

1007.6.6.1.7.3 When a continuous housing is mounted on an adjacent wall for public or egress stairs, it must provide coverage for steps and landings, from the top landing to the bottom landing.

1007.6.6.1.7.4 The LED driver for a continuous housing must be placed at the bottom landing of a stair.

Commentary: The LED driver is a component most likely to need maintenance, and the bottom landing assumes the most accessible location.

1007.6.6.1.7.5 Luminaires in stairs at stations must be mounted above the touch zone, unless integral to the handrail and specified to prevent vandalism and rated appropriately for the environment.

1007.6.6.1.8 Tunnel

1007.6.6.1.8.1 Luminaires in the tunnel area must be mounted clear of the vehicle dynamic envelope.

1007.6.6.1.8.2 Tunnel lighting must be located above the walkway and above touch zone to service the maintenance walkway.

1007.6.6.1.8.3 Tunnel lighting must be surface mounted.

1007.6.6.1.8.4 Maintenance facility personnel must access the tunnel lighting from the maintenance walkway.

1007.6.7 Lamp Type

1007.6.7.1 The maximum linear length of LED must be 4 feet long.

Commentary: Continuous LED housing must house the 4 feet of LED.

1007.6.7.1.1 For LED housing with customized length, provide one LED Driver for every 4 feet of linear length of the LED module.

Table 1007-8: Lamp Performance Criteria

Lamp: LED			
Detail	Life	CRI	CCT
Non-Public Space	At least 50,000 hours	70-100	3500K – 4000K
Public Indoor Space	At least 50,000 hours	80-100	3500K - 4000K
Public Outdoor Space	At least 50,000 hours	80-100	4000K - 4500K

1007.6.7.2 Exterior

1007.6.7.2.1 Exterior luminaires, including tunnel lighting, must have a BUG rating. As defined by IES, BUG is an acronym for (B) back light, (U) up light and (G) glare.

Commentary: If the exterior light fixture is used in the interior area or space, the light fixture must follow the BUG rating requirements shown below.

1007.6.7.2.1.1 The (B) back light describes the lumen distribution behind the luminaire. Luminaires with a back light rating of B = 0 must be selected for exterior luminaire located along the property line.

1007.6.7.2.1.1.1 If the exterior light does not have a back light rating of B = 0, then add a back shield to the light pole fixture to eliminate the light trespass to adjacent property and/or commercial or residential windows.

1007.6.7.2.1.1.2 The (U) describes the lumen distribution transmitted up from the luminaire. Up light is a major contributor to sky glow. Sound Transit requires luminaires with an uplighting rating of U = 0 for all exterior lights.

1007.6.7.2.1.1.2.1 Exception: Flagpole or Sound Transit signage at the facility entrance.

1007.6.7.2.1.1.3 The (G) describes the rating is for glare, Luminaires must have a glare rating of G = 0 or G = 1.

1007.6.7.2.1.1.3.1 When glare rating is not available, the exterior light fixture must include a diffuser, lens, or glare shielding.

1007.6.7.2.1.2 Do not use in-ground lighting or bollard lighting.

1007.6.7.3 Identification Tag

1007.6.7.3.1 The designer must assign a unique identification for each luminaire. The unique identification must follow the general callout Type LL-#E or Type LL-#X where:

1007.6.7.3.1.1 The first letter “L” designates the latest energy efficiency luminaire, with “L” for LED light fixture. See Table 1007-9 for Lamp Performance criteria.

1007.6.7.3.1.2 The second letter “L” is for the Installation Types, see Table 1007-10.

1007.6.7.3.1.3 The number sign “#” is unique number for instances of the luminaire.

1007.6.7.3.1.4 The letter “E” designates for the means of egress luminaire.

1007.6.7.3.1.5 The letter “X” designates for the exit sign.

Commentary: Use the following examples to identify general luminaire:

Type LS-1 is an LED light fixture, surface mounted with unique number.

Type LS-1E is an LED light fixture, surface mounted with unique number and designation for Means of Egress luminaire.

Type LP-1X is an LED light fixture, pendant mounted, with unique number and exit sign luminaire.

Type LLP-1 is an LED light fixture, light pole with unique number.

Table 1007-9: Installation Types

Designation for second "X"	Description for installation use
F	Festoon
H	Hazard
HB	High Bay
LP	Light Pole
P	Pendant
S	Surface / Ceiling mount
R	Recessed mount
WM	Wall Mount
WW	Wall Wash
X	Exit Sign

1007.6.7.4 Light Fixture Schedule

1007.6.7.4.1 The lighting designer must provide a light fixture schedule.

1007.6.7.4.1.1 The light fixture schedule must include the identification tag, luminaire description (based on the cut sheet provided in the lighting calculation), manufacturer's name and series, mounting height, mounting types, CCT, lumens output, load in amps, volts, and CRI.

Commentary: The designer can add additional information besides the information listed above.

1007.6.7.4.2 Light Pole Schedule

1007.6.7.4.2.1 The lighting designer must provide a light pole schedule.

1007.6.7.4.2.2 The light pole schedule must include the following: pole number (instance), identification tag, pole height, light pole fixture height (must include the pole base height), devices or accessories including the mounting height from the light pole base, and light pole's material, shape, and finish.

1007.6.8 Lighting Control

1007.6.8.1 The lighting control system and devices must be designed and located appropriately so that lighting layout, strategy, and control works as intended.

1007.6.8.2 The following areas must be exempt from Washington State Energy Code (or Seattle Energy Code) due to safety, security, and emergency area designation:

1007.6.8.2.1 Stations

1007.6.8.2.2 Parking garages

1007.6.8.2.3 Tunnels (including cross-passage way and tunnel station).

1007.6.8.2.4 Plazas or open plaza areas

1007.6.8.2.5 Pedestrian walkways

1007.6.8.3 Lighting control conductors must be in separate conduits from power.

1007.6.8.4 Lighting control integral to the light fixture or lighting control panel must not have a wireless or Bluetooth interface.

1007.6.8.5 Lighting control panels must interface with BMS through network connection or hardwire connection. See Set 1004 Building Management System.

1007.6.8.6 All exterior lighting control devices must be weatherproof and wet rated. For additional requirements, see Set 1005 Electrical Power.

1007.6.8.7 All lighting control devices must comply with energy code requirements. Unless the area or room is designated for safety, security, or emergency which is an exemption from the energy code.

1007.6.8.8 All lighting control panels must have a manual override-on. to control all lights allowing temporary operation of the lighting system for a minimum of two hours and up to four hours. Once the four hours elapse, the lighting control panel resumes control of the operation of the lighting system.

1007.6.8.8.1 The manual override-on must be a manual switch or push button located immediately adjacent to and outside of the lighting control panel.

Commentary: A non-electrical personnel must operate the manual override-on without obstruction such as password or opening electrical panels.

1007.6.8.9 All occupancy sensors must have an override switch option.

1007.6.8.9.1 Parking garage occupant sensor control function must automatically reduce the light level to 50 percent when there is no vehicle or pedestrian activity detected within a lighting zone for 20 minutes. Lighting must return to full power when a vehicle or pedestrian enters the space.

1007.6.8.10 Parking garage transition lights must be located at the entrance when vehicle enters the parking garage and at the parking garage roof top when vehicle enters the transition space between the roof top uncover space and the cover space.

1007.6.8.10.1 Parking garage entrance transition lights must be on during the daytime and must be off during nighttime.

1007.6.8.10.1.1 Pedestrian bridge deck and/or covered pedestrian walkway luminaires must be continuously lighted from dusk to dawn.

1007.6.8.11 Photocell

1007.6.8.11.1 One centralized photocell must control the entire exterior lighting system of a facility.

1007.6.8.11.2 When exterior lighting system has both 120 V and 277 V luminaires, provide one photocell for each voltage system. Do not control two different voltage systems with a single photocell. Both photocells must be in a single central location.

1007.6.8.11.3 Photocell location must be accessible by maintenance personnel. Location must be provided in the plan drawings.

1007.6.8.12 Manual Lighting Switch

1007.6.8.12.1 The following rooms in any facilities must have manual lighting switch and are exempt from Washington State Energy Code or Seattle Energy Code due to safety.

1007.6.8.12.1.1 Mechanical rooms.

1007.6.8.12.1.2 Main electrical rooms, switchgear, medium voltage rooms and electrical closets.

1007.6.8.12.1.3 UPS rooms.

1007.6.8.12.1.4 Elevator/escalator machine rooms and pits.

1007.6.8.12.1.5 Sprinkler riser rooms.

1007.6.8.12.1.6 Communication rooms.

1007.6.8.12.1.7 Shop pit area.

1007.6.8.12.1.8 Generator rooms.

1007.6.8.12.1.9 Signal room (if applicable – part of station structure).

1007.6.8.12.1.10 TPS room (if applicable – part of station structure).

1007.6.8.13 Occupancy Sensors may be used in the following rooms.

Commentary: Control function must follow the requirements specified in WSEC or Seattle Energy Code, unless noted otherwise.

1007.6.8.13.1 Crew rooms, lunchrooms, locker rooms and crew restrooms.

1007.6.8.13.2 Supervisor rooms.

1007.6.8.13.3 Public restrooms.

1007.6.8.13.4 Custodian rooms.

1007.6.8.13.5 Storage room/trash rooms.

1007.6.8.13.6 Offices/open plan office areas/enclosed offices.

1007.6.8.13.6.1 Conference room/meeting/multipurpose rooms.

1007.6.8.13.6.2 Hallway/service corridors.

1007.6.9 Voltage Requirement

1007.6.9.1 Normal and emergency power source voltages: 120 volts or 277 volts.

1007.6.9.2 Provide a lighting design with a single voltage serving luminaires for a facility.

Commentary: If voltage requirement for the Lighting System will be mixed between 120 volts or 277 volts system, inform Sound Transit Electrical SME.

1007.6.9.3 24 Vdc Lighting System

1007.6.9.3.1 Provide a universal step-down transformer in a junction box, within 3 feet of luminaires served, that is inaccessible by the public.

Commentary: For junction box requirements for outdoor or indoor, see Set 1006 Electrical Raceway.

1007.7 ENGINEERING MANAGEMENT REQUIREMENTS

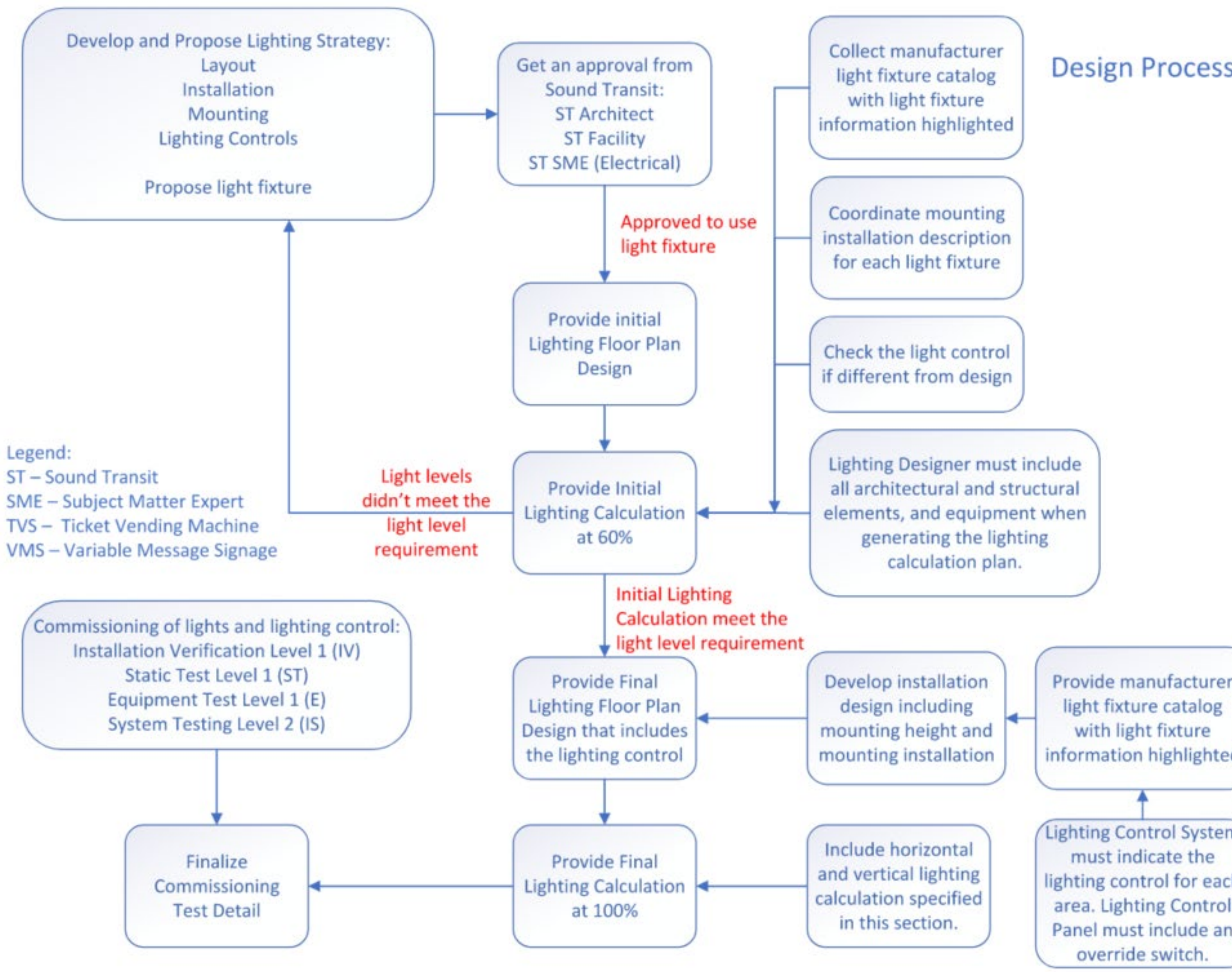
1007.7.1 Interface and Integration Management

1007.7.1.1 The design must consider and account for all interfaces to provide a fully integrated design. Adhere to Sound Transit's Interface Coordination and Integration Plan to inform design documents and verify coordination of interface scope and boundaries, providing constructable documentation, and functional designs.

1007.7.2 Design Management

1007.7.2.1 The diagram shown below is the design process for lighting and lighting system.

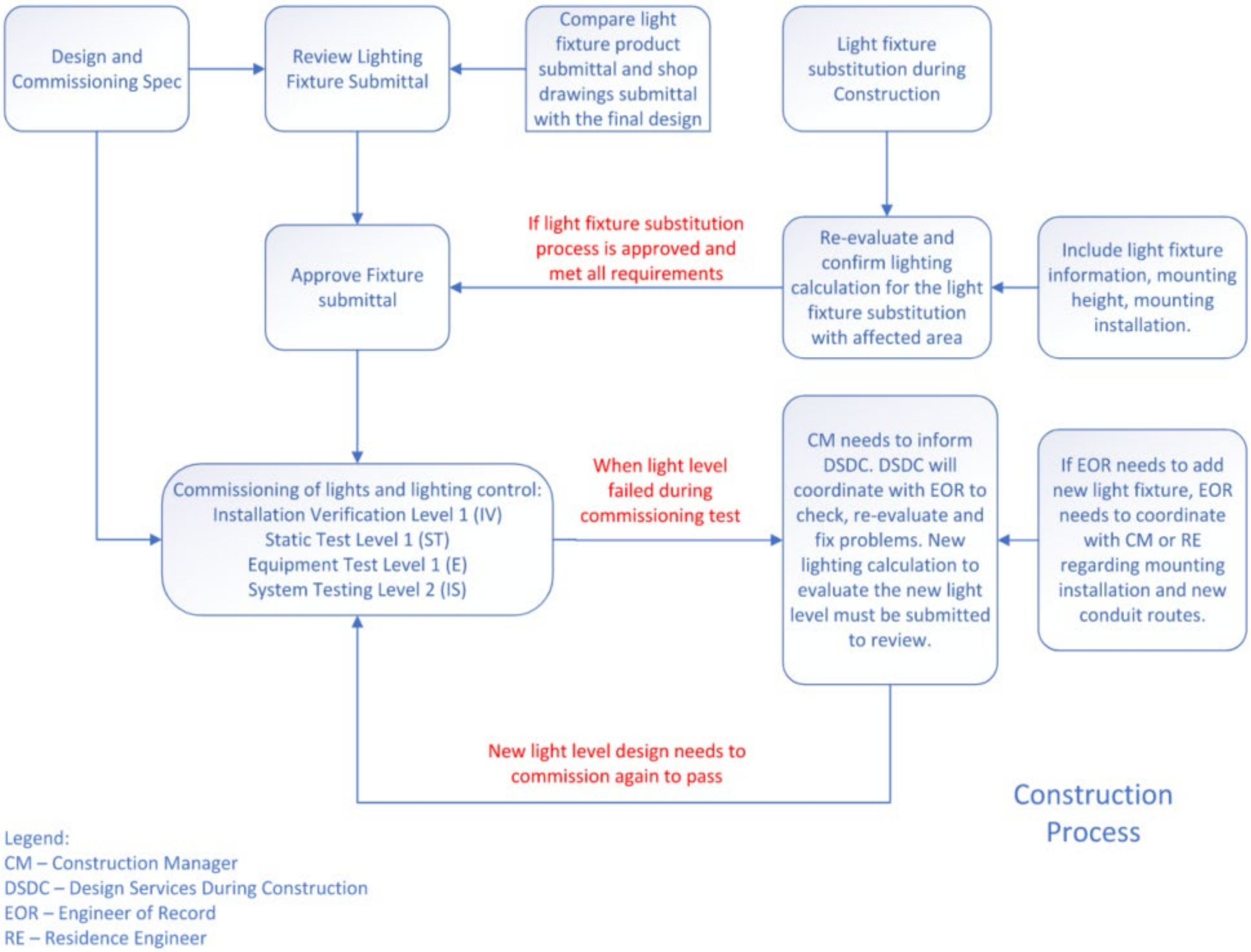
Figure 1007-6: Lighting and Lighting System Design Process



1007.7.3 Manufacturing and Construction Management

1007.7.3.1 The diagram shown below is the construction process for lighting and lighting system.

Figure 1007-7: Lighting and Lighting System Construction Process



1007.7.4 Installation Management

1007.7.4.1 Ensure the installation of the light fixture is accessible.

1007.7.4.2 When the luminaire requires replacement, facilities maintenance must be able to remove the luminaire without other obstruction.

1007.7.4.3 Luminaires must be located 10 feet clear from OCS or OCS hardware.

1007.7.5 Inspection and Testing Management

1007.7.5.1 The design must adhere to Sound Transit's General Testing and Commissioning Plan, incorporating into specifications test criteria and acceptance parameters for validation of design intent and function.

1007.7.6 Training, Pre-Revenue Operations

1007.7.6.1 The contractor must provide training for facility maintenance personnel for the light system including the lighting control panel, lighting control devices integral or external to the luminaire, the override manual switch, and the BMS overrides.

1007.7.7 Certification Management

1007.7.7.1 Sound Transit safety certification related to lighting and life safety systems must be completed prior to revenue service.

1007.8 APPENDICES (NOT USED)

END SET - 1007

1101 COMMON TECHNOLOGY

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SET - 1101 COMMON TECHNOLOGY

1101.1 INTRODUCTION

1101.1.1 Document Scope

Commentary: *Content can be provided as part of system-specific documentation, or combined across systems, as long as the content described below is specifically documented.*

Commentary: *These requirements apply to new systems and new integrations. These requirements are not a mandate to retrofit existing systems that are only being expanded to include new locations.*

1. *Examples that are not new systems or new integrations (out of scope):*
    a. *Adding stations to existing systems (SCADA, CCTV, PIMS, BMS, etc.) for an expansion effort.*
    b. *Adding new access control locations to existing Lenel systems.*
2. *Examples that are new systems or new integrations (in scope):*
    a. *Installing a new access control system and integrating it with existing systems like Genetec.*
    b. *Implementing a new Yard Management System that is not already in use at Sound Transit or integrating existing Yard Management Systems to provide a single tool to view all yards.*
    c. *Building new condition monitoring and notification system such as wind and wave monitoring for the I-90 bridge.*

1101.1.1.1 This set covers general technology requirements for communications; integrated automation systems; operational technologies consisting of electronic hardware and communications systems that monitor, manage, and report status of Sound Transit facilities; infrastructure and operating assets including:

- SCADA, (TCS, BMS, EVS, Train-To-Wayside)
- Access Controls (ACS)
- Fare Vending (SCR, TVMs)
- Track Intrusion Systems (TIDS)
- Public Address (PA), Variable Message Signs (VMS), and Passenger Information Management Systems (PIMS)
- Conditioning Monitor (EMI, Vibration Monitoring, Gas Monitoring)
- LRV Yard Monitoring (YardViewer)
- LRV Systems and Vehicle Monitoring (APC, AVL, MWS)
- Closed-Circuit Television (CCTV)
- Vertical Conveyance Monitoring (Knaq)
- Sounder Train Systems
- Bus Rapid Transit Bus Systems
- Maintenance Facility Systems
- Parking and Parking Garage Systems

1101.1.1.2 Each system with network connectivity or that can be connected to must be evaluated for technology requirements.

1101.1.1.3 System Interface Standard Specifications: This requirement set accompanies Sound Transit Standard Specification 27 26 26 Data Communications Integration. Coordination between the two is necessary.

1101.1.1.4 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of Sound Transit IT Enterprise Architecture Division to determine the technical source for the design criteria.

1101.1.2 Regulations, Codes, Standards, and Guidelines

1101.1.2.1 International Regulations, Codes, Standards, and Guidelines (Not Used)

1101.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

1101.1.2.2.1 National Institute of Standards and Technology Artificial Intelligence Risk Management Framework (NIST AI 100-1 or most current version). https://nvlpubs.nist.gov/nistpubs/ai/NIST.AI.100-1.pdf

1101.1.2.2.2 Department of Energy AI Risk Management Playbook for risk identification and mitigation https://www.energy.gov/ai/doe-ai-risk-management-playbook-airmp

1101.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines (Not Used)

1101.1.2.4 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

1101.1.2.5 Other Jurisdictions (Not Used)

1101.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

1101.1.2.6.1 Sound Transit Technology Architecture Guidance and Standards

1101.1.3 Abbreviations and Acronyms

1101.1.3.1 Access Controls (ACS)

1101.1.3.2 AI: Artificial Intelligence

1101.1.3.3 APC: Automatic Passenger Counting

1101.1.3.4 AVL: Automatic Vehicle Location

1101.1.3.5 BIA: Business Impact Assessment

1101.1.3.6 BMS: Building Management System

1101.1.3.7 BIA: Business Impact Assessment

1101.1.3.8 EMI: Electromagnetic Interference

1101.1.3.9 CCTV: Closed-Circuit Television

1101.1.3.10 EVS: Emergency Ventilation System

1101.1.3.11 Gen-AI: Generative AI

1101.1.3.12 GANs: Generative Adversarial Networks

1101.1.3.13 IT: Information Technology

1101.1.3.14 ICDs: Interface Control Document

1101.1.3.15 LLM: Large Language Model

1101.1.3.16 LRV: Light Rail Vehicle

1101.1.3.17 ML: Machine Learning

1101.1.3.18 MWS: Maintenance Wayside Services/Server

1101.1.3.19 NTD: National Transportation Database

1101.1.3.20 NLP: Natural Language Processing

1101.1.3.21 NIST: National Institute of Standards and Technology

1101.1.3.22 PIMS: Passenger Information Management System

1101.1.3.23 Public Address (PA)

1101.1.3.24 RPO: Recovery Point Objective

1101.1.3.25 RTO: Recovery Time Objective

1101.1.3.26 SCR: Secure Card Reader

1101.1.3.27 SNMP: Simple Network Management Protocol

1101.1.3.28 TCO: Total Cost of Ownership

1101.1.3.29 TCS: Train Control System

1101.1.3.30 TIDS: Track Intrusion Detection System

1101.1.3.31 TVM: Ticket Vending Machine

1101.1.3.32 VMS: Variable Message Signs

1101.1.4 Definitions and Classifications

1101.1.4.1 Recovery Point Objective (RPO): Defines the amount of data that can be lost due to a disaster or failure.

1101.1.4.2 Recovery Time Object (RTO): Defines the maximum time that an application, system, or process can be down without a significant impact to operations.

1101.1.4.3 Artificial Intelligence (AI): The use of the term AI refers to all systems that are based on, or are assisted by or integrated with, technologies that are commonly referred to as “Artificial Intelligence,” which includes Generative AI (Gen-AI), Machine Learning (ML), Deep Learning, Neural Networks, Computer Vision, Generative Adversarial Networks (GANs), Large Language Models (LLM), Natural Language Processing (NLP), Reinforcement Learning, Expert Systems, and Autonomous Systems.

1101.1.4.4 System or Solution Design: A design document must address the following items:

- Identify the main components of the solution, clarify where they are located (e.g., station, vehicle, data center), the interfaces between the components, any integrations into and out of the solution, and the flow of data into, out of, or between those components.
- Provide a narrative description that articulates how the components of the solution work, how the data flow, how the system interfaces/integrations work, and how manual integration processes are executed.
- Describe all technologies, tools, and frameworks used.
- Describe the performance, scalability, and security considerations based on Recovery Time Objective (RTO) and Recovery Point Objective (RPO).
- Provide clear diagrams and any relevant technical details to ensure Sound Transit can understand the impact to our technology landscape.

1101.1.5 References (Not Used)

1101.2 STAKEHOLDER NEEDS

1101.2.1 Passenger Experience

1101.2.1.1 Potential impacts and harms regarding the use of AI have been identified and mitigated.

1101.2.2 Operational Needs **(Not Used)**

1101.2.3 Recoverability and Resiliency **(Not Used)**

1101.2.4 Maintenance Needs **(Not Used)**

1101.2.5 Safety Needs **(Not Used)**

1101.2.6 Security Needs **(Not Used)**

1101.2.7 Reliability, Availability, and Maintainability Needs **(Not Used)**

1101.2.8 Environmental and Sustainability Needs **(Not Used)**

1101.3 SYSTEM REQUIREMENTS

Commentary: *Technology and business processes change more frequently than the ST Requirements Manual. For each project/program/effort, Designers need to assess changes and produce documentation that reflects the latest technology needs.*

1101.3.1 Technology Impact Assessment

1101.3.1.1 Designers must perform a Technology Impact Assessment to inform the system requirements. Designers must coordinate with relevant ST Subject Matter Experts to incorporate current needs, guidelines, policies, standards, and procedures. The Technology Impact Assessment must document the impacts described in section 1101.4.1.

1101.3.1.2 Compliance and Conformance Assessment
Commentary: *Designers must coordinate with ST Subject Matter Experts to understand how changes in the law and in regulations may drive changes in the Agency's processes or applications. New or changing needs must be considered in the context of governance, how the changes interact with the Agency's policies and values, and if policies or governance structures need to change.*

1101.3.1.2.1 Document must include current Technology Architecture standards and guidelines.

1101.3.1.2.2 Document must include current applicable Records Management and eDiscovery policies.

1101.3.1.2.3 Document must include current ST policies, guidelines, and practices regarding the inclusion of AI components.

1101.3.1.3 Availability, Recoverability, and Resiliency Assessment
Commentary: *Designers must coordinate with ST Subject Matter Experts to understand current and emerging business practices. Example: There is nothing in the ST Requirements Manual saying that LRVs need wireless or cellular connectivity at stations. With the plan to store LRV along the alignment, this connectivity could be added to some stations. It is not clear if it should be considered for new extension.*

1101.3.1.3.1 Designers must evaluate new systems and changed systems for availability, redundancy, and resiliency requirements, using the Information Security Business Impact Assessment (BIA) tool.

1101.3.1.3.2 Designers must produce a projected or expected transaction or event rate to guide the sizing of technology platforms and inform load testing efforts.
Commentary: *Designers must define performance-based requirements (what the solution needs to accomplish, not how the work will be accomplished). Example: store CCTV footage for all station cameras for 30 days.*

1101.3.1.3.2.1 Servers must be sized to support activities and transaction rates.

1101.3.1.3.2.2 New networks must be sized to support activities and transaction rates. Designers must also consider whether existing Agency networks need to be resized to support activities and transaction rates.

1101.3.1.3.2.3 Designers must consider whether existing Agency systems need to be resized to support integration activities and transaction rates.

1101.3.1.3.3 Designers must project growth over time that will impact the solution, including system expansion and growth in the number of users.

1101.3.1.3.4 Designers must determine Key Performance Indicators based on current operating conditions and procedures.
Commentary: *Example metrics to investigate: availability, uptime, response time, error rate, time to resolution, capacity utilization (compute, storage), bandwidth utilization.*

1101.3.1.4 Technology Ecosystem and Total Cost of Ownership (TCO) Assessment
Commentary: *Technology products, and especially the skills required to operate and maintain them, are a non-trivial expense. By minimizing technology diversity, this management cost can be minimized. Solutions, tools, and technology must be shared across organizational boundaries to minimize training and maintenance costs.*

1101.3.1.4.1 Designers must evaluate the 15-year TCO for solutions including hardware, software, maintenance, and training for new and changed systems. The TCO must consider reusing and integrating with existing systems.

1101.3.1.4.1.1 Designers must consider existing solutions used by the Agency prior to searching for a new tool. Before a new tool can be considered, a feasibility study or requirements analysis must be conducted, and its final report must conclude that no existing solution can meet the requirements.

1101.3.1.4.1.2 Designers must consider a custom solution only where no commodity or commercial off-the-shelf solution exists. Before a custom solution can be considered, a market study must be conducted, and its final report must conclude that no commercial off-the-shelf solutions exist that meets the Agency's needs.

1101.3.1.4.2 The impact of technical debt must be considered in the overall determination of benefit.

1101.3.1.5 System Integration Assessment
Commentary: *Today some systems, like Yard Management, are not integrated. Going forward they may need to be to support efficient operations.*

1101.3.1.5.1 Designers must examine business processes during the requirements phase to determine the opportunity and need for system integration.

1101.3.1.5.2 Products/solutions must be evaluated for their ability to integrate/interoperate using modern integration patterns and protocols. Designers must identify current and emerging standards that are relevant to the solution.

1101.3.1.6 Monitoring and Supportability Assessment

1101.3.1.6.1 Designers must evaluate monitoring requirements for all hardware and software components. Assessment must include thresholds, state changes, and consider whether ST or vendor will be responsible for acting on issues.

1101.3.2 Solution Requirements

1101.3.2.1 Designers must produce requirements that reflect the needs indicated in the Technology Impact Assessment.

1101.3.2.1.1 Designers must produce requirements for new and changed systems that meet or exceed availability, redundancy, and resiliency requirements, including RTO and RPO.

1101.3.2.1.2 Based on the BIA criticality and/or Hazard Analysis, Designers must produce requirements for new systems and new integrations to perform availability and disaster recovery testing that verifies that redundancy and resilience requirements are met prior to system going live.

1101.3.2.2 The solution must be designed to scale, without impacting performance or degrading Key Performance Indicators. Designers must produce requirements, including specific availability and performance metrics.

1101.3.2.3 New solutions requiring a user interface must provide a browser-based interface for operations users, rather than installing software on users' computers or devices.

1101.3.2.4 Solutions requiring more than 10 percent customization must have a long-term support contract with the solution's manufacturer/provider to provide ongoing feature upgrades and maintenance, break/fix support, help desk, and other responsibilities related to the customization.

1101.3.2.5 Custom software or integrations must conform to current Technology Architecture standards and guidelines.

Commentary: *The more that assets conform to common and supported standards, rather than proprietary implementations, the easier it will be to replace an asset, thereby minimizing costs and implementation efforts.*

1101.3.2.6 Statements of work and vendor/contractor engagements must include integration work, in addition to the purchase of the licenses.

1101.3.2.7 Monitoring and Supportability

1101.3.2.7.1 Software for monitoring, troubleshooting, tracing, and testing the solutions performance must be delivered along with the solution hardware and software.

1101.3.2.7.2 Designers must document solution monitoring requirements for all hardware and software components and interfaces. Requirements must include the items to be monitored and how monitoring will occur, define appropriate thresholds for state changes, and specify acceptable update frequencies and maximum delays.

1101.3.2.7.2.1 Solutions must provide documented URLs, remotely invokable scripts, or other similar techniques that can be called by the Agency monitoring tool to assess the health of the solution components.

1101.3.2.7.2.2 Solutions must enable health monitoring of all devices using the Agency monitoring tool (Solar Winds or equivalent) by enabling SNMP alerting and/or loading the Agency monitoring agent onto system components to allow for monitoring by the Agency monitoring tool.

1101.3.2.7.2.3 Solutions must identify points to monitor system and integration activity and performance so that the Agency monitoring tool can detect system failures or failover.

1101.3.2.7.2.4 All solution components must provide troubleshooting capabilities to isolate issues and identify impacted components.

1101.3.2.7.2.5 Log files must be available for aggregation within an Agency tool, including documentation that describes the structure and contents of the log files.

1101.3.2.7.3 All solution components must use technology that is supported by the original manufacturer or producer. Solutions containing or dependent on prototype, obsolete, discontinued components, or versions that are beyond standard support are prohibited.

1101.3.2.8 Internet of Things (IoT)

1101.3.2.8.1 All IoT devices must provide device heath monitoring capabilities, see Monitoring and Supportability section in this document.

1101.3.2.8.2 Designs must include a method for visualizing health of all installed devices.

1101.3.2.9 Purchase & Transition of Assets

1101.3.2.9.1 Vendor must transfer ownership of equipment purchased for Sound Transit to Sound Transit.

1101.3.2.9.1.1 Designers must list all equipment at the lowest level replaceable unit to allow spares quantity to be negotiated.

1101.3.2.9.1.2 Vendor must deliver more devices than required so that the Agency has a back stock of spares. The number of spares will be defined by part/system/assembly based on risk (such as vandalism) and failure rates. Pricing of spares will be proposed by vendor. Quantities will be approved by the Agency during execution. Pricing may include initial prices and projected price increase structures.

1101.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

1101.5 SYSTEM INTERFACE REQUIREMENTS (NOT USED)

1101.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

1101.6.1 Submittal Requirements
Commentary: Content can be provided by build contractor as part of system-specific documentation (see sections 1101.1.1.1.1–1101.1.1.1.14) or combined across systems as long as the content described below is specifically documented.

1101.6.1.1 Preliminary Design

1101.6.1.1.1 System or Solution Design: Build contractor must submit comprehensive design documentation.

1101.6.1.1.1.1 Identify the main components of the solution; clarify where the components are located (e.g., station, vehicle, data center); and understand the interfaces between the components, integrations in and out of the solution, and the flow of data in, out, or between those components. To the extent possible, component location should use current names (IDs) and nomenclatures already in use.

1101.6.1.1.1.2 Provide a narrative description articulating how the components of the solution work, how the data flow, and how the system interfaces and integrations work (including manual integrations).

1101.6.1.1.1.3 Describe all technologies, tools, and frameworks used.

1101.6.1.1.1.4 Identify the performance, scalability, and security considerations. Document the approach to meeting RTO and RPO.

1101.6.1.1.1.5 Clear diagrams and relevant technical details must be provided to ensure Sound Transit can understand the impact to our technology landscape.

1101.6.1.1.1.6 Proposed exceptions to requirements must be documented.

1101.6.1.1.2 Data Documentation: Build contractor must submit comprehensive data documentation.

1101.6.1.1.2.1 Provide a Data Inventory Deliverable, including preliminary metadata: object name, data type, size, format, acceptable values, indicate if data are required, and indicate if data are unique.

1101.6.1.1.2.2 Provide data diagram(s) or drawing(s) depicting entities, data objects, concepts, or tables; relationships between entities; and include primary and foreign keys where applicable.

1101.6.1.1.3 Interface Control Documents (ICDs): Build contractor must submit comprehensive data communication integration content in the Interface Control Documents.

1101.6.1.1.3.1 Provide a Data Inventory Deliverable for the interface, including preliminary metadata: object name, data type, size, format, acceptable values, and indicate if data are required, and if data are unique.

1101.6.1.1.3.2 Provide data diagram(s) or drawing(s) for the interface depicting entities, data objects, concepts, or tables; relationships between entities; and include primary and foreign keys where applicable.

1101.6.1.1.3.3 Provide Quality tests(s) for the interface: The automated test or tests that will be applied to the data element upon entry and the actions required based on test results.

1101.6.1.1.3.4 Provide business rule(s) for the interface: Provide direct traceability to business rules as relevant for each field, e.g., for Passenger Load element is associated with Business Rule 1.

1101.6.1.1.3.5 Provide Originating process(es): The process that creates the data, e.g., thumbwheel on LRV.

1101.6.1.1.3.6 Provide Consuming process(es): The process or processes that use the data, e.g., PA/VMS; NTD Reporting.

1101.6.1.1.3.7 Modifying process(es): The process or processes through which the data can be modified, e.g., SCADA Train Control.

1101.6.1.1.4 Artificial Intelligence Documentation: Build contractor must submit documentation describing the use of Artificial Intelligence. If AI is not being used, then this section must state plainly that no AI is being used. If AI is being used in the system, product, or service, then the following sections must be included in the Preliminary Design and demonstrate conformance with Sound Transit policies, guidelines, and practices regarding the use of AI components.

1101.6.1.1.4.1 Provide AI Declaration: A statement describing where and how AI is being used.

1101.6.1.1.4.2 Provide Ethics Statement: A statement from contractor describing their ethical use framework for AI, and how contractor ensures the safety of Sound Transit staff, passengers, and data.

1101.6.1.1.4.3 Provide Risk and Impact Assessment: Contractor must provide a Risk and Impact Assessment of the use of AI within the system/product/service. The assessment must align with ST's published guidelines on what to consider for such an assessment.

1101.6.1.1.5 Final Design

1101.6.1.1.5.5 System or Solution Design must be updated to provide final details including logical and physical design, networking, and protocols used.

1101.6.1.1.5.6 Data Documentation must be updated to include additional or changed attributes.

1101.6.1.1.5.7 Artificial Intelligence Documentation must be updated to include changes or additional detail and demonstrate conformance with Sound Transit policies, guidelines, and practices regarding the use of AI components.

1101.6.1.1.5.7.1 Updated AI Declaration must include additional or changed information.

1101.6.1.1.5.7.2 Updated Risk and Impact Assessment must include additional or changed information.

1101.6.1.1.5.7.3 Governance and Management of AI: Documentation on contractor's governance and management of AI use. The documentation must address:

1101.6.1.1.5.7.3.1 Observability: Describe transparency and explainability of data use and decision making.

1101.6.1.1.5.7.3.2 Fairness and Bias Mitigation: Document contractor's assurance of fairness and their mitigations against bias and which biases.

1101.6.1.1.5.7.3.3 Human-Centered Ethics: Document how contractor's processes prioritize human values, rights, privacy, and well-being in decision-making.

1101.6.1.1.5.7.3.4 Data Privacy and Security: Describe frameworks, policies, audits, and other mechanisms in use.

1101.6.1.1.5.7.3.5 Safety and Security: Describe frameworks, policies, audits, and other mechanisms in use.

1101.6.1.1.5.7.3.6 Accountability and Governance: Describe frameworks, policies, audits, and other mechanisms in use.

1101.6.1.1.6 Test Documentation: Build contractor must submit comprehensive design documentation.

1101.6.1.1.6.1 Test Plan must document test cases clearly showing input values, execution preconditions, and expected results. The Test Plan must describe how the defects will be tracked, prioritized, worked, and resolved.

1101.6.1.1.6.2 Test Data: Submit any data set used for testing so that ST can evaluate the quality of the test.

1101.6.1.1.6.3 Requirements Traceability Matrix must show the relationship between requirements and test cases.

1101.6.1.1.6.4 Test Summary Report must show all tests conducted and the results, including defects identified.

1101.6.1.1.6.5 Performance Testing Plan must document how performance will be tested and measured.

1101.6.1.1.6.6 Availability and Disaster Recovery Test Plan document how availability and disaster recovery testing will be performed and measured.

1101.6.1.1.7 System Support

1101.6.1.1.7.1 Comprehensive user guides and manuals that cover full operation and administration of the system.

1101.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

1101.8 APPENDICES (NOT USED)

END SET - 1101

1102 PASSENGER INFORMATION MANAGEMENT SYSTEMS (PIMS)

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FIGURES

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SET - 1102 PASSENGER INFORMATION MANAGEMENT SYSTEM (PIMS)

1102.1 INTRODUCTION

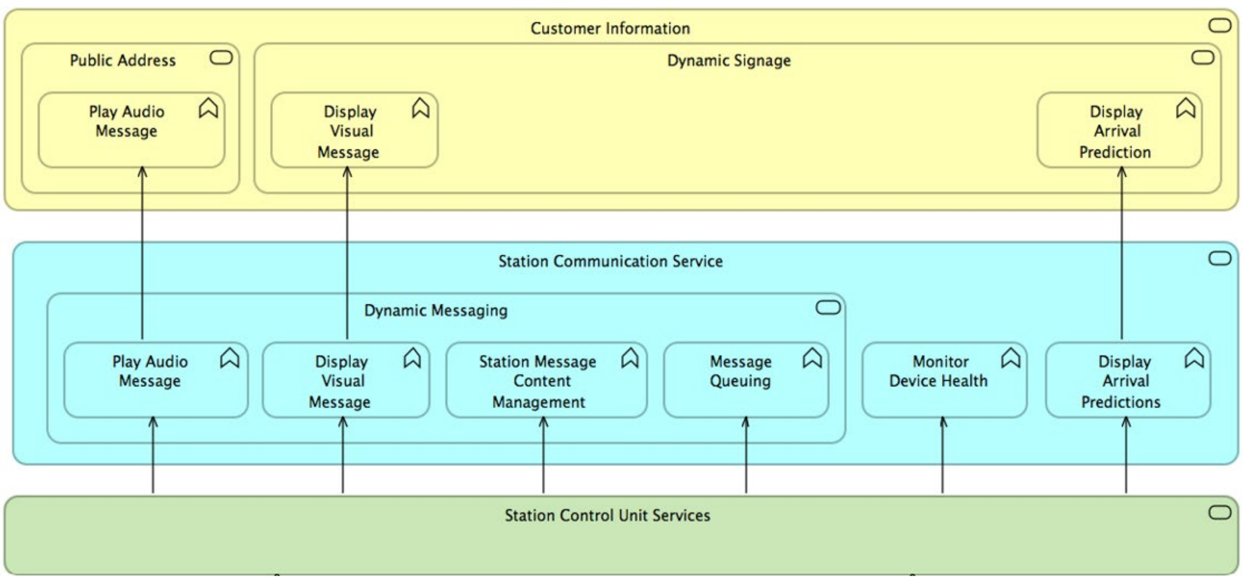
1102.1.1 Document Scope

1102.1.1.1 This document contains the requirements for passenger information system. This section includes requirements for dynamic signage and message management.

1102.1.1.2 Architecture

1102.1.1.2.1 The diagram below is the summary architectural overview of services for all stations and all modes.

Figure 1102-1: PIMS Overview



1102.1.1.3 International Regulations, Codes, Standards, and Guidelines (Not Used)

1102.1.1.4 Federal and National Regulations, Codes, Standards, and Guidelines

1102.1.1.4.1 NFPA 101, Life Safety Code.

1102.1.1.4.2 NFPA 730, Guide for Premises Security.

1102.1.1.4.3 NFPA 731, Standard for the Installation of Electronic Premises Security Systems.

1102.1.1.4.4 Mobility Data Interoperability Principles and Standards (interoperablemobility.org).

1102.1.1.4.5 NFPA 72 Fire Life Safety.

1102.1.1.4.6 IEEE Standard 802.3X – IEEE Standard for Ethernet.

1102.1.1.5 State and Local Regulations, Codes, Standards, and Guidelines (Not Used)

1102.1.1.6 Industry Regulations, Codes, Standards, and Guidelines (Not Used)

1102.1.1.7 Other Jurisdictions (Not Used)

1102.1.1.8 Sound Transit Regulations, Codes, Standards, and Guidelines (Not Used)

1102.1.2 Abbreviations and Acronyms and Definitions and Classifications

1102.1.2.1 APC–automatic passenger counting

1102.1.2.2 FPTV–flat panel television

1102.1.2.3 I/O–input/output

1102.1.2.4 PIMS-passenger information management systems

1102.1.2.5 SCU–station control unit

1102.1.2.6 VMS–variable message sign

1102.1.2.7 EVS – emergency ventilation system

1102.2 STAKEHOLDER NEEDS

1102.2.1 Passenger Experience and Operational Needs

1102.2.1.1 Please see Section 1102.3 System Requirements.

1102.2.2 Maintenance Needs

1102.2.2.1 Station components and sub-components including, but not limited to, all delivered hardware, such as signs and station control units must be designed for swap/replacement on site with an identical unit within one day.

- The interior of the System equipment must be safe and easy to access. There must be adequate space to insert keys; grasp, lift, and turn internal components; and remove and replace components, connections, and consumables. Guides, rails, tracks, handles, and captive fasteners must be provided to facilitate module installation and removal.
- For ease of service and replacement, all electrical connections between components and subassemblies must be established by connectors that allow rapid removal of a component or subassembly. Plug-in connectors must be equipped with strain relief to prevent damage to cables and connectors.
- Components requiring frequent adjustment or maintenance must be conveniently located, as determined during design and testing, and designed to facilitate access and adjustment utilizing tool-free techniques wherever possible.
- All devices must have clear labels and symbols that, at a minimum, indicate safety warnings, servicing steps, and wiring connections.
- The System must have a modular design for all relevant components. These modules must support field replacement to return a device to service in minimal time in the event of a failure. The System must also permit upgrades and configuration changes without requiring component replacement or redesign.
- The replacement of field devices or components must be quick and secure, as determined during design review.

1102.2.3 Safety Needs

- Please see Set 601 Fire/Life Safety for interfaces to audio and messaging at stations in the event of an emergency. PIMS has to have the ability to function within the larger fire life safety design.

1102.2.4 Security Needs (Not Used)

1102.2.5 Reliability, Availability and Maintainability Needs Add SCU Redundancy (Phoebe to send email)

1102.2.6 Environmental and Sustainability Needs (Not Used)

1102.3 SYSTEM REQUIREMENTS

1102.3.1 VMS

1102.3.1.1 PIMS directs that all VMSs for all Sound Transit facilities. Only two types are approved—bar style VMS 42-inch and 46-inch signs. The specification for these signs is governed by Sound Transit Standard Specification 27 51 16 Public Address Variable Message Signs (Digital Displays).

1102.3.2 SCUs

1102.3.2.1 System Sub-components

1102.3.2.1.1 Main component of the system

1102.3.2.1.1.1 The SCU is an integrated component in the form of an industrial rack-mounted computer at each station. It must perform the functions of communications with the PIMS head end, communications with station dynamic signs, communications to the audio system, and I/O with the emergency ventilation system and fire systems at stations where emergency messaging is needed.
Virtual SCU for facilities that do not integrate with fire life safety and audio systems.

1102.3.2.1.2 Other components

1102.3.2.1.2.1 System integration

1102.3.2.1.2.2 System interfaces

1102.3.2.1.2.3 Controls

1102.3.2.1.2.4 Power

1102.3.2.1.2.5 Standards and protocols

1102.3.2.1.2.6 Installation

1102.3.2.1.2.7 Mounting

1102.3.2.1.2.8 Enclosures

1102.3.2.1.2.9 Terminations

1102.3.2.1.2.10 Network transmission

1102.3.2.1.2.11 Users

1102.3.3 Scalability

1102.3.3.1 Locations and topology

1102.3.3.1.1 Quantity

1102.3.4 Accessibility

1102.3.4.1 Monitoring and management

1102.3.5 Security/Safety

1102.3.5.1 Safety and crime prevention

1102.3.5.2 Destruction of property, vandal resistance

1102.3.5.2.1 Sign placement must be above the 9-foot touch zone described in the Set series 800 Architecture

1102.3.5.3 Hazard and violation reporting

1102.3.5.4 Preventing soiled equipment

1102.3.6 Environmental Conditions

1102.3.6.1 Indoor

1102.3.6.2 Outdoor

1102.3.7 **Operations**

1102.3.7.1 General

1102.3.7.2 Normal operations

1102.3.7.3 Alarm/emergency/abnormal operations

1102.3.7.4 Disaster operations

1102.3.7.5 Special events operations

1102.3.8 Performance Requirements

1102.3.8.1 Availability

1102.3.8.2 Range of operation

1102.3.8.3 Response time

1102.3.8.4 Capabilities and features

1102.3.8.5 Capacity

1102.3.8.5.1 Storage capacity

1102.3.8.5.2 Channel capacity

1102.3.8.5.3 Display buffer

1102.3.8.5.4 Input Request capacity

1102.3.8.5.5 Remote access

1102.3.8.6 Quality

1102.3.8.7 Reliability

1102.3.8.7.1 Redundancy - (network device loss tolerance)

1102.3.8.7.1.1 Logical (network device loss tolerance)

1102.3.8.7.1.2 Physical (device/pathway loss tolerance)

1102.3.8.7.2 Electrical

1102.3.8.7.2.1 Backup power and power loss tolerance

1102.3.8.8 Electromagnetic interference and compatibility

1102.3.8.8.1 Radio interference

1102.3.8.9 Documentation

1102.3.8.9.1 Summary

1102.3.8.9.2 Labeling

1102.3.8.9.3 Design package

1102.3.8.9.4 Drawings

1102.3.8.9.4.1 As-builts

1102.3.8.9.4.2 One-line diagrams

1102.3.8.9.4.3 Site plans

1102.3.8.9.4.4 Shop drawings

1102.3.8.9.4.5 Schematics

1102.3.8.9.5 Documents

1102.3.8.9.5.1 Point list

1102.3.8.9.5.2 Time tables

1102.3.8.9.6 Simulations

1102.3.8.9.6.1 Test results

1102.3.8.9.6.2 Maintenance

1102.3.8.10 General Maintainability

1102.3.8.10.1 Inaccessibility

1102.3.8.10.2 Locations (accessible serviceable)

1102.3.8.10.3 Necessary Accessible Features on Equipment

1102.3.8.10.4 Routine Maintenance

1102.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

1102.4.1 System Breakdown Structure

1102.4.2 System Sites and Locations

1102.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 1102-1: Interface Between PIMS And Other Disciplines

SET SERIES	SET NAME	SET 1102 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	
300	Operational Communications	X
400	Vehicle	X
500	Track	
600	Fire-Life Safety	X
700	Structures	
800	Architecture	X
900	Civil	
1000	Mechanical-Electrical and Building Systems	
1100	Technology	X
1200	Security	X

1102.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

1102.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

1102.7.1 Interface and Integration Management

1102.7.2 Design Management

1102.7.3 Manufacturing and Construction Management

1102.7.4 Installation Management

1102.7.5 Inspection and Testing Management

1102.7.6 Training, Pre-Revenue Operations

1102.7.7 Certification Management

1102.8 APPENDICES

1102.8.1 Digital Signage/Public Address Management

1102.8.1.1 Signage Content Requirements

1102.8.1.2 Train arrivals

1102.8.1.2.1 The system must display vehicle arrivals and relevant details including:
i. Route/line color.
ii. Destination.
iii. Arrival or departure time.
iv. Indication if train is out of service.

1102.8.1.2.2 Provide visual and audio announcements when vehicles are close to the station, examples include the following:
i. Train arriving in two minutes.
ii. Train now arriving.

1102.8.1.2.3 Track/platform number for next train

1102.8.1.2.4 Display the track or platform that the next train will arrive on, particularly useful for cases where trains are reverse running.

1102.8.1.2.5 Car/vehicle capacity

1102.8.1.2.6 Display information about how full a car/vehicle is based on passenger load (APC). Provide number of cars in multi-car train consist.

1102.8.1.2.7 Service announcements

1102.8.1.2.7.1 Display scheduled and even initiated service announcements.

1102.8.1.2.7.2 Displays ad hoc remote and ad hoc station/platform driven service announcements.

1102.8.1.2.8 Destination and route being served.

1102.8.1.2.9 Provide patrons with detail on the destination and route, even if the train is deviating from a standard schedule. If the vehicle is not on regular route, indicate where it is going (e.g., airport to Beacon Hill only). Applies to shuttle train and multiple lines.

1102.8.1.2.10 Display informational details

1102.8.1.2.10.1 Informational messages should provide non-emergency information such as:
i. Elevator & escalator outages
ii. Changes to circulation (routes through the station)
iii. Reminder: tap on/off
iv. Entering fare paid zone

1102.8.1.3 Partner alerts

1102.8.1.3.1 Display service alerts from transit partners, example Amtrak delays. In the future, new partner alert systems will be added, example KCM alerts that impact customers leaving University of Washington Station.

1102.8.1.4 Location or station specific alerts

1102.8.1.4.1 The system must allow display of location or station specific information.

1102.8.1.5 Car number

1102.8.1.5.1 When a patron uses an emergency button or emergency phone on board, the car number where the emergency is located must be displayed on signs.

i. Internal signs alert the conductor
ii. External signs tell emergency personnel which car they should approach when the train is arriving at the station. Current functionality displays the car number on all external destination signs.

1102.8.1.6 Partner agency train arrivals

1102.8.1.6.1 Display partner agency and other modes arrival information on Sound Transit signs where stations are shared. Examples include partner bus agency arrivals at Link stations adjacent to transit centers and Amtrak arrivals at Sounder stations.

1102.8.1.7 Bus arrivals

1102.8.1.7.1 Signs must display predicted bus arrival information. Bus predictions may be generated by the PIMS system (e.g., Sound Transit BRT services). Other predictions may be generated by partner agencies such as King County Metro. Signs at a given location must display bus predicted arrivals based on user configured parameters (e.g., bus routes).

1102.8.1.8 Direction of travel

1102.8.1.8.1 Provide the ability to display direction of travel or bearing for train.

1102.8.1.9 Next station information for onboard signs

1102.8.1.9.1 Display next station and station arrival information.

1102.8.1.10 Parking availability/capacity

1102.8.1.10.1 Provide the ability to display available parking and/or parking capacity details.

1102.8.1.11 Vision for the Future

1102.8.1.12 Signage for PIMS is intended to serve the following scenarios. Consider these scenarios in the design:

i. Walking towards station from parking facility
ii. Arriving, paying
iii. Heading toward platform
iv. Waiting for vehicle
v. Boarding
vi. Riding on vehicle
vii. Alighting
viii. Heading toward exits, leaving

1102.8.2 Signage Control

1102.8.2.1 Message Management

1102.8.2.1.1 Scheduled messages

1102.8.2.1.1.1 Allow users to schedule messages. Schedule must provide configurable parameters including but not limited to:

i. Priority
ii. Start and End Date/Times
iii. Repeat Intervals
iv. Repeat Type

1102.8.2.2 Ad hoc messages

1102.8.2.2.1 Allow users to create ad hoc messages with configurable parameters including:
i. Priority
ii. Start and End Date/Times
iii. Repeat Intervals
iv. Repeat Type

1102.8.2.3 Event initiated messages

1102.8.2.3.1 Allow user to create messages and corresponding triggers that cause messages to play automatically when an event occurs, including but not limited to:
i. Vehicle arriving in X minutes, triggered by location
ii. Vehicle now arriving, triggered by location
iii. Vehicle arriving on track/platform Y, triggered by train crossing to non-primary track

1102.8.2.4 Message clean-up

1102.8.2.4.1 Provide the ability to remove or delete messages from the system.

1102.8.2.5 Configuration based content

1102.8.2.5.1 The system must provide customization of real time data based on configuration of the sign, including location, zone, group, type.

1102.8.2.5.2 Allow users to push messages to groups of PA/VMS based on predefined configurations including, but not limited to: Location, Groups, Zones, Types. The system should also be able to target specific incidents and surface, such as temporary changes to circulation (elevator/escalator outages), emergency/evacuation notices, "Train arriving. Please stand back to allow emergency personnel to access car XX."

1102.8.2.6 Configurable prioritization

1102.8.2.6.1 Message hierarchy and prioritization for play must be configurable by an authorized user without vendor intervention.

1102.8.2.7 Search and sort messages

1102.8.2.7.1 Provide ways to find previous messages such as categories, searching, and /or sorting messages.

1102.8.2.8 Message templates

1102.8.2.8.1 Allow users to create reusable templates for publishing message content (text and audio).

1102.8.2.9 Search and sort message templates.

1102.8.2.9.1 Provide ways to find templates easily such as categories, searching, and /or sorting templates.

1102.8.2.10 Multiple format templates.

1102.8.2.10.1 Allow multiple formats to be tied in a single template. Users may have a short message for dot matrix signs, a longer message for large flat panel, and audio messages.

1102.8.2.11 Text and audio sync

1102.8.2.11.1 Text and audio must be paired / synchronized for simultaneous play. For ADA compliance, all audio messages must have a text component. Text messages do not require an audio message.

1102.8.2.12 Text only messages

1102.8.2.12.1 Allow text only messages.

1102.8.2.13 Message staging

1102.8.2.13.1 Provide a way to understand what is or will be playing at a point in time based on the defined message hierarchy.

i. Users need a way to preview a message queue or indication of what will be played to understand behaviors including but not limited to clipping, overlap, and cross-talk.
ii. Demonstrate what happens if a message is pre-empted by an event triggered or ad hoc message.

1102.8.2.14 Message mirroring

1102.8.2.14.1 Provide the ability to mirror PA/VMS details to a lab or control center. Live stream the PA/VMS details from a selected station to the LCC to support coordinating operational response with Rail Supervisors in the field during special events and incidents.

1102.8.2.15 Message preview

1102.8.2.15.1 Provide a message preview. Let user see/listen to the planned message that they have staged in the context of a location, with the other scheduled content.

1102.8.2.16 Message playback

1102.8.2.16.1 Provide a historic playback. Let user see/listen to the message that actually played at a location at a point in time. Provide indication when messages were triggered but not played and when messages were pre-empted or clipped.

1102.8.2.17 Play message immediately

1102.8.2.17.1 Message must play at a specified target locations within three seconds of the command being sent from the head end or other interfacing system (such as EVS PLC).

1102.8.2.18 PA broadcast

1102.8.2.18.1 Allow PA announcements to be broadcast live and allow PA announcements to be recorded and played after recording is completed. PA broadcasts can be initiated from within a station or a control center.

1102.8.2.18.2 Announcements should filter out background noise (cross talk or reverberation) when broadcasting live or recording.

1102.8.2.18.3 Based on configurable priorities, live announcements may need to pre-empt or queue scheduled or event driven messages.

1102.8.2.19 Text to audio

1102.8.2.19.1 Generate audio from text.

1102.8.2.20 Audio preview

1102.8.2.20.1 Provide preview to listen to generated audio.

1102.8.2.21 Enhance text to audio

1102.8.2.21.1 Allow editing of generated audio to improve message quality using phonetic.

1102.8.2.22 Multilingual support

1102.8.2.22.1 Provide the ability to play messages in multiple languages. Sound Transit communication is provided in Spanish, Simplified Chinese, Traditional Chinese, Vietnamese, Russian, Tagalog, and Korean.

1102.8.2.23 Emergency systems integration

1102.8.2.23.1 Station fire/life safety

1102.8.2.23.1.1 PA/VMS controller must interface with Station Control Unit (SCU) to provide locally stored messages which can be triggered by the station fire-life-safety systems, EVS and back-office system(s). SCU must be able to play these locally stored messages even when the central PA/VMS or other back-office system(s) are not accessible.

i. Emergency notifications and evacuation messages must preempt all other messages, including arrival predictions.
ii. Emergency alert screens must allow an emergency layout that is configurable by user with administrator privileges.

1102.8.2.24 Suppress prediction display

1102.8.2.24.1 Allow an authorized user to suppress the display of arrival predictions for all or some subset of signs. This feature will prevent the system from providing incorrect data during a service disruption when predictions cannot be reliably made. PIMS must require minimal clicks to remove predictions and replace with alternate message/layout templates.

1102.8.2.24.2 Allow user to resume display of predictions after issue has cleared.

1102.8.2.25 Remote message management

1102.8.2.25.1 PIMS must allow authorized users to perform message management functions while not connected to back-office workstation or sign control terminal (using connected devices including but not limited to laptops, phones, tablets):

i. Perform key message management activities
ii. Stage/Deploy all content without physically accessing any SCU, VCU, or other field device.
iii. Information such as platform changes, emergency messages, and train delays needs to be easy to publish to the signs from a mobile device (phone or tablet).
iv. Remote Message Management tool(s) must conform to all agency security standards including secure network traversal.

1102.8.2.26 Thin client message management

1102.8.2.26.1 PIMS must provide a thin client for message management. Authorized user must be able to perform all functions from their Agency issued equipment. Users will not be required to use a dedicated back-office workstation or signage control terminal. PIMS must allow users to perform all management activities without physically connecting to field devices including but not limited to SCUs (station) or VCUs (on-vehicle).

1102.8.2.27 Message management from mobile device

1102.8.2.27.1 Allow conductor or station agent to change the sign content or trigger messages using a phone or mobile device. This must be a simple process with minimal clicks, so that the user can initiate the change quickly using previously created sign and PA content.

1102.8.2.28 PA broadcast from mobile device

1102.8.2.28.1 Using a mobile device, allow user to broadcast live and allow PA announcements to be recorded and play after recording is completed.

1102.8.2.28.2 Announcements should filter out background noise (cross talk or reverberation) when broadcasting live or recording.

1102.8.2.28.3 Based on configurable priorities, live announcements may need to pre-empt or queue scheduled or event driven messages.

1102.8.2.29 Suppress prediction display from mobile device.

1102.8.2.29.1 Allow user to suspend and re-enable display of predictions using a mobile device.

1102.8.2.30 Future integration

1102.8.2.30.1 Allow for integration with new technologies, examples: security cameras that trigger warnings/announcements, payment systems, connection information from partner mobility providers (e.g. carshare, bikeshare, microtransit)

1102.8.2.31 Multiple mode support

1102.8.2.31.1 Authorized users need a single centralized content management system where they can manage and distribute customer information for all transit modes.

1102.8.2.31.2 Many transit customers ride more than one mode of transit in their daily commute, and some facilities can apply to multiple modes. To provide more timely information to customers some messages need to be sent to multiple modes or multiple stations.

1102.8.2.32 PA/VMS configuration

1102.8.2.32.1 Flexible system configuration

1102.8.2.32.1.1 System, VMS, and PA details must be configurable without vendor intervention. Configurable items such as:

i. Modes (e.g., light rail, heavy rail, bus)
ii. Locations
iii. Groups
iv. Zones
v. Types
vi. Stations
vii. Priorities

1102.8.2.33 Granularity

1102.8.2.33.1 The system must provide content programming access control down to the level of individual signs/speakers and sets of signs/speakers.

1102.8.2.34 Flexible layout and style configuration

1102.8.2.34.1 UI styles, branding, layouts should be configurable without vendor intervention, including:

i. Font
ii. Text Size
iii. Contrast
iv. Colors
v. Clock
vi. Line Colors (multiple per sign)
vii. Logos, Images, Shapes, Letters
viii. Pictograms
ix. Symbols
x. Language
xi. Punctuation
xii. Defining and sizing areas for content types: image, video, text, etc.

1102.8.2.35 Flexible signage behaviors

1102.8.2.35.1 Signage behaviors should be configurable without vendor intervention, including:

i. Emergency Message Behaviors
ii. Message Hierarchy
iii. Prioritization/Preemption
iv. Frequency
v. Duration
vi. Sync with Voice
vii. Scroll, Roll or Pagination Rate
viii. Dwell Time (length of time visible)

1102.8.2.36 Role based privileges

1102.8.2.36.1 Provide role-based privileges for message management.

1102.8.2.36.2 Roles include the following:

i. Message Publisher: can trigger previously created messages
ii. Message Creator: can create messages.
iii. Template Manager: can create content templates for use by message creator
iv. Approver
v. Admin

1102.8.3 Input Sources

1102.8.3.1 The system must support IP based streamed live and recorded media content delivered over wired, wireless, and cellular networks.

1102.8.3.2 Analog Inputs

1102.8.3.2.1 System must accept analog inputs (balanced, unbalanced audio).

1102.8.3.3 Wired microphone

1102.8.3.3.1 System must support use of hard-wired microphones

1102.8.3.4 Wireless microphone

1102.8.3.4.1 System must provide the ability to communicate wirelessly to make announcements - wireless microphone required.

1102.8.4 Phone Call

1102.8.4.1 System must accept audio announcements from an authorized and authenticated user using a phone call.

1102.8.4.2 Publishing Workflow

1102.8.4.2.1 The system should provide but not require content publishing workflow, such as: preview, draft, pending, approved, live, expired.

1102.8.5 Partner Integrations

1102.8.5.1 Send Content to Partner Agency

1102.8.5.1.1 System must allow content to be sent to signs that are owned and operated by Partner Agencies (examples: King County Metro, Community Transit, Pierce Transit, and Amtrak).

1102.8.5.1.2 Content such as:

i. Train Details: route, direction, platform
ii. Estimated Arrival times
iii. Service Alerts

1102.8.5.2 Receive Content from Partner Agency

1102.8.5.2.1 System will allow message content to be sourced, created or sent from Partner Agencies to Sound Transit operated signs.

1102.8.5.2.2 Content such as:

i. Train/Bus Details: route, direction, platform/bay
ii. Estimated Arrival times
iii. Service Alerts

1102.8.5.3 Integration with Internal Signage Control System

1102.8.5.3.1 The system must be capable of sending content to other internal signage control systems (e.g., onboard signage control for Siemens LRV and TLE platform signage control).

1102.8.5.3.2 Content such as:

i. Train Details: route, direction, platform
ii. Estimated Arrival times
iii. Service Alerts

1102.8.6 Vehicle Monitoring and Arrival Predictions

1102.8.6.1 Train/Bus Identification

1102.8.6.1.1 Train/Bus identification data capture

1102.8.6.1.1.1 Capture and store data to uniquely identify train/bus and key characteristics of its journey. Make this data available to downstream systems. Please reference Table 1102-2 below.

Table 1102-2: Train and Bus Identification Data

Route	Number (and/or color) associated with the trip
Train/Bus Number	The identifier for this train consist. Today train #s are used to identify the type of train. 1-39 are revenue service 3-car. 40-59 are 2-car trippers used for rush hour. Other numbers are for Gap, Extra, Ice, and Training coaches. The numbers used can change over time.
Trip or Run Number	Automatically assigned today based on train #, origin, and start time. Heavily used by reporting because other data points like in/out of service and route are not available. Not used by LCC.
Journey ID	Journey is a map of a trip, like trip number. It includes origin, destination, and each stop along the way. Unlike trip, it is not associated with a scheduled time.
Origin	Location where trip begins.
Destination	Location where trip ends
Start Time	Scheduled and actual times when the train begins its journey
End Time	Scheduled and actual times when the train ends its journey
Direction	Planned heading or bearing
In/Out of Service	Indicates whether train is open to passengers
Train Consist/Vehicle IDs	Car #s that make up the train (vehicle ids)
Crew Detail	Unique identifier for the driver or crew.
Yard	Where the train lives when it is out of service. Nice to have.
On Duty Time	When crew starts, 30-60 minutes prior to train start time
Off Duty Time	When crew ends 30-60 minutes prior to train start time
Schedule Type	Examples: Weekday, Saturday, Sunday

Service Day	The service day runs from approximately 5am to 1am the next calendar day
Service Change Info	The date this schedule went into effect or the version of the schedule
Special Service Indicator	
Holiday Indicator	
Trip Type	Scheduled, Gap, Extra, Training, etc
Block Number	Bus

1102.8.6.1.2 Train/Bus Identification Data Edit

1102.8.6.1.2.1 Allow train/bus operators or control center staff to efficiently update identification data when necessary.

i. Add/Remove/Replace trains
ii. Cancel scheduled trips

1102.8.6.1.2.2 Change train/bus identification information

1102.8.6.1.3 Reduce Manual Data Entry Errors

1102.8.6.1.3.1 Today it is possible for operators to manually enter data, like the train number, incorrectly. The new system should limit manually entered data and/or provide mechanisms to catch and correct erroneous data in real-time.

1102.8.6.2 Train/Bus Location Monitoring

1102.8.6.2.1 Real-time location monitoring

1102.8.6.2.1.1 PIMS system must acquire vehicle location in real time and make available for integrated systems in real-time. Facilitates arrival predictions, which feeds customer information systems.

1102.8.6.3 Real-time state monitoring

1102.8.6.3.1 Capture train location and train state information frequently throughout the trip. Store data and make available to downstream systems in real-time. Please reference Table 1102-3 below.

Table 1102-3: Train Status and Location Data

Data	Description
Location	Such as GPS coordinates
Mileage	Used to track revenue and non-revenue miles traveled
Speed	Actual speed not average. Can improve predictions over time.
Direction/Bearing/Heading	Actual direction or bearing. Today this is north or south, may change with East Link. Used by LCC.
Station Name/ID	Name and/or ID of the station, when applicable
Schedule/Headway Deviation	Used by LCC when they need to speed up or hold trains. Most important at stations. Schedule is important for managing breaks. Headway is important for managing customer wait times.
Track/Platform	Which track the train is running on and/or which platform the train will arrive on. Used by LCC.
Platform/Stop Arrival Time	Actual time when the vehicle has arrived at a stop. Needed by service planning.

Platform Departure Time	Actual time when the vehicle has leaves a stop. Needed by service planning.
Station Arrival Time/Door Open Time	First time the doors open after arrival at a stop. Needed by service planning.
Station Departure Time/Door Close Time	Last time the doors close after arrival at a stop. Needed by service planning.
Vehicle Load/APC	Count of boardings and alightings (ons and offs) or car weight. Needed by service planning.

1102.8.6.4 Real-time route/stop monitoring

1102.8.6.4.1 Capture route or stop change details in real-time. If an operator or controller makes a change to the scheduled route, platform or cancels a stop, it should be captured.

1102.8.6.5 Headway/Schedule Conformance

1102.8.6.5.1 Manage headway/schedule conformance. Intelligently determine when trains are not running to headway/schedule to facilitate a return to conformance

i. Provide conformance information to control center staff
ii. Provide conformance information to operator
iii. Provide conformance data to SCADA system in a manner at least equivalent to the existing functionality described under 1.1.4 Current State

1102.8.6.6 View Real-time locations remotely

1102.8.6.6.1 Provide way to view location details in real-time without using a dedicated vehicle monitoring workstation. Allows supervisors to see a live picture of vehicles and status. Must be accessible from multiple devices: laptop, phone, tablet.

1102.8.6.7 Station arrival event

1102.8.6.7.1 The system must determine when a vehicle has arrived at a station and ensure that station signage is synched (no longer displaying future arrival). The arrival event occurs when the vehicle becomes available to passengers.

1102.8.7 Arrival Predictions

1102.8.7.1 Prediction without schedule

1102.8.7.1.1 The system must predict arrival times for subsequent stops based on the mode, location, route, and destination. Predictions should be available even when a schedule is not defined for a vehicle.

1102.8.7.1.2 May require integration with or creation of systems to replace existing methods using the following:

i. Tiploc Table/Track Circuit
ii. Dead Reckoning
iii. Trapeze
iv. GPS

1102.8.7.2 Suspend predictions

1102.8.7.2.1 The system must allow control center staff to suspend predictions by mode. This prevents predictions from being generated and passed to downstream systems. Suspending one mode must not impact other modes.

1102.8.7.3 Resume predictions

1102.8.7.3.1 Allow user to re-enable prediction generation after a disruption.

1102.8.7.4 Prediction clean-up

1102.8.7.4.1 During a disruption, erroneous predictions can be generated. The system must provide automated and manual methods to remove or ignore erroneous predictions. Clean up methods should allow resumption of normal service in less than 10 minutes.

1102.8.7.5 Prediction accuracy assessment

1102.8.7.5.1 The System must track and assess the accuracy of predictions. The System must meet or exceed prediction accuracy by mode. The System must be designed to improve accuracy over time.

1102.8.7.6 Prediction accuracy goals

Table 1102-4: Accuracy Goals by Mode

Time Between Prediction and Arrival	Link	Sounder	Tacoma Link	BRT
Less than 2 minutes	99% of trains arrive within +/- 1 minute of prediction	Not applicable		
5 minutes	Greater than 96% of trains arrive within +/- 1 minute	Greater than 97% of trains arrive within +/- 1 minute		
10 minutes	Greater than 93% of trains arrive within +/- 1 minute	Greater than 95% of trains arrive within +5/-1 minute		
20 minutes	Greater than 90% of trains arrive within +/- 1 minute	Greater than 95% of trains arrive within +5/-1 minute		

1102.8.7.7 Configurable prediction rules

1102.8.7.7.1 Each transit mode has significantly different profiles which will drive how predictions are calculated based on factors including but not limited to: average speed and dwell time.

i. The System must use mode specific parameters for predictions
ii. Mode specific parameter values must be configurable without vendor engagement (example: dwell time, speed).

1102.8.7.8 Self-improving predictions

1102.8.7.8.1 The System must use historic predictions and actual arrival times to improve predictions based on real data.

1102.8.7.8.2 Environmental factors, such as at-grade travel, can cause deviations in headway and/or schedule compliance. Once the common interruptions have been detected, they can be factored into subsequent predictions to increase their accuracy.

1102.8.7.9 Real-time prediction enhancement

1102.8.7.9.1 The System must modify predictions in real-time based on real-time conditions by integrating with external sources (examples: Waze, weather apps).

1102.8.8 Schedule and Route Management

1102.8.8.1 Scheduling

1102.8.8.1.1 Standard schedules

1102.8.8.1.1.1 Store standard schedules. At a minimum the schedule defines the routes, stop locations, and stop times for each run/trip.

1102.8.8.1.2 Exception schedules

1102.8.8.1.2.1 Allow exception schedules to be created/loaded. The solution should allow for the temporary addition of routes and/or trips to provide special service including but not limited to concerts or stadium events.

1102.8.8.1.3 Staged schedules

1102.8.8.1.3.1 Allow a schedule to be deployed with a future start date so that schedules can be staged.

1102.8.8.1.4 Real-time schedule changes

1102.8.8.1.4.1 Allow schedule to be adjusted intraday, during revenue service. One example: start the morning on an exception schedule then switch to a standard schedule in the middle of the day.

1102.8.8.1.5 Terminus stations

1102.8.8.1.5.1 System must be able to support multiple locations (more than 10 possible) for train turn around/end of line. The termini must be easy to change (minimal set up that can be configured without vendor involvement) as the line extends. An authorized user must be able to designate any station as the terminus for a trip/journey.

1102.8.8.2 Routing

1102.8.8.2.1 Standard routes

1102.8.8.2.1.1 Define standard routes, including but not limited to multiple routes/lines, the stops that a vehicle will make, the platform, and/or the track, the planned dwell time.

1102.8.8.2.2 Exception routes

1102.8.8.2.2.1 Define routine exception routes that can be reused. These are well-defined rerouting response to certain types of service disruption (examples include but are not limited to: snow routes or bus bridges). The solution should allow PIMS operators to activate a rerouting scenario during revenue service so that arrivals can be accurately predicted during such disruption.

1102.8.8.2.3 Dynamic reroutes and service changes

1102.8.8.2.3.1 Allow control center to dynamically re-route service. When a route or service change is executed, communicate change to PA/VMS, AVL, Prediction Engine, and downstream systems.

1102.8.8.2.3.2 Examples of dynamic re-routes and service changes include:

i. Detours including but not limited to single tracking or skipped stops
ii. Adding extra trains
iii. Ad hoc bus bridges
iv. Turning a train prior to the terminus (ending trip early, starting next trip early, and marking stations/stops as skipped/cancelled

1102.8.8.2.3.3 Allow vehicle operators to update route/stops served from the vehicle.

1102.8.9 Data Management

1102.8.9.1 Data Management Approach

1102.8.9.1.1 This program will make large amounts of operational data available to other internal and external systems in real-time. Long-term reporting, or any reporting over time or in aggregate, will be supported in a data archive. The Contractor must work with the Agency and/or the data archive vendor to design, build, and test integrations between PIMS and Legacy Systems/third-party applications.

1102.8.9.2 Real-time, Asynchronous Data Transfer

1102.8.9.2.1 The Contract should implement a publish-subscribe environment (or equivalent solution) to facilitate the transfer of key data points for consumption by PIMS components or downstream systems.

1102.8.9.2.2 All data produced by PIMS or flowing through PIMS needs to be provided to downstream systems in real-time such that it can be prioritized and consumed in an asynchronous fashion with no loss of data.

1102.8.9.3 Data Correlation

1102.8.9.3.1 To the extent possible, provide mechanism to correlate data across systems at the time the data is captured. Pass correlated data to the publish-subscribe environment for use by downstream systems.

1102.8.9.3.2 Correlated Data Example

1102.8.9.3.2.1 The following shows a before and after example of how raw APC data might be augmented with relevant data points to tie it to a specific train and/or journey:

Raw APC Data

```
<apc>
  <in>15</in>
  <out>7</out>
  <lat>47.6062</lat>
  <long>-122.3321</long>
</apc>
```

Correlated APC Data

```
<apc>
  <time>01/22/2017 15:45:08 PST</time>
  <mode>link</mode>
  <route>blue<route>
  <train>52</train>
  <trip>2178</trip>
  <in>15</in>
  <out>7</out>
  <lat>47.6062</lat>
  <long>-122.3321</long>
</apc>
```

1102.8.9.4 Data Catalog

1102.8.9.4.1 Data and events published by the solution for downstream consumption should be documented so as to inform consumers of the data structure, the meaning of the data attributes, acceptable data values, and information necessary to consume that data, such as connection information or messaging topic.

1102.8.10 Operations Management

1102.8.10.1 Elevator/Escalator Status

1102.8.10.1.1 Capture Elevator and Escalator Events/Outages. Hourly data is available from RC SCADA BMS today. The System must provide monitoring and escalation to enable Facilities work and support customer notifications. The System must be extensible to include real-time data when it becomes available. The system must be extensible to include status for those elevators and escalators which do not currently report status as they could be upgraded to provide status in the future.

1102.8.10.2 Vision for the Future

1102.8.10.2.1 The following items are not in scope for this effort. They are included to help proposers understand the direction the Agency wants extend passenger information.

i. Real-time Operations Dashboard
ii. Automated Issue Detection and Classification
iii. Automated Ticket Creation
iv. Automate Service Disruption Alerts
v. Capture Platform Capacity Data

END SET - 1102

1103 FARE VENDING

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SET - 1103 FARE VENDING

1103.1 INTRODUCTION

1103.1.1 Document Scope

1103.1.1.1 This section describes the field components of fare vending operations which are common to all Sound Transit modes.

1103.1.1.1.1 Fare vending equipment installed at each station includes VM or TVM and SCR or WV.

1103.1.1.2 The fare vending equipment is integrated into a larger multi-agency system, next generation ORCA, which is not covered in this requirement set.

1103.1.1.3 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 1103 owner to determine the technical source for the design criteria.

1103.1.1.4 System Context Diagram

Figure 1103-1: TVM Context Diagram

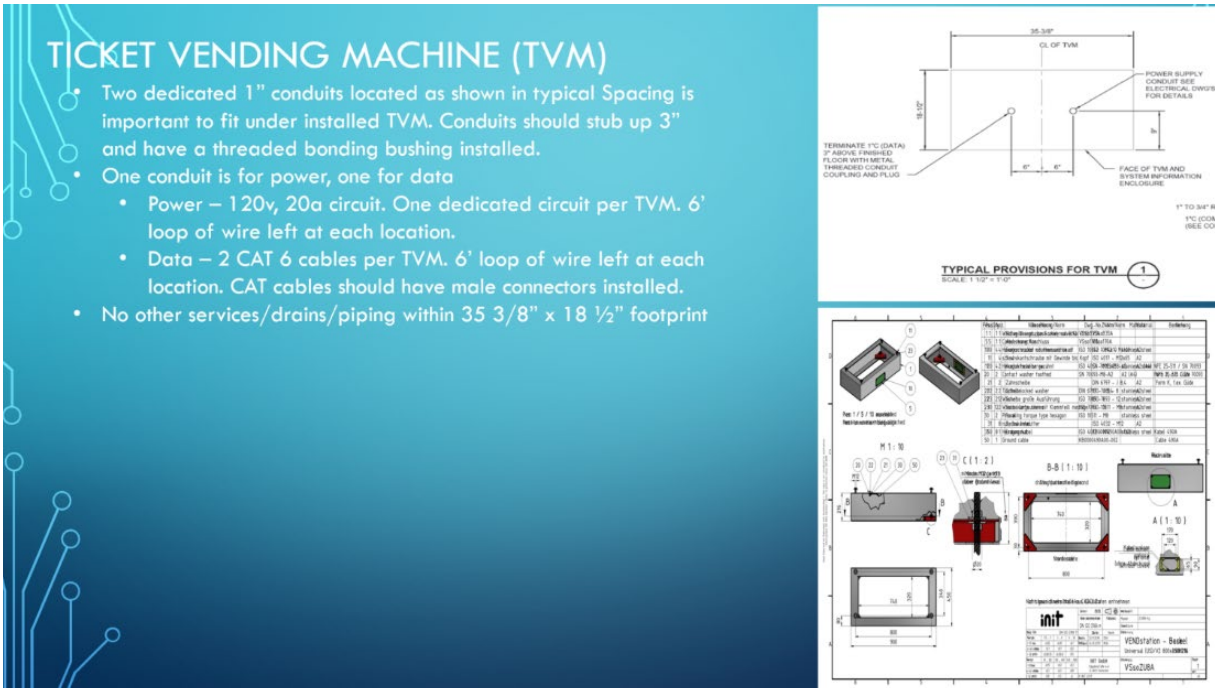
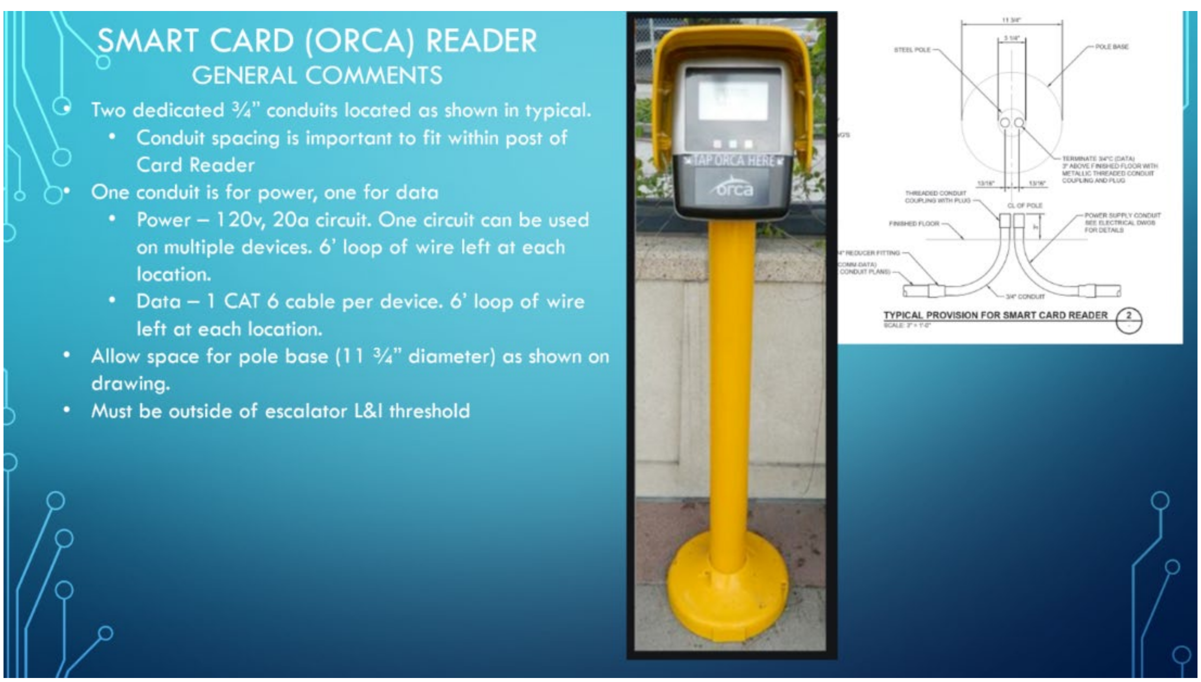


Figure 1103-2: SCR Context Diagram Ticket



1103.1.2 Regulations, Codes, Standards, and Guidelines

1103.1.2.1 International Regulations, Codes, Standards, and Guidelines (Not Used)

1103.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines (Not Used)

1103.1.2.3 State and Local Regulations, Codes, Standards, and Guidelines (Not Used)

1103.1.2.4 Industry Regulations, Codes, Standards, and Guidelines

1103.1.2.4.1 Refer to IEEE standards for network communications.

1103.1.2.4.2 Refer to NEC standards for electrical and wiring guidelines.

1103.1.2.4.3 Refer to Sound Transit Set 300 for all fare venting equipment that is connected to the Sound Transit network.

1103.1.2.4.4 All equipment must be UL approved.

1103.1.2.5 Other Jurisdictions

1103.1.2.6 Sound Transit Regulations, Codes, Standards, and Guidelines

1103.1.2.6.1 Devices such as SCRs which are powered via POE must also maintain an empty conduit for any future power needs.

1103.1.2.6.2 Power Over Ethernet must be an option for Wayside Validators even though most Wayside Validators will use line power.

1103.1.2.6.3 Please see the Architecture Set for locations of devices with respect to the Fare Paid Zone.

1103.1.3 Abbreviations and Acronyms (Not Used)

1103.1.3.1 TVM–ticket vending machine

1103.1.3.2 VM–vending machine

1103.1.3.3 WV–wayside validator

1103.1.3.4 SCR–smart card reader

1103.1.3.5 POE–power over Ethernet

1103.1.4 Definitions and Classifications (Not Used)

1103.1.5 References (Not Used)

1103.2 STAKEHOLDER NEEDS

1103.2.1 Passenger Experience (Not Used)

1103.2.2 Operational Needs

1103.2.2.1 TVM

1103.2.2.1.1 Ticketing locations must be consistent across stations and accessible to all passengers along the main path of circulation.

1103.2.2.1.2 TVMs must be at both platforms.

1103.2.2.1.3 Locate the TVMs under a shelter at the platform. Passengers and machines must be protected from the weather.

1103.2.2.1.4 TVM concrete pad must be provided and coordinated for conduit infrastructure. Station layout must include location of pull boxes. Coordinate with Systemwide Electrical for conduit routing.

1103.2.2.1.5 Coordinate placement of TVMs with Sound Transit's manufacturer's requirements and the Transit Systems group. Provide all clearances per the TVM drawings.

1103.2.2.1.6 TVMs must include Sound Transit signage per the Sound Transit Customer Signage Manual.

1103.2.2.2 SCR

1103.2.2.2.1 The number of SCRs must be determined by the size of the platform. Provide one SCR for every 100 feet of platform at minimum. For example, a platform 650 feet long would have at minimum six SCRs. Placement of SCRs must follow the requirements in this section.

1103.2.2.2.2 Where SCRs are placed along the platform, they must be visible to passengers exiting the train.

1103.2.2.2.3 SCRs must be within 5 feet of the station entries.

1103.2.2.2.4 Smart Card Readers must be at the base of accessibility ramps leading to mini-high platforms. See Sounder standard drawings.

1103.2.3 Maintenance Needs (Not Used)

1103.2.4 Safety Needs (Not Used)

1103.2.5 Security Needs (Not Used)

1103.2.6 Reliability, Availability and Maintainability Needs (Not Used)

1103.2.7 Environmental and Sustainability Needs (Not Used)

1103.3 SYSTEM REQUIREMENTS (NOT USED)

1103.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

1103.4.1 System Breakdown Structure

1103.4.2 System Sites and Locations

1103.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 1103-1: Interface Between Fare Vending and Other Disciplines

SET SERIES	SET NAMES	SET 1103 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	
300	Operational Communications	X
400	Vehicle	
500	Track	
600	Fire/Life Safety	
700	Structures	X
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	
1100	Technology	X
1200	Security and CCTV	X

1103.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS (NOT USED)

1103.7 ENGINEERING MANAGEMENT REQUIREMENTS

1103.7.1 Interface and Integration Management (Not Used)

1103.7.2 Design Management (Not Used)

1103.7.3 Manufacturing and Construction Management (Not Used)

1103.7.4 Installation Management (Not Used)

1103.7.5 Inspection and Testing Management (Not Used)

1103.7.6 Training, Pre-Revenue Operations

1103.7.6.1 Fare vending equipment and network connectivity, as well as any related training, must be in advance of any pre-revenue operations.

1103.7.7 Certification Management (Not Used)

1103.8 APPENDICES (NOT USED)

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1201 CYBERSECURITY

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SET - 1201 CYBERSECURITY

1201.1 INTRODUCTION

1201.1.1 Document Scope

1201.1.1.1 This set covers cybersecurity for communications networks, integrated automation systems, operational technologies consisting of electronic hardware and communication systems that monitor, control, manage, and report status of Sound Transit facilities, infrastructure and operating assets shown in below table.

1201.1.1.2 Sound Transit Facilities, Infrastructure, and Operating Systems include the following:

i. TPSS and Utility Power Monitoring (DCAM, LCMS)
ii. SCADA, (TCS, BMS, EVS)
iii. Fire Alarm Control Panel Monitoring (Fireworks)
iv. Signaling
v. Access Controls (ACS)
vi. Phones (PBX) and Emergency Phones (ETEL/PET/CES)
vii. Closed-Circuit Television (CCTV)
viii. Field Control Systems (TCS, BMS, EVS)
ix. Fare Vending (SCR, TVMs)
x. Track Intrusion Systems (TIDS)
xi. Land Mobile Radio (LMR)
xii. Public Address and Variable Message Signs (PA/VMS)
xiii. Passenger Information Management System (PIMS)
xiv. Conditioning Monitor Systems (EMI, Vibration Monitoring, Gas Monitoring, Wind and Wave, Corrosion Control)
xv. LRVs, LRV Yard and Vehicle Monitoring (YardViewer, MWS)
xvi. Wireless Communications (Wi-Fi)
xvii. Networks (TCN, EFN, Transit, Radio, TPSS, and other)
xviii. CAD/AVL (bus and light rail)
xix. Sounder Train Systems
xx. Bus Systems
xxi. Maintenance Facility Systems
xxii. Parking Garage Systems
xxiii. Office Facilities System

1201.1.1.3 All systems with network connectivity or that can be connected to should be evaluated for cybersecurity requirements.

1201.1.1.4 System Interface Standard Specifications

1201.1.1.5 This requirement set accompanies Sound Transit Standard Specification 25 05 11 Cybersecurity for Integrated Automation (Operational Technology). Coordination between these two documents is necessary.

1201.1.1.6 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Requirements Set 1201 owner to determine the technical source for the design criteria.

1201.1.2 Regulations, Codes, Standards, and Guidelines

1201.1.2.1 International Regulations, Codes, Standards, and Guidelines

1201.1.2.2 MITRE Corporation.

1201.1.2.3 Common Weakness Enumeration (CWE) 3.2 – A Community-Developed List of Software Weakness Types.

1201.1.2.4 National Institute of Standards and Technology (NIST)NIST SP 800-53 Rev 5, Recommended Security and Privacy Controls for Federal Information Systems and Organizations https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-53r5.pdf , September 2020.

1201.1.2.5 NIST SP 800-82 Rev 2, Guide to Industrial Control Systems (ICS) Security [Guide to Industrial Control Systems (ICS) Security (nist.gov)] , May 2015 North American Electric Reliability Corporation (NERC).

1201.1.2.6 North American Electric Reliability Corporation (NERC) Critical Infrastructure Protection (CIP) "CIP-005 Standard Cyber Security – Electronic Security Perimeter."

1201.1.2.7 North American Electric Reliability Corporation (NERC) Critical Infrastructure Protection (CIP) "CIP-006 Standard Cyber Security – Electronic Access Controls."

1201.1.2.8 North American Electric Reliability Corporation (NERC) Critical Infrastructure Protection (CIP) "CIP-007 Standard Cyber Security – Systems Security Management."

1201.1.2.9 Open Web Application Security Project (OWASP).

1201.1.2.10 OWASP Dependency Check.

1201.1.2.11 OWASP Top Ten.

1201.1.2.12 Federal and National Regulations, Codes, Standards, and Guidelines.

1201.1.2.13 Department of Homeland Security (DHS).

1201.1.2.14 DHS Catalog of Control Systems Security: Recommendations for Standards Developers, April 2011, U.S. Department of Homeland Security National Cybersecurity and Communications Integration Center, ICS-CERT.

1201.1.2.15 DHS Recommended Practice: Improving Industrial Control System Cybersecurity with Defense-in-Depth Strategies Industrial Control Systems Cyber Emergency Response Team September 2016.

1201.1.2.16 Federal Information Processing Standards (FIPS).

1201.1.2.17 FIPS PUB 199, "Standards for Security Categorization of Federal Information and Information Systems" December 2003.

1201.1.2.18 United States Code (U.S. Code).

1201.1.2.19 44 U.S. Code, Section 3542 – Definitions.

1201.1.3 State and Local Regulations, Codes, Standards, and Guidelines (Not Used)

1201.1.4 Industry Regulations, Codes, Standards, and Guidelines

1201.1.4.1 American Public Transportation Association (APTA).

1201.1.4.2 APTA SS-CCS-RP-001-10 Securing Control and Communications Systems in Transit Environments Part 1: Elements, Organization and Risk Assessment/Management.

1201.1.4.3 APTA-SS-CCS-RP-002-13 Securing Control and Communications Systems in Rail Transit Environments Part II: Defining a Security Zone Architecture for Rail Transit and Protecting Critical Zones American National Standards Institute (ANSI).

1201.1.4.4 ANSI/ISA 62443 Security for Industrial Automation and Control Systems.

1201.1.5 Sound Transit Regulations, Codes, Standards, and Guidelines

1201.1.5.1 Sound Transit Engineering Procedures.

1201.1.5.2 Sound Transit Systems Guidance Drawings.

1201.1.5.3 Sound Transit Standard Specifications.

1201.1.5.4 Sound Transit Information Security Standards Policy 1100 Implementation Guidance and Controls.

1201.1.5.5 Sound Transit Information Security Standards Policy 1101 Acceptable Use of Technology Handbook.

1201.1.5.6 Sound Transit Standard Specification 25 05 11 Cybersecurity for Integrated Automation (Operational Technology).

1201.1.5.6.1 Sound Transit Information Security Standards Documents.

1201.1.5.6.1.1 Access Control Standard.

1201.1.5.6.1.2 Anti-Malware Standard.

1201.1.5.6.1.3 Cryptography Standard.

1201.1.5.6.1.4 Data Classification & Protection Standard.

1201.1.5.6.1.5 Device Security Standard.

1201.1.5.6.1.6 Identity Management.

1201.1.5.6.1.7 Log Management.

1201.1.5.6.1.8 Secure Design Standard.

1201.1.5.6.1.9 Vulnerability Management

1201.1.5.6.1.10 Cloud Hosting Standard.

1201.1.5.6.1.11 Media Protection Standard.

1201.1.5.6.1.12 Red Hat Enterprise Linux 7&8 Standard.

1201.1.5.6.1.13 SQL Server Standard.

1201.1.5.6.1.14 Cisco Firewall and IOS

1201.1.5.6.2 Standards Abbreviations and Acronyms

1201.1.5.6.2.1 ACL–access control list

1201.1.5.6.2.2 ACS–access control system

1201.1.5.6.2.3 BIOS–basic input/output system.

1201.1.5.6.2.4 BMS–building management system

1201.1.5.6.2.5 CIS–center for internet security.

1201.1.5.6.2.6 CVSS–common vulnerability scoring system

1201.1.5.6.2.7 DMZ–demilitarized zone

1201.1.5.6.2.8 DNS–domain name system

1201.1.5.6.2.9 DoS–denial of service.

1201.1.5.6.2.10 EP–engineering procedures.

1201.1.5.6.2.11 EVS–emergency ventilation system

1201.1.5.6.2.12 FLSZ–fire, life-safety security zone

1201.1.5.6.2.13 FTP–file transfer protocol.

1201.1.5.6.2.14 GPO–group policy object

1201.1.5.6.2.15 HMI–human machine interface

1201.1.5.6.2.16 HTTP–hypertext transfer protocol

1201.1.5.6.2.17 HTTPS–hypertext transfer protocol secure

1201.1.5.6.2.18 ICS–industrial control systems

1201.1.5.6.2.19 IED–intelligent electronic devices

1201.1.5.6.2.20 IFC–issued for construction

1201.1.5.6.2.21 InfoSec–information security

1201.1.5.6.2.22 IOT–internet of things

1201.1.5.6.2.23 IP–internet protocol

1201.1.5.6.2.24 MDS–managed document service

1201.1.5.6.2.25 MEP–managed service provider

1201.1.5.6.2.26 MitM–man in the middle

1201.1.5.6.2.27 NIDS–network intrusion detection systems

1201.1.5.6.2.28 OCSZ–operationally critical security zone

1201.1.5.6.2.29 OS–operating system

1201.1.5.6.2.30 OWASP–Open Web Application Security Project

1201.1.5.6.2.31 PoE–power over Ethernet

1201.1.5.6.2.32 PLC–programmable logic controller

1201.1.5.6.2.33 RBAC–role-based access control

1201.1.5.6.2.34 RFID–radio frequency identification

1201.1.5.6.2.35 RHEL–Red Hat Enterprise Linux

1201.1.5.6.2.36 RTU–remote terminal unit

1201.1.5.6.2.37 SCADA–supervisory control and data acquisition

1201.1.5.6.2.38 SCSZ–safety-critical security zone

1201.1.5.6.2.39 SIEM–security information and event management

1201.1.5.6.2.40 SQL–Structured Query Language

1201.1.5.6.2.41 SSH–secure shell

1201.1.5.6.2.42 SSID–service set identifier

1201.1.5.6.2.43 SSO–single sign-on

1201.1.5.6.2.44 TCP–transmission control protocol

1201.1.5.6.2.45 TCS–train control system

1201.1.5.6.2.46 UDP–User Datagram Protocol

1201.1.5.6.2.47 UEFI–Unified Extensible Firmware Interface

1201.1.5.6.2.48 VPN–Virtual Private Network

1201.1.5.6.2.49 WLAN–wireless local area network

1201.1.5.6.2.50 XSS– cross site scripting

1201.1.6 Definitions and Classifications

1201.1.6.1 Availability: Providing the data when needed or ensuring timely and reliable access to and use of information. Loss of availability is the disruption of access to or use of information from a system. Availability is the highest priority for integrated automation systems and operational technologies.

1201.1.6.2 Integrity: Ensuring that the data presented are the true valid master source of the data or guarding against improper information modification or destruction and includes ensuring information nonrepudiation and authenticity. A loss of integrity is the unauthorized modification, insertion, or destruction of information.

1201.1.6.3 Confidentiality: Keeping the data unseen by others, or preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information. A loss of confidentiality is the unauthorized disclosure of information.

1201.1.6.4 Defense-in-depth: Primary strategy for achieving Sound Transit's cybersecurity objectives (availability, integrity, confidentiality). This strategy requires distribution of systems and devices within zones of security to provide layers of backup in the event a security control fails, or an attempt is made to exploit new or unaddressed vulnerabilities in accordance with APTA-SS-CCS-RP-002-13:

1201.1.6.5 External zone: The area of connectivity to the Internet, peer locations, and backup or remote offsite facilities. This is not a DMZ, but it is the point of connectivity usually considered untrusted (lowest security priority).

1201.1.6.6 Enterprise zone: The area of connectivity for corporate communications. Email servers, DNS servers, and other IT business system infrastructure are typical resources in this zone (medium security priority).

1201.1.6.7 OCSZ: The area of connectivity where a majority of monitoring and control takes place. It is a critical area for continuity and management of a control network. Operational support and engineering management devices are in this zone alongside data acquisition servers and historians. This zone is central to the operation of both the end devices and the business requirements of the corporate zone (high security priority).

1201.1.6.8 FLSZ: The area of connectivity to devices such as PLCs, HMI, and basic input/output devices such as actuators and sensors (very high security priority).

1201.1.6.9 SCSZ: The area that directly controls and often automatically the devices that control the safety level of an end device, such as safety instrumented system extremely high security priority.

1201.1.7 References (Not Used)

1201.2 STAKEHOLDER NEEDS

1201.2.1 Passenger Experience (Not Used)

1201.2.2 Operational Needs (Not Used)

1201.2.3 Maintenance Needs

1201.2.3.1 Do not employ any obsolete, at or near end of life, or unsupportable technologies, components, or equipment. All equipment, components, embedded hardware, firmware, operating systems, or software included in designs must be supportable for a minimum of 3 years following substantial completion. The designer must verify the solution designed in IFC meets this requirement. The contractor must verify submitted solution meets this requirement.

1201.2.3.2 Information technology and integrated systems must be delivered with an operating system and/or firmware version still supported by the manufacturer. Where an operating system is within 18 months of becoming obsolete (vendor no longer supporting the version of the OS with security updates) during the three years the operating systems are supported by the vendor after substantial completion the time of installation, the designer must require the contractor to provide an upgrade path to a supported version of the operating system, including identifying any hardware changes required to support the upgrade.

1201.2.3.3 Maintainability requirements only apply to design specification approved equipment and software and must be verified by the designer at time of design acceptance of IFC. Designer must also have contractor provide verification of requirements at substantial completion.

1201.2.3.4 Software update licensing: In addition to all other licensing requirements, all software licensing must include licensing of the following software updates while the license is active:

1201.2.3.4.1 Security and bug fix patches issued by the software manufacturer.

1201.2.3.4.2 Security patches to address any vulnerability identified in the National Vulnerability Database at http://nvd.nist.gov with a CVSS severity rating of medium or higher.

1201.2.4 Safety Needs

1201.2.5 Security Needs

1201.2.5.1 Designers must follow the Sound Transit Security Data Classification and protection Standard.

1201.2.5.2 Designers must follow EP-03 in classifying, encrypting, transmitting (between all parties internal or external), saving, and destroying all classified information.

1201.2.5.3 Designers must provide Sound Transit proof of secure destruction of all information, documentation, and data upon final acceptance and transmission of final record documentation to Sound Transit. The designer must not retain any cybersecurity information without written authorization from Sound Transit.

1201.2.5.4 Separation Agreement

1201.2.5.4.1 Designers must maintain policies and agreements with key support personnel to prevent exposure of sensitive information and protect Sound Transit's systems security posture per EP-03. This includes required separation agreements, notifications to Sound Transit, and documentation.

1201.2.6 Reliability, Availability, and Maintainability Needs (Not Used)

1201.2.7 Environmental and Sustainability Needs (Not Used)

1201.3 SYSTEM REQUIREMENTS

1201.3.1 General Requirements

1201.3.1.1 The cybersecurity requirements of this set are intended, through the prevention and mitigation of cyber threats, to maintain three security objectives for all Sound Transit integrated automation systems and operational technologies: availability, integrity, and confidentiality per FIPS PUB 199 and as defined in 44 U.S Code, Section 3542.

1201.3.2 Cyber Threat and Vulnerability Mitigation

1201.3.2.1 System Hardening

Commentary: System hardening refers to changes to the default configuration of a network device and its OS, software applications, and required third-party software to mitigate system security vulnerabilities.

1201.3.2.1.1 Provide for the removal of all unnecessary services and programs that are not required for normal system operation, security, and maintenance.

1201.3.2.1.2 Designs must comply with Sound Transit Information Security Hardening Standards:
i. Secure Design standard
ii. Cisco Firewall standard
iii. Windows Hardening standard
iv. Red Hat Linux 7/8 standard

1201.3.2.1.3 If an operating system is specified or used that is not covered by existing Sound Transit standards, Sound Transit must be notified in writing with specific justification of why the OS is not covered by Sound Transit's standards and additional hardening requirements to provide a secure system. Sound Transit subject matter experts, maintainers, and Information Security must approve the change.

1201.3.2.1.4 Designs must comply with NERC CIP-007-1 R2, "Ports and Services."

1201.3.2.1.5 Unused services in systems left enabled are possible entry points for exploits on the network. Use of only the services necessary for systems operation and maintenance limits possible entry points. Designers must require contractor to notify Sound Transit of any unused services and the reason for enabling the service if unused services cannot be disabled.

1201.3.2.2 Vulnerability Scans

1201.3.2.2.1 Sound Transit Information Security is responsible for conducting vulnerability scans across the infrastructure to ensure the design complies with Sound Transit standards, and with these requirements. Evidence of non-compliance with Sound Transit standards identified during the vulnerability scan will require justification in writing.

1201.3.2.2.2 Endpoint Protection and Maintenance

1201.3.2.2.2.1 Systems implemented on Windows server operating systems, Windows 10 and 11, and Linux (RHEL) are required to be protected by endpoint security. Sound Transit uses CrowdStrike to provide this control, and the endpoint must be able to communicate with the Internet via a proxy server to ensure real time alerts are sent on detection of a security event. The designer must ensure that the system is capable of supporting this control. If there is any technical reason why CrowdStrike cannot or should not be installed inform Sound Transit Information Security and the system owner within ST in writing and provide an alternative endpoint protection solution or mitigating controls. Ensure the system can communicate with Sound Transit's infrastructure that distributes security patches to Windows and Linux based assets. Sound Transit will provide hostnames/IP addresses of the update servers.

1201.3.2.2.3 Log Monitoring

1201.3.2.2.3.1 Systems implemented on Windows server, Windows 10 and 11, and Linux are required to send security event log data to the Sound Transit SIEM. There are two acceptable methods of sending security log data to the Sound Transit SIEM, they are:

1201.3.2.2.3.1.1 Install AlienVault Agent onto assets to forward security events to a proxy server on the agency DMZ.

1201.3.2.2.3.1.2 Configure the local server to forward security events to STP-TS-AVAULT01 (log sensor) on the Transit DMZ.

1201.3.2.2.3.2 Security event information in the SIEM will allow Sound Transit's managed service provider to monitor the environment 24 hours a day 7 days a week. Ensure the system supports this requirement.

1201.3.2.2.3.3 Neither CrowdStrike nor AlienVault Agent are required on any non-Windows or Linux assets, nor should they be installed on any systems where installation would compromise the system certification or void any support warranty.

1201.3.3 Hardware Configuration

Commentary: Most control system network devices have multiple communication and data storage capabilities. These can introduce vulnerabilities, such as viruses, root kits, malware, bots, or key-loggers.

1201.3.3.1 Provide for the physical removal or disabling of unnecessary hardware or its altered configuration through software.

1201.3.3.2 Designs must allow hardware configuration activities including configuring network devices to limit access from only specific locations (e.g., IP filtering) or requiring additional verification of user credentials (e.g., password, personal identification number, crypto key, or token).

1201.3.3.3 Designs must provide for local hardening with similar verification for protecting system BIOS and/or UEFI configuration parameters, and limiting system access through local media (e.g., disabling or removing USB ports, CD or DVD drives, and other removable media devices).

1201.3.3.4 Evidence must be provided to show that all systems have been configured to comply with CIS level 1 hardening per NIST SP 800-53 Rev 4. This may be applied locally or via a GPO if domain connected. In addition to CIS level 1 hardening, evidence must be provided to show which physical ports on any Windows or Linux asset need to be enabled. Sound Transit Information Security will implement a security policy via CrowdStrike that disables all physical USB ports by default, except for those identified by the evidence shared with Sound Transit justifying the requirement.

1201.3.3.5 Designs must ensure configuration of network devices to limit access to and from specific locations, where appropriate, and provide documentation of the configuration.

1201.3.4 Operating Systems, Applications and Third-Party Updates

1201.3.4.1 Provide evidence that the infrastructure components will be maintained (security patching) in accordance with NERC CIP-007-1 R3. Where the OS is either Windows or Linux based, the system maintenance period must comply with Sound Transit's Vulnerability Management standard. The system must be capable of receiving automated updates from Sound Transit's patch management system.

1201.3.4.2 All patches must be validated. Digital signature may be required by ST for patching to validate authenticity. Provide any required special maintenance instructions from the vendor if needed.

1201.3.5 Perimeter Protection

Commentary: Perimeter protection refers to providing a clear demarcation between the protected internal networks, unprotected, and untrusted external networks.

1201.3.5.1 Firewalls

Commentary: Firewalls are network devices which block selective (filter) traffic between network zones (subnets) or from a network to a device. Overly permissive, nonexistent, or unpatched firewalls create vulnerabilities by allowing unauthorized access.

1201.3.5.1.1 Designs requiring data exchanges between security zones must provide firewall rule sets and/or other equivalent documentation. The basis of the rule set must be "deny all," with exceptions explicitly identified by the designer. All information is business sensitive and requires protection as such. Firewall rules must conform to General Firewall Polices for ICS and Recommended Firewall Rules for Specific Services found within NIST SP 800-82.

1201.3.5.1.2 Firewall rules must define the source and destination objects and the required protocols.

1201.3.5.2 Network Intrusion Detection Systems (NIDS)

Commentary: Firewalls or other vulnerabilities may allow unauthorized access which are detectable by a NIDS. A NIDS identifies unauthorized or abnormal network traffic.

1201.3.5.2.1 Provide recommended placement of a NIDS within the systems network. Confirm with Sound Transit IT Information Security if there are NIDS already in place to support the design and ensure this is reflected in the design documentation. The below information in 1201.2.4.2.1 to 1201.4.2.3 is still required for NIDS integration.

1201.3.5.2.2 Designs must specify for Sound Transit all necessary information to configure any recommended NIDS, including traffic profiles with expected communication paths, network traffic, and expected utilization boundaries for anomaly-based NIDS.

1201.3.5.2.3 Appropriate signatures for a signature-based NIDS.

1201.3.5.2.4 Alerts from the NIDS should be sent to Sound Transit's SIEM.

1201.3.6 Account Management

Commentary: Account management is essential to maintain and secure a systems network. Account management regulates user access, limits permission to only those required, and mitigates vulnerabilities in default accounts. It also covers password management. Sound Transit employs RBAC to ensure only the required privileges should be assigned to an account.

1201.3.6.1 Employ account management incorporating the following:

1201.3.6.2 Authentication: The ability to verify an identity based on "what you have" (i.e., key, digital certificate, or smart card), "what you know" (i.e., username and password), and "what you are or do" (e.g., biometrics).

1201.3.6.3 Authorization: The ability to control user permissions within the system to include network access.

1201.3.6.4 Accounting: The ability to provide an audit trail of activities within the system. This is typically accomplished through logging activities of significance, such as a login, changing passwords, or making significant system changes.

1201.3.6.5 Generic and shared accounts are not permitted.

1201.3.6.6 Disabling, removing, or modifying well-known or guest accounts: Designs must specify hardening activities including disabling, removing, or modifying such accounts or changing default passwords.

Commentary: Default accounts and passwords are available on many systems and are often publicly available in published materials allowing unauthorized system access. Disabling, removing, or modifying *well-known or guest accounts and changing default passwords are necessary to reduce system vulnerabilities.*

1201.3.7 Session Management

Commentary: Sound Transit prohibits weak session practices and insecure protocols. Unauthorized access is achievable through clear-text accounts and passwords along with weak session security practices. Only access protocols that encrypt or securely transmit user-login credentials (names and passwords), are acceptable under this requirement.

1201.3.7.1 Designs must specify hardening activities including disabling the use of insecure protocols to access network devices (HTTP and Telnet), enabling secure protocols (transport layer security or tunneling through secure shell terminal emulation for instance), and setting appropriate system parameters to enforce minimum levels of encryption.

1201.3.7.2 Inactive sessions must timeout after 20 minutes of inactivity.

1201.3.7.3 Designs must comply with the most recent version of Sound Transit Information Security Cryptography standard.

1201.3.8 Password/Authentication Policy and Management

Commentary: Instant availability requirements in systems often result in a weak password policy. Weak passwords introduce vulnerabilities to the systems network.

1201.3.8.1 Designs must include hardening activities, including enforcing password complexity limits, restricting user login attempts, and locking out accounts after repeated failed attempts. Designs must comply with all password requirements contained within the latest version of Sound Transit Information Security Access Control standard.

1201.3.8.2 Designs must provide a configurable account password management system that allows for selection of password length, frequency of change, setting of required password complexity, number of login attempts, inactive session logout, password history, screen lock by application, and denial of repeated or recycled use of the same password.

1201.3.8.3 Designs must provide a mechanism for rollback of security authentication policies during emergency system recovery or other abnormal operations, where normal security procedures negatively affect operations.

1201.3.9 Account Auditing and Logging

Commentary: Account auditing and logging allows Sound Transit to verify maintenance of authorized operations. Logging is also necessary for forensic analysis and anomaly detection.

1201.3.9.1 Designs must specify account logging providing an audit trail of user activity that allows traceability of specific actions to a single user/process, location, and time in a verifiable manner. Designs must allow for retaining logs for 90 days online and 270 days offline, and log format should be compatible with Sound Transit SIEM. Designs to comply with all logging and monitoring requirements contained within the latest version of Sound Transit Information Security Log Management standard.

1201.3.9.2 Auditing must be via a system whereby account activity is logged and is auditable both from a management (policy) and operational (account use activity) perspective.

1201.3.9.3 Security event logs must be transmitted to the Sound Transit SIEM.

1201.3.10 Role Based Access Control (RBAC) for Systems Applications

Commentary: RBAC refers to the system's ability to make access decisions based on the role(s) of individual users/processes in the systems environment. Using RBAC results in significant improvements in security. RBAC limits the exposure to risk associated with unauthorized actions by assigning the least privileges corresponding to the assigned duty or function. The use of roles to control access is Sound Transit's required means for developing and enforcing system wide security policies and for streamlining security management processes.

1201.3.10.1 Designs must provide for user accounts with configurable access and permissions associated with the defined user role. Logging must resolve individual users and applications throughout accessing of resources.

1201.3.10.2 Designs must adhere to least privileged permission schemes for all user accounts, and application-to-application communications in accordance with the latest version of SOUND TRANSIT INFORMATION SECURITY Access Control Standard.

1201.3.10.3 When RBAC schemes are established, designs must ensure protection (e.g., encrypted).

1201.3.11 SSO

Commentary: SSO refers to a means of user authentication such that a single login allows a user to have authorized role-based access across a network or between programs and systems without requiring re-authentication to each application.

1201.3.11.1 Designs must provide single SSO authentication in conjunction with RBAC and multi-factor authentication to enhance security:

1201.3.11.2 Provide an SSO such that RBAC enforcement is equivalent to that enforced because of direct login.

1201.3.11.3 Provide a means of allowing SSO to a suite of applications via SSH, terminal services, or other authenticated means. This system must be RBAC capable.

1201.3.11.4 Designs must protect key files and ACLs used by the SSO system from non-administrative users reading, writing, or deleting access of protected files. The SSO must be able to resolve individual user's logins to each application.

1201.3.12 Coding Practices

1201.3.12.1 Infrastructure components are vulnerable to both network and application layer-based security threats. To reduce the risk of cyber security threats at the application level, all application software installed (i.e., not the OS) must protect the agency from cyber security threats. Such threats include:

1201.3.12.1.1 Code injection

1201.3.12.1.2 Buffer overflows

1201.3.12.1.3 Input validation

1201.3.12.1.4 XSS

1201.3.12.1.5 Broken access control

1201.3.12.2 A comprehensive and up-to-date list, including an explanation of threats an application is exposed to can be found on the OWASP website: https://owasp.org/www-project-top-ten/

1201.3.12.3 Sound Transit has aligned its Secure Code Standard with the recommendations from the OWASP. All applications installed on Sound Transit infrastructure must comply with this Standard.

1201.3.12.4 Provide evidence to show compliance with this requirement to Sound Transit Information Security. The following forms of evidence will be accepted:

1201.3.12.4.1 A written statement signed by a company official stating that the application has been coded in accordance with the OWASP (top 10) principles.

1201.3.12.4.2 Evidence that the application source code has been reviewed by a secure code analysis tool, or a third-party organization skilled and equipped to perform a manual review of source code. Evidence should be either a summary of the findings of the code analysis or a report generated by the code scanning tool or third-party provided to Sound Transit Information Security. Any vulnerabilities identified with a CVSS v3.1 score greater than 7-8.9 (high) and 9-10 (critical) must be resolved by the code provider and vendor.

1201.3.12.4.3 Make the source code available for Sound Transit Information Security to review in Sonar Cloud (source code analysis tool). Vulnerabilities identified by Sound Transit will be resolved by the designer based on risk, priority, and compensating or mitigating controls.

1201.3.12.5 CVSS is the industry standard for ranking security vulnerabilities. More information on this can be found here: https://www.first.org/cvss/user-guide

1201.3.13 Coding for Security

1201.3.13.1 Designs must require documentation of development practices and standards applied to all systems software, including firmware, used to ensure a high level of defense against unauthorized access. Coding and development practices must include the following at a minimum:

i. Require all inputs are checked for reasonable values.
ii. Encrypt all data files.
iii. Mitigate security impacts of OS and other third-party libraries.
iv. Require all OS and other third-party libraries have an update policy.
v. Forbid buffer overflow.
vi. Require log files are unalterable.
vii. Use end-to-end authentication and integrity checks on process-to-process data communications.
viii. Require no clear-text passwords or encryption keys are embedded in the code or communicated.

1201.3.14 Malware Detection and Protection

Commentary: Malware is any unauthorized software. Malware consists of many different types of software and may include bots, Trojans, worms, viruses, backdoors, and zombies. Malware detection can occur on a host or a network-based device. Sound Transit control networks connect to other networks or receive updates via media; malware can enter the network and affect process control and/or communications.

1201.3.14.1 Designs must provide one of the following malware protection methods in the scope of supply and delivery:

1201.3.14.2 Provide a host-based malware detection scheme for the control system network that meets current Sound Transit standards per Sound Transit Information Security Anti-Malware Standard. This method must verify adequate system performance for host-based malware detection, quarantine (instead of automatically deleting) suspected infected files and provide an updating scheme for the signatures. Malware detection must include:

i. Full system scans conducted daily.
ii. All file writes scanned in-real time.
iii. Anti-virus configured to quarantine suspicious files or delete files that cannot quarantine.
iv. The system configuration must send alerts to the appropriate monitoring teams, this includes Sound Transit Operations Asset Technology and Sound Transit Information Security.
v. Virus signatures should be updated daily at a minimum.

vi. Monitor changes to system files and generate an alert to Sound Transit Operations Asset Technology and Sound Transit Information Security.

vii. Disabling of anti-virus software must be prevented and should generate an alert to Sound Transit Operations Asset Technology and the agency SIEM.

viii. If the Design is not providing the actual host-based malware detection scheme, the designers must ensure Sound Transit receives malware detection licenses and settings compatible with Sound Transit existing malware systems and all provided applications and software.

1201.3.15 Host Name Resolution

Commentary: DNS servers are susceptible to many types of cyber exploits including spoofing, cache poisoning, and DoS attacks.

1201.3.15.1 To protect against DNS exploits, Sound Transit exclusively controls the DNS servers within the OCSZ, FLSZ, and SCSZ security zones (control systems networks).

1201.3.15.2 Designs must follow Sound Transit's standard network addressing and name resolution methodology. ST is transitioning to base all communication upon DNS device names and not IP addresses. Confirm with Sound Transit IT and OT which systems have transitioned from static IP addressing to dynamics IP addressing and device naming.

1201.3.15.3 Coordinate with Sound Transit for assignment of IP addresses and device naming conventions. See Sound Transit IT's IP schema and device naming convention for reference.

1201.3.16 End Devices

Commentary: End devices refer to components in the control system that gather information or control a process. These include sensors, cameras, controllers, VFDs, and processors. Network and security architectures will change during the lifecycle of end devices, which necessitates detailed end device specifications (e.g., latency, calibrations, protocols, interoperability, and default security settings).

Commentary: End devices are being delivered with common open-source computer software (e.g., The Web, FTP, TELNET) for ease of maintenance and configuration. Well-known and published exploits exist for these applications, and they are susceptible to new and emerging exploits. Some manufacturers are including security functions (e.g., encryption and authentication) to protect these devices.

Commentary: End devices are generally located in remote areas raising physical security vulnerability concerns.

Commentary: Intelligent electronic devices, RTUs, and PLCs incorporate microprocessors and are "smart" end devices. Sensors, cameras, and meters traditionally incorporate limited processing capabilities and are also known as "dumb" end devices. Communication (serial or Ethernet) to/from "smart" or "dumb" end devices to the control system may be intercepted and modified adversely affecting the controlled process. The trend is toward sensors, cameras, and meters that incorporate microprocessors, making all end devices "smart devices."

1201.3.16.1 Provide for securing of all end devices from unauthorized cyber and physical modifications or use:

1201.3.16.1.1 Provide physical and cyber security features including authentication, encryption, access control, event and communication logging, monitoring, and alarming.

1201.3.16.1.2 Clearly identify the physical and cyber security features and provide the methodologies for maintaining the features including the methods to change settings from the manufacturer default conditions.

1201.3.16.1.3 Verify that the addition of security features does not adversely affect connectivity, latency, bandwidth, response time, throughput, and safety certifications when connected to new and existing equipment. The designer must create a baseline test to record these network qualities before implementation of security features. The designer must also create a post implementation test to record these same network qualities for comparison after implementation of security features. The designer must work with Sound Transit IT and OT to determine an acceptable variance for the affected network and associated systems to test against. This must be formalized in designer provided specifications.

1201.3.16.1.4 Provide instructions for the removal or disabling of all software components that are not required for the operation and maintenance of the device.

1201.3.16.1.5 Provide evidence that the OS, firmware, application and middleware versions are within n-2 of the relevant software components current release (n-2 means within two releases of the latest version of production (stable) code offered by the vendor). Where it has been identified that a component exceeds the n-2 release, provide an upgrade path to Sound Transit, including changes to hardware and software components. This requirement is to ensure Sound Transit does not take delivery of systems at or close to their end of life.

1201.3.17 Remote Access

Commentary: Remote access refers to the ability to connect to a computer or network from a different location via web interface, serial, Ethernet TCP/IP, VPN, or wireless.

1201.3.17.1 TCP/IP

Commentary: Poor TCP/IP implementations and/or implementations that do not fully comply with TCP/IP requests for comments can result in protocol stacks that contain vulnerabilities. Hardening interfaces prevent common problems such as buffer overflows, the inability to handle packet fragmentation, or malformed network traffic. These mitigations prevent intentional or accidental exploitation of vulnerabilities that can lead to a device or function being compromised or targeted, or can produce a DoS.

1201.3.17.1.1 All system designs must provide physical and cyber security features including, authentication, encryption, access control, event and communication logging, monitoring, and alarming to protect all /IP devices and any configuration computers from unauthorized modification or use.

1201.3.17.1.2 Inclusion of security features must not adversely affect communications connectivity, latency, bandwidth, response time, and throughput. Create a baseline test to record these network qualities before implementation of security features. Create a post implementation test to record these same network qualities for comparison after implementation of security features. Work with ST IT and OT to determine an acceptable variance for the affected network and associated systems to test against. This must be formalized in designer provided specifications.

1201.3.17.1.3 All system designs must use a TCP/IP implementation that fully complies with the current TCP/IP request for comments.

1201.3.17.1.4 Designs must be IPv6 (internet protocol version) compatible.

1201.3.17.1.5 Provide the ability to inspect encrypted traffic where supported.

1201.3.17.1.6 IPv6 implementations require manufacturer or independent third-party security validation through such techniques as fuzzing.

1201.3.17.1.7 Remote access must support and implement multi-factor authentication.

1201.3.18 Web-Based Interfaces

Commentary: Web-based interfaces are vulnerable to injection attacks and failures such as buffer overflows, memory corruption, and directory transversal. These interfaces require secure coding and sanitation. Therefore, they require careful consideration before inclusion in system designs.

1201.3.18.1 Designs must harden web interfaces against these types of vulnerabilities including:

i. Command injection.

ii. Remote file included.
iii. XSS.
iv. SQL injection.
v. Abuse of sessions.
vi. Directory traversal attacks.
vii. Input manipulation.

1201.3.18.2 Protect web applications employing HTTPS against buffer overflows, memory corruption, and directory traversal.

1201.3.18.3 HTTP must be disabled, and HTTPS used.

1201.3.18.4 Provide physical and cyber security features including, authentication, encryption, access control, event and communication logging, monitoring, and alarming to protect the system from unauthorized modification or use.

1201.3.18.5 Inclusion of security features must not adversely affect communications connectivity, latency, bandwidth, response time, and throughput. Create a baseline test to record these network qualities before implementation of security features. Create a post implementation test to record these same network qualities for comparison after implementation of security features. Work with ST IT and OT to determine an acceptable variance for the affected network and associated systems to test against. This must be formalized in designer provided specifications.

1201.3.18.6 Designs must require removing or disabling of all software components and services that are not required for the operation and maintenance of the devices that run an HTTP server.

1201.3.18.7 Web-based interfaces must follow secure coding practices and reporting for all software. This must include both Web applications and Web servers.

1201.3.19 Serial Communications Security

Commentary: Protocols used in serial communications are exploitable to gain control of network devices. An attacker can gain further control of the network then leverage these devices.

1201.3.19.1 Employ mitigation strategies to prevent exploitation from occurring within the serial domain.

1201.3.19.2 Provide physical and cyber security features including authentication, encryption, access control, event and communication logging, monitoring, and alarming to protect the system from unauthorized modification or use.

1201.3.19.3 Designs must employ link encryptors to protect field communications (e.g., bump-in-the-wire devices).

1201.3.19.4 Inclusion of security features must not adversely affect communications connectivity, latency, bandwidth, response time, and throughput. Create a baseline test to record these network qualities before implementation of security features. Create a post implementation test to record these same network qualities for comparison after implementation of security features. Work with ST IT and OT to determine an acceptable variance for the affected network and associated systems to test against. This must be formalized in designer provided specifications.

1201.3.20 Physical Security

Commentary: Physical access to cyber equipment circumvents all cyber security controls. Systems networks and devices require protection from physical access as well as cyber access.

Commentary: This requirement set focuses on cybersecurity language for communications and systems. Physical security is a key port of a total security posture. This section is not to supersede other physical *security requirements. Suggestions made in this section conform to common physical security issues related to cybersecurity components.*

1201.3.20.1 Physical Access of Cyber Components

1201.3.20.1.1 Physical access to systems must conform to the same level of security as the surrounding systems cyber access.

Commentary: Unlocked control cabinets, and operator or engineering workstations in unsecured rooms and buildings often only require access by a computer or systems-knowledgeable person to have a significant impact on operations by changing set points, altering code, performing manual overrides, or cycling systems with the intent of burning up motors or disrupting the process.

1201.3.20.1.2 . Like all networking equipment, all cybersecurity equipment must be secured in designated rooms and locked panels per Sets 815 Telecommunication Spaces and 1203 Access Control and 301 Network Infrastructure.

1201.3.21 Communications Security

1201.3.21.1 Access to all wireless WIFI or short-range communications must be limited to within Sound Transit secured areas (this does not include radio or cellular communication). Require verification that wireless ranges are within ST secured areas after implementation by a method deemed appropriate by the designer.

1201.3.21.2 Designs must ensure all communication channels or network connections are direct as possible. Follow topology standards found in Set 301 Network Infrastructure., Do not use daisy chaining of access switches, unnecessary connections/patching of media, or unnecessary media converters. Media converters or POE extenders should be avoided if can be accommodated by modifications to networking equipment.

1201.3.22 Wireless Technologies

1201.3.22.1 When wireless technologies connect IOT devices, Sound Transit prohibits the bridging to any agency network. All IOT devices must employ multi-factor authentication for those devices directly connected to the Internet.

1201.3.22.2 Sound Transit prohibits use of SSID broadcast for any wireless communications.

1201.3.22.3 Designs must employ corresponding wireless technologies security elements, such as passwords or security codes, to protect devices from unauthorized access, modification, or use.

1201.3.22.4 RFID

Commentary: RFID has some of the same type of weaknesses as other wireless technologies, though in practice most current RFID installations include the transmitting device and the reader in very close proximity to each other. Nevertheless, vulnerabilities still exist. Besides being vulnerable to common attacks such as eavesdropping, MitM, and DoS, RFID technology is, susceptible to spoof and power attacks.

Commentary: Most current RFID systems are not secure due to their primary mission (i.e., inventory of materials). In cases where they perform a secure function, such as tracking hazardous materials used in a process, Sound Transit requires special care in deploying these systems.

1201.3.22.4.1 RFID system designs must provide encryption of radio signals.

1201.3.22.4.2 Designers must identify mitigations for eavesdropping, MitM, and DoS attacks, including spoofing and power attacks with the specified RFID technology.

1201.3.23 802.11 Technology

Commentary: The reference, 802.11, refers to a family of specifications developed by IEEE for wireless local area network (WLAN) technology. It specifies a wireless interface between a wireless device and a *base station (access point) or between two wireless devices (peer- to-peer); 802.11 devices operate in the 5 gigahertz and 2.4 gigahertz public spectrum bands. Because these transmissions are through the air, these are susceptible to interception or interference by those having the proper equipment.*

Commentary: Despite the availability of strong encryption for user communication, the management frames of IEEE 802.11 messages do not employ encryption, leaving the door open for DoS attacks. Several tools are available that can cause users to drop off the network or send messages to hamper the functionality of wireless endpoints. Such tools include Wi-Fi jammers, designed to block IEEE 802.11 transmissions, and rogue access points, that are set up in hopes of attracting connections then stealing sensitive information or altering communications. Adding to and enabling attacks is the fact that Wi-Fi access points are often set up quickly and without security foresight. This results in the use of weak or no encryption, allowing attackers to impersonate wireless endpoints in hopes of providing false data.

1201.3.23.1 Designs must document the range of the Wi-Fi device, power requirements, and the designated frequencies of operation for each device.

1201.3.23.2 Designs must include alarm settings in accordance with the needs of the system.

1201.3.23.3 Designs must provide for cooperative Wi-Fi nodes that can distinguish jamming from channel saturation and provide operational alerts.

1201.3.23.4 Designs must specify devices with the standard security measures in accordance with 802.11 standard and support the required level of encryption.

1201.3.23.5 Designs must provide test data with analysis showing that basic attacks such as malformed packet injection do not cause specified Wi-Fi devices to crash, hang, or otherwise malfunction.

1201.3.23.6 Designs must never employ Wi-Fi devices that only support protocols or standards considered deprecated, obsolete, or known to the industry to be security-compromised at the time of delivery to Sound Transit.

1201.3.23.7 WPA2 or above should be implemented on Wi-Fi networks. Wi-Fi networks that are required to support end devices used by staff, contractors, or vendors should be configured to provide one-time passwords or keys to access the resources following successful authentication and authorization.

1201.3.24 Cellular Technology

Commentary: Cellular technology may be used to manage and control industrial processes where cabling is not an option. Although the law provides penalties for the interception of cellular telephone calls, it is easily accomplished and impossible to detect.

1201.3.24.1 Designs employing cellular technology must identify all specific protocols required for the cellular system to communicate with the control network, including other equipment that can communicate with the cellular system.

1201.3.24.2 Designs employing cellular technology must identify the range of the cellular system, power requirements, and the designated frequency of operation for each device.

1201.3.25 Security By Design

Commentary: Not all integrated automation systems and operational technologies are vulnerable or are at risk of cyber threats. However, these systems manage critical infrastructure assets that are vital to Sound Transit operations. Whether the threats are real or perceived, it is in the agency's best interest to provide protection of these assets.

1201.3.25.1 All integrated automation systems and operational technology designs must incorporate cybersecurity throughout all stages of the project lifecycle. Designs must provide not only mitigations for cyber threats and vulnerabilities but also provide Sound Transit with the ability to continually manage, monitor and maintain cybersecurity risk.

Commentary: Sound Transit places emphasis on cybersecurity beginning in the planning and design stages as it becomes more difficult and costly to add cybersecurity as systems are developed and deployed. Cybersecurity controls and mitigations included in initial designs are more effective and efficient than those applied after a system becomes operational.

1201.3.26 System Architecture

1201.3.26.1 Network security design must adhere to Department of Homeland Security Recommended Practice by following APTA-SS-CCS-RP-002-13 Securing Control and Communications Systems in Rail Transit Environments. Design must define security zones and systems/devices within or that span different zones. Design must identify all communications conduits (data paths) between security zones per standards found within ANSI/ISA/IEC-62443 Industrial Network and System Security. A zone with a lower level of security is not permitted to support connectivity to a zone with a higher level of security without appropriate controls in place. A zone with a higher level of security is permitted to support connectivity to a zone with a lower level of security. Airgaps should not be used as a security control, nor should they be integral to the design of systems.

1201.3.26.2 System Layout

1201.3.26.3 Cybersecurity requirements are required in all Sound Transit networkable systems in offices, garages, stations, TPSSs, signal houses, end of line facility, and all systems along the alignments. Additionally, cybersecurity is required in systems interfacing with third-party systems such King Country Metro and other counties where Sound Transit systems interface.

1201.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS (NOT USED)

1201.4.1 System Breakdown Structure

1201.4.2 System Sites and Locations

1201.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 1201-1: Interface Between Cybersecurity and Other Disciplines

SET SERIES	SET NAME	SET 1201 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	X
400	Vehicle	X
500	Track	X
600	Fire/Life Safety	X
700	Structures	
800	Architecture	
900	Civil	
1000	Mechanical/Electrical and Building Systems	X
1100	Technology	X
1200	Security	X
1004	Building Monitoring & Control	X

1201.5.1 Interfacing Sections and Modes
This Cybersecurity set interfaces with the specific sets below.

i. Train Control – Light Rail (123)
ii. Traction Power (220)
iii. Stray Current Corrosion Control (222)
iv. Network Infrastructure (301)
v. Telephony (302)
vi. Radio (303)
vii. Audio Systems (304)
viii. SCADA (324)
ix. LRV (421)
x. Fire-Life Safety (601)
xi. Telecommunication Spaces (815)
xii. Building Monitoring and Control (1004)
xiii. Passenger Information Management System (PIMS) (1102)
xiv. Fare Vending (1103)
xv. CCTV/TIDS (1202)
xvi. Access Control System (1203)
xvii. Light Rail
xviii. Tacoma Light Rail
xix. Stride (BRT)
xx. Sound Transit Express
xxi. Sounder
xxii. Facilities (maintenance, parking, operations)

1201.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

1201.6.1 Cybersecurity

1201.6.1.1 Cybersecurity requirements involve in different subsystems elements, which are critical to implement to protect Sound Transit networkable systems:

i. System Hardening
ii. Host Intrusion Detection (HID)
iii. File System and Operating System Permissions
iv. Hardware Configuration
v. Perimeter Protection
vi. Firewalls
vii. Network Intrusion Detection Systems (NIDS)
viii. Account Management
ix. Session Management
x. Password/Authentication Policy and Management
xi. Account Auditing and Logging
xii. Role Based Access Control (RBAC) for Systems Applications
xiii. Single Sign-On (SSO)
xiv. Coding Practices
xv. Coding for Security
xvi. Vulnerability Remediation
xvii. Malware Detection & Protection
xviii. Host Name Resolution
xix. End Devices
xx. Remote Access
xxi. Web-Based Interfaces
xxii. Serial Communications Security
xxiii. Physical Security
xxiv. Physical Access of Cyber Components
xxv. Communications Security
xxvi. Wireless Technologies
xxvii. Bluetooth Technology
xxviii. Internet of Things (IOT) networks only.
xxix. Radio Frequency Identification Technology (RFID)
xxx. 802.11 Technology
xxxi. Mobile Radios
xxxii. Cellular Technology
xxxiii. Maintainability

1201.6.1.2 Cybersecurity requirements apply to all modes of operation including Light Rail, Tacoma Light Rail, Sounder, Sound Transit Express Bus, Bus Rapid Transit (Stride). The requirements also span all building types across these modes including stations, wayside facilities, maintenance facilities, parking facilities/garages.

1201.7 ENGINEERING MANAGEMENT REQUIREMENTS

1201.7.1 Interface and Integration Management

1201.7.1.1 System Interface Standard Specifications: This requirement set accompanies Sound Transit Standard Specification 25 05 11 Cybersecurity for Integrated Automation (Operational Technology). Coordination between the two is necessary.

1201.7.2 Design Management

1201.7.2.1 Early-Stage Design Documentation

1201.7.2.1.1 Designers must provide the following as baseline documentation, but additional design documentation, design submittal phasing, and design detail may be required as defined in the Sound Transit EP-03, based on the contract delivery methods. Designs are required for use by Sound Transit, other designers, contractors, vendors, and suppliers to achieve design approval and for post-IFC project activity. Designers must facilitate coordination between contractor and Sound Transit for owner provided equipment, coordination of owner provided equipment in the design, coordinate submittals with sufficient detail by the contractor for Sound Transit to order the Sound Transit provided equipment, and proper coordination of construction phasing for installation, configuration, and testing. See Sound Transit Systems Guidance drawings for reference.

1201.7.2.1.2 Cybersecurity networked device schedules: Provide a cybersecurity networked device schedule for each VLAN documenting all network connections. Populate schedules with information available at each stage of design as defined by EP-03. Designers must also require contractor to progress the design deliverable during construction as a submittal to verify provided information and also add new design details provided during configuration. Designers must coordinate with Sound Transit for information to be determined by Sound Transit IT, PSO and OET.

Cybersecurity Networked Device Schedule:

i. Installing Contract Number
ii. Facility ID
iii. Station Acronym
iv. Cabinet/Panel ID
v. Room DC Location
vi. Switch ID
vii. Port #
viii. Number of Ports Required
ix. Number of Ports Provided
x. Port Type
xi. PoE
xii. PP Port
xiii. System
xiv. Device Type
xv. Device Name
xvi. Service Location
xvii. Device Description and Location
xviii. Date Needed
xix. Date Installed/Modified
xx. Mounting
xxi. Power Requirements
xxii. Rugged/non-Rugged
xxiii. Switch Model
xxiv. Power Supply Model
xxv. Switch Manufacturer
xxvi. MAC Address
xxvii. Serial Number
xxviii. Asset Tag
xxix. SFP Type
xxx. Comment
xxxi. VLAN
xxxii. IP Address
xxxiii. Subnet Mask
xxxiv. Default Gateway
xxxv. Soft Port(s) - Optional
xxxvi. Security (Contractor Input)
xxxvii. Foreign Destination(s)
xxxviii. Transport Layer Protocol
xxxix. Application Protocol
xl. Descriptive Purpose
xli. Operating System type and version, including patch and revision levels
xlii. Firmware type and version

xliii. Details of security hardening applied to the device
xliv. For wireless, networked devices provide the following information:
xlv. Device ID
xlvi. Device Description
xlvii. Location
xlviii. Receiving Device IDs
xlix. SSID (including those hidden or not being broadcasted)
l. Communication type
li. Protocol
lii. Encryption
liii. RF Frequency
liv. Radiated Power (dBm)
lv. Free-space Range
lvi. As-installed Range
lvii. Operating System type and version, including patch and revision levels
lviii. Firmware type and version

1201.7.2.1.3 Designers must provide the cybersecurity networked device schedules as editable Microsoft Excel files.

1201.7.2.1.4 Cybersecurity Riser Diagrams

1201.7.2.1.4.1 Provide a cybersecurity riser diagram of the complete systems within each VLAN including all network and controller hardware. Diagrams only apply to new or modified equipment. Data connections shown may be physical or logical.

1201.7.2.1.4.2 The riser diagrams must depict the five appropriate security zones conforming to DHS Recommended Practice: Improving Industrial Systems Cybersecurity with Defense-in-Depth Strategies Industrial Systems Cyber Emergency Response Team September 2016 as referenced within APTA-SS-CCS-RP-002-13 Securing Control and Communications Systems in Rail Transit Environments Part II: Defining a Security Zone Architecture for Rail Transit and Protecting Critical Zones:

i. External zone
ii. Enterprise zone
iii. OCSZ
iv. FLSZ
v. SCSZ

1201.7.2.1.4.3 The riser diagrams must represent all devices and associated systems listed in the cybersecurity networked device schedule.

1201.7.2.1.4.4 Designer must require contractor to update and resubmit to Sound Transit the designer provided riser diagrams to note all communication conduits between devices with the following noted for each path:

i. Source device name and MAC and/or IP address.
ii. Destination device name and MAC and/or IP address.
iii. Protocol (TCP, UDP, etc.) and port or range of ports and a description of what each TCP/UDP service are used for and why it is required.
iv. Verification that all unused ports to be logically disabled, including USB ports on network switches.

1201.7.2.1.4.5 The riser diagram must depict all communications conduits (data paths) between security zones per standards found within ANSI/ISA/IEC-62443 Industrial Network and System Security. A zone with a lower level of security is not permitted to support connectivity to a zone with a higher level of security without appropriate controls in place. A zone with a higher level of security is permitted to support connectivity to a zone with a lower level of security. airgaps should not be used as a security control, nor should they be integral to the design of systems unless required by the specific system or network requirement set, system guidance drawings or other Sound Transit standards.

1201.7.2.1.5 Device and Software Cybersecurity Documentation. Acquire and review manufacturer cybersecurity documentation for all named and specified intelligent electronic devices and software applications. Use manufacturer documentation to inform designs:

1201.7.2.1.5.1 IED documentation.

1201.7.2.1.5.1.1 Documentation that describes secure configuration of the device.

1201.7.2.1.5.1.2 Documentation that describes secure operation of the device.

1201.7.2.1.5.1.3 Documentation that describes effective use and maintenance of security functions or mechanisms for the device.

1201.7.2.1.5.1.4 Documentation that describes known vulnerabilities regarding configuration and use of administrative (i.e., privileged) functions for the device.

1201.7.2.1.5.1.5 Documentation that describes user-accessible security functions or mechanisms in the device and how to effectively use those security functions or mechanisms, or a specific indication that there are no user-accessible security functions or mechanisms in the device.

1201.7.2.1.5.1.6 Documentation that describes methods for user interaction, which enables individuals to use the device in a more secure manner.

1201.7.2.1.5.2 Software applications documentation:

1201.7.2.1.5.2.1 Administrator documentation that describes secure configuration of the software.

1201.7.2.1.5.2.2 Administrator documentation that describes secure installation of the software.

1201.7.2.1.5.2.3 Administrator documentation that describes secure operation of the software.

1201.7.2.1.5.2.4 Administrator documentation that describes effective use and maintenance of security functions or mechanisms for the software.

1201.7.2.1.5.2.5 Administrator documentation that describes known vulnerabilities regarding configuration and use of administrative (i.e., privileged) functions for the software.

1201.7.2.1.5.2.6 Administrator documentation that describes security roles that are setup including users and their associated security access details.

1201.7.2.1.5.2.7 User documentation that describes user-accessible security functions or mechanisms in the software and how to effectively use those security functions or mechanisms.

1201.7.2.1.5.2.8 User documentation that describes methods for user interaction, which enables individuals to use the software in a more secure manner.

1201.7.2.1.5.2.9 User documentation that describes user responsibilities in maintaining the security of the software.

1201.7.2.1.5.2.10 Designers must make all manufacturer cybersecurity documentation available to Sound Transit and other designers, contractors, vendors and suppliers of integrated automation and operational technologies. Design must require contractor to submit final manufacturers' cyber security documentation to Sound Transit as part of final submittals.

1201.7.3 Manufacturing and Construction Management (Not Used)

1201.7.4 Installation Management (Not Used)

1201.7.5 Inspection and Testing Management (Not Used)

1201.7.6 Training, Pre-Revenue Operations

1201.7.6.1 The designer must require that all personnel carrying out cybersecurity work must have completed the Department of Homeland Security's Industrial Systems Cyber Security (301) training prior to start of the work.

1201.8 APPENDICES (NOT USED)

END SET - 1201

1202 CLOSED-CIRCUIT TELEVISION (CCTV) AND TRACK INTRUSION DETECTION SYSTEM (TIDS)

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SET - 1202 TABLE OF CONTENTS

TABLES

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SET - 1202 CLOSED-CIRCUIT TELEVISION (CCTV) AND TRACK INTRUSION DETECTION SYSTEM (TIDS)

1202.1 INTRODUCTION

1202.1.1 Document Scope

1202.1.1.1 This set establishes CCTV design criteria for Sound Transit facilities including TIDS, CCTV and transmission, video analytics, and object identification.

1202.1.1.2 This requirement set establishes minimum requirements for the CCTV and TIDS.

1202.1.1.3 CCTV and TIDS are ever changing technologies, as such, the design of CCTV and TIDS requires a generic design approach. the specification of actual models for CCTV and TIDS equipment must be coordinated with sound transit, transit systems technology.

1202.1.1.4 If there is a conflict between these requirements and adopted codes and standards, the most restrictive will apply. This set applies to all Sound Transit modes including sounder and bus rapid transit.

1202.1.1.5 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the requirements set 1202 owner to determine the technical source for the design criteria.

1202.1.1.6 This set applies to Link Light Rail, Sounder Commuter Rail, Bus Rapid Transit, and all Sound Transit properties.

1202.1.2 Regulations, Codes, Standards, and Guidelines

1202.1.2.1 International Regulations, Codes, Standards, and Guidelines

1202.1.2.1.1 Institute of Electrical and Electronics Engineers (IEEE).

1202.1.2.1.2 International Electrotechnical Commission, IEC 60068-2-64, Vibration.

1202.1.2.1.3 International Electrotechnical Commission, IEC 60068-2-27, Shock Resistance.

1202.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

1202.1.2.2.1 International Telecommunication Union (ITU).

1202.1.2.2.1.1 H.264, 2019 Edition, Advanced Video Coding for Generic Audio Visual Services.

1202.1.2.2.1.2 H.265, 2021 Edition, High Efficiency Video Coding MPEG4 (ISO/IEC 23008-5), Advanced Video Coding (H.265).

1202.1.2.2.2 International Telecommunication Union (ITU).

1202.1.2.2.3 IEEE 802.3at, Standard for Power over Ethernet enhancements (25.5W)

1202.1.2.2.4 IEEE 802.3bt, Standard for Third Generation Power over Ethernet (for PoE++, 4PPoE)

1202.1.2.2.2 National Electrical Manufacturers Association (NEMA).

1202.1.2.2.3 National Electrical Code (NEC), NFPA 70, with state and local amendments.

1202.1.2.3 National Fire Protection Association (NFPA) - NFPA 130 Industry Regulations, Codes, Standards, and Guidelines.

1202.1.2.3.1 Underwriters Laboratories (UL): Per IEC60950-1 Component Application Standard.

1202.1.2.4 UL 2044 (3rd Edition, 2008) Standard for Commercial Closed Circuit Television Equipment.

1202.1.2.5 State and Local Regulations, Codes, Standards, and Guidelines (Not Used)

1202.1.2.6 Other Jurisdictions (Not Used)

1202.1.2.7 Sound Transit Regulations, Codes, Standards, and Guidelines

1202.1.2.7.1 Sound Transit Equipment and Facilities Numbering Standards. - Rev 4.

1202.1.2.7.2 Sound Transit Systems Guidance Drawings.

1202.1.3 Abbreviations and Acronyms

1202.1.3.1 AHJ–authority having jurisdiction

1202.1.3.2 ALPR–automatic license plate recognition

1202.1.3.3 CCTV–closed-circuit television

1202.1.3.4 IP–internet protocol

1202.1.3.5 LCC–Link control center

1202.1.3.6 LRV–light rail vehicle

1202.1.3.7 NVR–network video recorder

1202.1.3.8 OCS-Overhead contact system

1202.1.3.9 PoE–power over Ethernet

1202.1.3.10 PTZ-PAN TILT ZOOM

1202.1.3.11 TIDS–track intrusion detection system

1202.1.3.12 UNC-Unified national coarse

1202.1.4 Definitions and Classifications

1202.1.4.1 Enclosed station: a station or portion thereof that does not meet the definition of an open station (NFPA 130).

Commentary: Enclosed stations classification applies to tunnel stations and other stations where tenability of the platform and its means of egress from could be affected by a station or LRV fire. An open station with a roof that extends over the trainway, for example, could potentially be classified as an enclosed station. An engineering analysis may be needed to classify such a station as an open station (see set series 800 Architecture).

1202.1.4.2 Image resolution is classified into four categories: detection, observation, recognition, and identification and must be defined by the camera manufacturer.

Commentary: The definitions of detection, observation, recognition, and identification can change over time. Consult the Sound Transit specified CCTV camera manufacturer to reference the most up-to-date definitions.

1202.1.4.3 Pixel density: A metric used to estimate image quality.

Commentary: In practice, conditions such as lighting levels, object motion, and lens focus may alter the image quality. Pixel density is often represented as pixels per foot or pixels per meter.

1202.1.4.4 Public: Spaces open to the general public, containing trash receptacles, sidewalks, lighting, and city streets, not directly serving Sound Transit facilities, and not maintained by Sound Transit and/or Sound Transit management partners.

1202.1.4.5 Restricted: Spaces maintained by Sound Transit and/or Sound Transit management partners and where access is only granted based on qualified credentials.

1202.1.4.6 Semi-private: Spaces maintained by Sound Transit and/or Sound Transit management partners with predetermined hours of operation and where access is tightly controlled.

1202.1.4.7 Semi-public: Civic spaces that extend from the sidewalk to stations/building facades maintained by Sound Transit and/or Sound Transit management partners. This space includes areas that are generally open to the public without restriction (e.g., the building façade, entrance, ground floors, and ground plazas).

1202.1.5 References (Not Used)

1202.2 STAKEHOLDER NEEDS

1202.2.1 Passenger Experience (Not Used)

1202.2.2 Operational Needs

1202.2.2.1 CCTV cameras must not obstruct view of signal indications along alignment. where practicable, track signals must be viewable for CCTV camera.

1202.2.2.2 CCTV system must provide visibility of critical areas during power outage and playback to stakeholders.

1202.2.3 Maintenance Needs

1202.2.3.1 The designer must reduce the time needed to replace and maintain CCTV cameras.

1202.2.3.2 CCTV cameras must not require the disconnection of power for the OCS to conduct maintenance on cameras.

1202.2.3.3 Designer must coordinate with Sound Transit when a six foot ladder is not sufficient for maintenance.

1202.2.3.4 The designer must provide updated CCTV cameras with industry standard features and functionality.

1202.2.3.5 CCTV camera equipment in public, semi-private, and semi-public spaces must be located equal to or higher than 9 feet and must not exceed 15 feet in height.

Commentary: Locate each CCTV camera to reduce the exposure to damage and to reduce the maintenance effort needed to service the equipment. The 15-foot maximum height facilitates ease of maintenance with standard ladders.

1202.2.3.6 When the minimum nine-foot-high mounting threshold requirement cannot be met, the designer must provide cameras located as close to the nine-foot threshold as practicable.

1202.2.3.7 Coordinate procurement of CCTV equipment with Sound Transit to ensure appropriate equipment quantities and the function and maintenance of the CCTV system.

1202.2.4 Safety Needs

1202.2.4.1 The CCTV system must provide video surveillance at locations where Sound Transit vehicle/pedestrian collisions are probable.

1202.2.4.2 Passenger movements around semi-private and semi-public areas must be visible via CCTV system.

1202.2.5 Security Needs

1202.2.6 Reliability, Availability, and Maintainability Needs

1202.2.6.1 Reliability and Durability

1202.2.6.1.1 Equipment associated with the CCTV camera system must possess a mean time between failure of at least five years. This equipment includes IP cameras, network video recorders, and Ethernet extenders. See Sound Transit Standard Specification Section 27 80 00 Communications Reliability Program.

1202.2.6.2 Availability

1202.2.6.2.1 Network Device Loss Tolerance

1202.2.6.2.1.1 See Set 301 Network Infrastructure.

1202.2.6.2.2 Device and Pathway Loss Tolerance.

1202.2.6.2.2.1 See Set 301 Network Infrastructure.

1202.2.6.2.3 Power Loss Tolerance

1202.2.6.2.3.1 Provide backup power of the CCTV camera system using the communications UPS. See Set 1005 Electrical Power.

1202.2.6.2.3.2 Provide CCTV camera with removeable media storage capabilities to serve as secondary storage.

1202.2.6.3 Maintainability

1202.2.6.3.1 Where practicable, designs must employ only one supported model to meet an individual requirement.

Commentary: This is a Model Reduction requirement. Model Reduction has been incorporated to reduce incompatibility, reduce unreliability due to new unconfirmed components, reduce compliance issues, increase usable inventory space, reduce redesign, reduce additional training, reduce unreliable integration, increase spares, and ease documentation.

1202.2.6.3.2 Coordinate with Sound Transit, Transit Systems Technology prior to procurement for approved CCTV camera models.

1202.2.7 Environmental and Sustainability Needs

1202.2.7.1 The CCTV system must provide protection against dust and liquids.

1202.2.7.2 The CCTV cameras must be polyvinyl chloride free.

1202.3 SYSTEM REQUIREMENTS

1202.3.1 General Requirements

1202.3.1.1 CCTV as it relates to fixed guideway transit and passenger rails systems is focused on giving stakeholders visibility into the events at public, semi-public, and semi-private areas of transit facilities.

1202.3.1.2 To support the generation of CCTV, which is relevant, timely, and clearly presented, designers must provide video coverage of locations listed in the section 1202.4.2 system sites and locations.

1202.3.1.3 Coordinate CCTV design with Sound Transit Operations, Sound Transit Facilities, and Sound Transit Safety and Security departments to obtain appropriate image resolution at different locations to meet stakeholder intent.

1202.3.1.4 Ethernet Extenders must not be used when more than two CAT6 ethernet runs are co-located more than 200 feet away from an upstream access layer switch.

1202.3.1.5 Apply the specified CCTV camera manufacturer image resolution definitions/zones to CCTV field-of-view coverage designs.

Commentary: This requirement's purpose is to define resolution and image quality for CCTV cameras. Typical zones include identification (80px/foot), recognition(60px/foot), observation(40px/foot), and detection zones(10px/foot).

1202.3.2 Functional Requirements

1202.3.2.1 For details regarding the required NEMA ratings, enclosures, and telecommunications spaces, see set 1006 electrical raceway and set 815 telecommunication spaces.

1202.3.2.2 Environmental Conditions

1202.3.2.2.1 All outdoor CCTV equipment must have an IP66/NEMA 4X environmental protection rating.

1202.3.2.3 Lighting

1202.3.2.4 CCTV cameras must be located below lighting fixtures when practicable.

Commentary: This requirement serves to minimize the glare present by cameras located too close to lighting fixtures.

1202.3.2.5 TIDS

1202.3.2.6 TIDS must provide constant monitoring of stationary and mobile non-revenue vehicles and people that foul the track guideway (transit right-of-way).

1202.3.2.7 TIDS must not use PTZ cameras to meet detection requirements.

1202.3.2.8 TIDS must trigger audio warnings via IP speakers and visual warnings via strobe lights.

1202.3.2.9 CCTV must be networked to the Operations Control Center via Sound Transit Network as directed by Sound Transit, Transit Systems Technology.

1202.3.2.1 Recording

1202.3.2.1.1 Video events must be recorded locally to local NVR.

1202.3.3 Performance Requirements

1202.3.3.1 Provide a network video recorder at each station capable of storing fourteen full days of video at full HD 1080 pixels resolution and 15 frames per second.

1202.3.3.2 Provide a network video recorder compatible with current Sound Transit CCTV network.

1202.3.3.3 Provide a network video recorder that exports data compatible with current Sound Transit CCTV network.

1202.3.3.4 Provide CCTV equipment compatible with current Sound Transit Video Management System

1202.3.3.5
The CCTV system must utilize swivel action/anti-collision or Sound Transit approved equivalent for mounting locations where the nine-foot minimum threshold height cannot be met (i.e., in garages).

1202.3.3.6 CCTV equipment locations must be maintainable and accessible without requiring fouling of the track.

1202.3.4 Response Time and Network Feeds

1202.3.4.1 See Set 301 Network Infrastructure for details on response time and video feeds.

1202.3.4.2 The CCTV system must be compatible with video surveillance sharing capabilities of the existing Sound Transit CCTV system.

1202.3.5 Capability (Not used)

1202.3.5.1 The CCTV camera must be able to discern between vehicles types and people.

1202.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

1202.4.1 System Breakdown Structure

1202.4.1.1 The video surveillance system comprises the following elements:

i. IP video cameras
ii. Mounting systems
iii. Video enabled callbox intercom
iv. NVRs
v. Ethernet extender(s)
vi. Software and camera licenses

1202.4.1.2 For each configuration, implement the scalability and model reduction requirements to obtain an optimized design.

1202.4.2 System Sites and Locations

1202.4.2.1 Provide CCTV coverage of the following areas including predictable obstructions:

1202.4.2.1.1 Detection

i. Corridors and pedestrian areas
   a. Pedestrian interconnections within semi-private zones
   b. Pedestrian walkways within semi-private zones
ii. Hidden corners at the station
iii. At-grade intersections
iv. Staff parking lots
v. Property perimeter
vi. Restricted exterior locations
vii. Property perimeter
viii. Tracks
   a. Cross tracks
   b. Layover tracks
   c. Tail tracks
   d. Tracks from both ends of station
   e. Tracks at end of line to be extended

1202.4.2.1.2 Recognition

i. Access Points
   a. Maintenance access points
   b. Alignment at passenger interaction (e.g. where there exists fouling of the tracks and physical occupation of alignment
   c. Roof access points
ii. Buildings
   a. Outside ancillary building
   b. Outside signal bungalow
   c. Outside traction power substation
iii. Bus shelters associated with multimodal facilities
iv. Pedestrian corridors
v. Pedestrian bridges
vi. Escalators
vii. Gathering areas
viii. Grade crossings
ix. Passenger parking garages

x. Passenger platforms
xi. Semi-private plazas
xii. Generator
xiii. Buildings
    a. Fuel ports
    b. Storage areas
    c. Genset
xiv. Rooms
    a. Communications rooms
    b. Inside communications rooms
    c. Outside communications rooms
    d. Outside electrical rooms
    e. Outside fire control rooms
    f. Inside security rooms
xv. Semi-private areas with foot traffic
xvi.
xvii. Staff entrances and exits
    a. Operations and maintenance facility staff entrances and exits
xviii. Public stairwells
xix. Interlocking track
xx. Tunnels
    a. Tunnel access points
    b. Tunnel facilities
    c. Tunnel portals

1202.4.2.1.3 Identification

i. Access Points
    a. Semi-public to restricted space card reader area
    b. Semi-private to restricted space card reader area
ii. Bicycle Storage
    a. Bicycle cages
    b. Bicycle parking
iii. Card readers at access points from public to private spaces
iv. Choke points
v. Elevators
    a. Elevator cabs
    b. Elevator landings and lobbies
vi. Entrances and Exits
vii. Fare vending
    a. Ticket vending machines
    b. Fare vending areas
viii. Yard leads
ix. Public to private card reader access point
x. Restroom
    a. Public restroom entrances
    b. Public restroom intercom callbox (exterior)
    c. Staff restroom area
xi. Telephony
    a. Customer emergency phones
    b. Passenger emergency phones

xii. Vehicle storage areas
xiii. Vehicle entrances and exits
   a. Garage vehicular entrances and exits
   b. License plates at garage entrances and exits
   c. Operations and maintenance facility vehicular entrances and exits
xiv. Yard tracks

1202.4.2.2 Apart from obstructed views, provide 360-degree video surveillance visual coverage at fare vending zones

1202.4.2.3 Non-TIDS CCTV equipment must not be installed at the following locations:
i. Driveways in garages where impact with vehicles is probable.
ii. Above midspan of stairs and escalators.
iii. In spaces behind architectural cladding materials.
iv. Along trackway, not at station, and inaccessible by maintenance ladder (e.g., above parking spaces).
v. On overhead contact system poles.
vi. Within 10 feet of OCS lines.
vii. Requires maintainer to be within 10 feet of OCS.
viii. In areas where intended use will restrict the use of a maintenance ladder (e.g., underneath bridges and walkways).
ix. Areas that require any part of a maintainer's body to be suspended over an edge more than six feet above the nearest ground.

1202.4.2.4 Provide TIDS coverage of the following areas at grade-type changes

Commentary: Currently, there are three grade-types. These include at-grade, grade-separated, and tunnel stations. Any transition from one grade type to another, such as a transition from at-grade to grade separated as seen between the Rainier Beach and Tukwila International Boulevard Stations, requires track intrusion detection.

1202.4.2.5 Provide TIDS coverage at entrances to tunnels.

1202.4.2.6 Provide TIDS coverage at entrances to enclosed track.

1202.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 1202-1: Interface Between CCTV/TIDS And Other Disciplines

SET SERIES	SET NAME	SET 1202 INTERFACE
100	Train Control and Signals	X
200	Traction Electrification	X
300	Operational Communications	
400	Vehicle	X
500	Track	
600	Fire-Life Safety	
700	Structures	
800	Architecture	
900	Civil	
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	
1200	Security	X

1202.5.1 Vehicle

1202.5.1.1 CCTV must be provided for Sound Transit vehicles. See Set 421 Light Rail Vehicle.

1202.5.2 Security

1202.5.2.1 Intrusion detection (system).

1202.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

1202.6.1 Video Surveillance Elements

1202.6.1.1 Provide system sub-components to provide proper operation of the CCTV system.

1202.6.1.2 Provide video surveillance system that transmits video images from the specified, surveyed locations to the local NVR for storage.

1202.6.1.3 Provide video surveillance system that transmits video images to stakeholders.

1202.6.1.4 Provide video surveillance system that meets the performance metrics listed within the current document.

1202.6.1.5 CCTV Cameras

1202.6.1.5.1 When not employing TIDS, CCTV cameras must use a fixed lens/lenses or manually adjustable lens(es).

1202.6.1.5.2 CCTV cameras must be powered by PoE, PoE+ as defined by IEEE 802.3af/at, or 802.3bt where camera communication occurs over Ethernet cabling.

1202.6.1.5.3 ALPR cameras must have built-in illuminator with the capability of maintaining camera function under 0 lux (total darkness).

1202.6.1.5.4 Standards and Protocols – Compression

1202.6.1.5.4.1 CCTV camera must accept the following video compression encoding formats:

1202.6.1.5.4.1.1 H.264.

1202.6.1.5.4.1.2 H.265.

1202.6.1.5.4.1.3 Ultra 265.

1202.6.1.5.4.1.4 Motion JPEG (MJPEG).

1202.6.1.6 Mounts must use standard UNC compatible threading.

1202.7 ENGINEERING MANAGEMENT REQUIREMENTS

1202.7.1 Interface and Integration Management

1202.7.1.1 CCTV camera equipment must be compatible and integrate seamlessly with the existing Sound Transit CCTV system.

1202.7.1.2 Designs must ensure that all the devices, equipment, materials, cabling, and any other items that will be used in this network implementation can be integrated and configured into the existing Sound Transit CCTV system.

1202.7.1.3 The CCTV design must ensure that all system elements are compliant with industry standards and are commercially available off the shelf.

1202.7.1.4 CCTV camera system must integrate with audio at public bathrooms when audio is present.

1202.7.2 Design Management (Not Used)

1202.7.3 Manufacturing and Construction Management (Not Used)

1202.7.4 Installation Management (Not Used)

1202.7.5 Inspection and Testing Management (Not Used)

1202.7.6 Training, Pre-Revenue Operations (Not Used)

1202.7.7 Certification Management (Not Used)

1202.8 APPENDICES (NOT USED)

END SET - 1202

1203 ACCESS CONTROL SYSTEMS

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SET - 1203 TABLE OF CONTENTS

TABLES

FIGURES

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SET - 1203 ACCESS CONTROL SYSTEMS

1203.1 INTRODUCTION

1203.1.1 Document Scope

1203.1.1.1 Access control pertains to the rules, regulations, and methods used to manage access through entry points in normal and fail-secure emergency conditions.

1203.1.1.2 Provide an access control system to grant the central operator the authority to issue, revoke, change access for Sound Transit personnel and authorized guests.

1203.1.1.3 The access control system must allow the central operator to define access types based on time, group association, location, area classification.

1203.1.1.3.1 Access control as it relates to fixed guideway transit and passenger rails systems is focused on granting stakeholders the ability to manage the flow of personnel, patrons, and unknown entities at Sound Transit facilities. To facilitate access control information relating to successful and unsuccessful access attempts, access alarms, and their respective locations which is relevant, timely, clearly presented, designers must consider the locations where access control is installed and the systems to which access control incorporates. When these design principles are successfully taken into consideration, they aid operations, security, and passenger experience. The access card system facilitates these tasks by displaying alarm events, generating access reports, and mapping access control devices and access control readers.

1203.1.1.3.2 Outdoor and indoor perimeter security must be maintained by utilizing access control at portals.

1203.1.1.4 If there is a conflict between these requirements and adopted codes and standards, the most restrictive will apply.

1203.1.1.5 This set applies to Link Light Rail, Sounder Commuter Rail, Bus Rapid Transit, and all Sound Transit properties.

1203.1.1.6 Where the designer of record encounters cases of special designs not specifically covered by these criteria, the designer of record must bring them to the attention of the Sound Transit Design Requirements Set 1203 owner to determine the technical source for the design criteria.

1203.1.2 Regulations, Codes, Standards, and Guidelines

1203.1.2.1 International Regulations, Codes, Standards, and Guidelines

1203.1.2.1.1 IEC 60950-1 - Information Technology Equipment - Safety - Part 1: General Requirements.

1203.1.2.1.2 ISO 15693 - Cards and security devices for personal identification - Contactless proximity objects, type A.

1203.1.2.1.3 ISO 14443 - Cards and security devices for personal identification - Contactless vicinity objects.

1203.1.2.1.1 IEEE 802.3at, Standard for Power over Ethernet enhancements (25.5W)

1203.1.2.1.2 IEEE 802.3bt, Standard for Third Generation Power over Ethernet

1203.1.2.2 Federal and National Regulations, Codes, Standards, and Guidelines

1203.1.2.2.1 American with Disabilities Act (ADA)

1203.1.2.2.2 CE Compliant

1203.1.2.2.3 FCC Part 15 Devices NFPA 70, National Electrical Code (NEC) with State and Local amendments.

1203.1.2.2.4 NFPA 80, Standard for Fire Doors and Other Opening Protectives.

1203.1.2.2.5 National Electrical Manufacturers Association (NEMA).

1203.1.2.2.6 NFPA 13 - Standard for the Installation of Sprinkler Systems.

1203.1.2.2.7 NFPA 101 – Life Safety Code.

1203.1.2.2.8 NFPA 730 - Guide for Premises Security.

1203.1.2.2.9 NFPA 731 - Standard for the Installation of Premises Security Systems.

1203.1.2.2.10 UL 10C - Positive Pressure Fire Tests of Door Assemblies.

1203.1.2.2.11 UL 294 - Access Control System Units.

1203.1.2.2.12 UL 294B - Power Over Ethernet (PoE) Power Sources for Access Control Systems.

1203.1.2.2.13 UL 1076 - Proprietary Burglar Alarm Units and Systems.

1203.1.2.2.14 UL 2044 (3rd Edition, 2008) - Standard for Commercial Closed Circuit Television Equipment.

State and Local Regulations, Codes, Standards, and Guidelines (Not Used)

Industry Regulations, Codes, Standards, and Guidelines (Not Used)

1203.1.2.3 Other Jurisdictions (Not Used)

1203.1.2.4 Sound Transit Regulations, Codes, Standards, and Guidelines

1203.1.2.4.1 Sound Transit Equipment and Facilities Numbering Standards. - Rev 4.

1203.1.2.4.2 Systems Guidance Drawings Set Rev 1.

1203.1.2.4.3 Sound Transit Systems Guidance Drawings.

1203.1.3 Abbreviations and Acronyms

1203.1.3.1 ACP-Access Control Panel or Access Door Controller

1203.1.3.2 ACS-Access Control System

1203.1.3.3 BMS-Building Management System

1203.1.3.4 NEC-National Electrical Code

1203.1.3.5 NFPA-National Fire Protection Agency

1203.1.3.6 PoE–Power over Ethernet

1203.1.3.7 SMS-Short Message/Messaging Service

1203.1.3.8 SOC-Security Operations Center

1203.1.3.9 TCN-Train Control Network

1203.1.3.10 TCS-Train Control System

1203.1.3.11 UL-Underwriter's Laboratories

1203.1.4 Definitions and Classifications

1203.1.4.1 Alarms: visual and/or audible indications meant to warn and/or bring to attention to abnormal conditions and/or events

1203.1.4.1.1 Local annunciator: device capable of generating alarms near the point of alarm initiation. The local annunciator is also referred to as a sounder or a siren.

Access portals: Standard doors, automatic doors, security grilles, vertical lift gates, swing gates, and sliding gates.

Commentary: Overhead doors, though once formerly used, are no longer used at Sound Transit facilities.

1203.1.4.1.2 Enclosed Station. A station or portion thereof that does not meet the definition of an open station (NFPA 130).

Commentary: Enclosed stations classification applies to tunnel stations and other stations where tenability of the platform and its means of egress from could be affected by a station or LRV fire. An open station with a roof that extends over the trainway, for example, could potentially be classified as an enclosed station. An engineering analysis may be needed to classify such a station as an open station (see Set series 800 Architecture).

1203.1.4.1.3 ISO/IEC 14443: Contactless smartcards with a range of up to 4 inches; i.e. proximity cards.

1203.1.4.1.4 ISO/IEC 15963: Contactless smartcards with a range of 39 inches; i.e. vicinity cards.

1203.1.5 References (Not Used)

1203.2 STAKEHOLDER NEEDS

1203.2.1 Passenger Experience

1203.2.1.1 Prevent unauthorized passengers from accessing restricted areas at Sound Transit operated properties.

1203.2.2 Operational Needs (Not Used)

1203.2.3 Maintenance Needs

1203.2.3.1 ACP must be located for maintenance accessibility.

1203.2.3.2 ACP must not be located in elevator machine rooms.

1203.2.3.3 ACP must be deployed to allow access to appropriate maintenance personnel.

1203.2.4 Safety Needs

1203.2.4.1 Prevent unauthorized passengers and personnel from accessing restricted areas at Sound Transit operated properties.

1203.2.5 Security Needs

1203.2.5.1 Prevent unauthorized passengers and personnel from accessing restricted areas at Sound Transit operated properties.

1203.2.5.2 Station and garage elements within arms-reach to the public must be rated the following where practicable:

- Vandal Resistant
- Theft Resistant

1203.2.6 Reliability, Availability and Maintainability Needs

1203.2.6.1 Where practicable, designs must employ only one supported model to meet individual requirements.

Commentary: This is a model reduction requirement. Model reduction has been incorporated to reduce incompatibility, reduce unreliability due to new unconfirmed components, reduce compliance issues, increase usable inventory space, reduce redesign, reduce additional training, reduce unreliable integration, increase spares, and ease documentation.

1203.2.7 Environmental and Sustainability Needs (Not Used)

1203.2.7.1 Access card readers must use power management

1203.3 SYSTEM REQUIREMENTS

1203.3.1 General Requirements

1203.3.1.1 Access control equipment must be listed as supported by current, specified access control system manufacturer.

1203.3.2 Functional Requirements

1203.3.2.1 At Link Light Rail stations, employ fail-secure, electric strike door locks at all locations, not requiring access by fire, life, safety personnel.

Commentary: Added based on Fire/Life Safety consultation. Avoid magnetic Lock equipment, or maglock. In some instances, electric strike door locks may not be possible when retrofitting older doors.

1203.3.2.2 Provide real-time, remote surveillance capability for ACS.

Commentary: Security operations center requires instantaneous knowledge about what portals are accessed.

1203.3.2.3 All alarms must report to the SOC..

1203.3.2.4 ACS alarms must report points required by directive drawing *JBS503 Building Management Systems BMS Summary Indications*.

1203.3.2.5 Access door controller must be compatible and integrate with the existing access control server at Sound Transit.

1203.3.2.6 Access door controllers must be compatible and integrate with the existing access control server at Sound Transit.

Commentary: The access door controller contains electronic circuit boards. These electronic circuit boards must be able to communicate and perform the required functions demanded by the access control system to be considered compatible.

1203.3.2.7 Access cards must utilize data format readable by existing Sound Transit access door controller.

Commentary: This requirement is to ensure access card reader and access control system interoperability.

1203.3.2.8 Access door controllers must be networked to the Operations Control Center via Sound Transit Network as directed by Sound Transit, Transit Systems Technology.

1203.3.2.9 Access door controller must be able to monitor field wiring in open and closed-circuit conditions.

1203.3.3 Performance Requirements

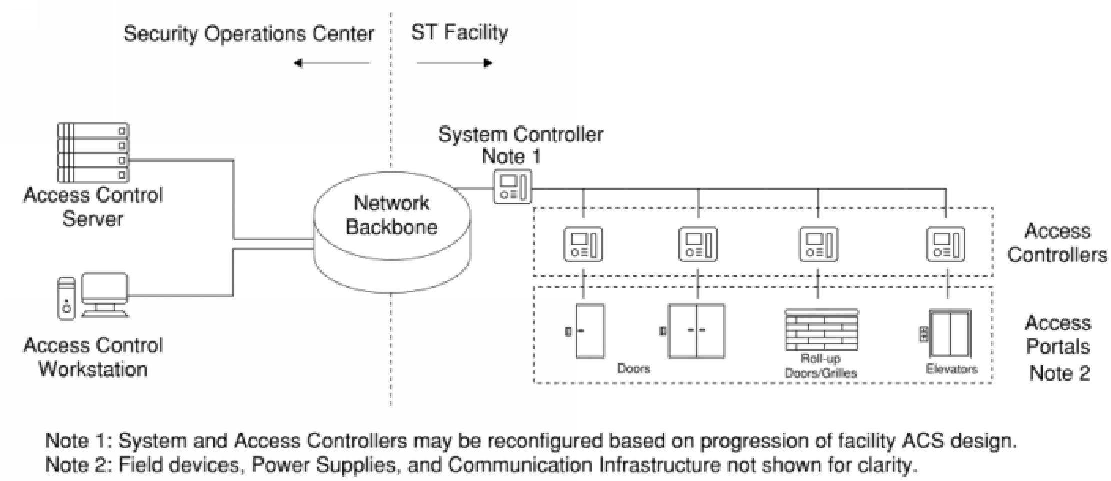
1203.3.3.1 All access card readers must be capable of reading the format and frequency of the access cards currently being issued and all Sound Transit supported legacy access cards.

Commentary: There may be two varieties of access cards being used by Sound Transit. Design the access control system to support the legacy access control equipment unless written permission is obtained.

1203.3.3.2 Position switches must be magnetic type and flush mounted whenever possible.

1203.4 SYSTEM ARCHITECTURE (HIGH-LEVEL DESIGN) REQUIREMENTS

Figure 1203-1: System Architecture



1203.4.1 System Breakdown Structure

1203.4.1.1 See Set 801 Architectural Materials, Elements, and Furnishings.

1203.4.1.2 Access control system must include end-of-line resistors in addition to equipment mentioned in Set 801 Architectural Materials, Elements, and Furnishings.

1203.4.2 System Sites and Locations

1203.4.2.1 See Set 801 Architectural Materials, Elements, and Furnishings.

1203.5 SYSTEM INTERFACE REQUIREMENTS

System interfaces identifies the coordination points between this requirement set and other requirement sets.

Table 1203-1: Interface Between Access Control Systems and Other Disciplines

SET SERIES	SET NAME	SET 1203 INTERFACE
100	Train Control and Signals	
200	Traction Electrification	
300	Operational Communications	
400	Vehicle	
500	Track	
600	Fire/Life Safety	X
700	Structures	
800	Architecture	X
900	Civil	X
1000	Mechanical-Electrical and Building Systems	X
1100	Technology	
1200	Security	X

1203.5.1 Vehicle (Not Used)

1203.5.2 Mechanical-Electrical and Building Systems (Not Used)

1203.5.3 Security (Not Used)

1203.6 SUBSYSTEM AND SYSTEM ELEMENT (DETAILED) REQUIREMENTS

1203.6.1 Access Control Elements

1203.6.1.1 Access Card Readers

1203.6.1.1.1 Access card reader must provide visual indications for reader status.

1203.6.1.1.2 Access card reader must provide visual indications for granted and denied access.

1203.6.1.1.3 Access card reader must be standalone, discrete access control element.

1203.6.1.1.4 Access card reader must be multiclass, multifrequency style reader as defined by ISO 14443 and ISO 15693.

1203.6.1.1.5 Access card reader must UL 294 listed

1203.6.1.2 Access Control Server

1203.6.1.2.1 The server must store card access transactions in an industry standard database.

1203.6.1.3 Access Control Workstation

1203.6.1.3.1 Access control panels must be an industrial grade enclosure with knockouts for field wiring and have a key-locked and tamper protected door.

1203.6.1.3.2 Refer to Set 1005 Electrical Power for backup power requirements. See Set Electrical Power 1005.

1203.6.1.3.3 Access door controller must support supervision, monitoring, and processing of reader tampering.

1203.6.1.3.4 Access door controller must support supervision, monitoring, and processing of reader communications.

Table 1203-2: Equipment Standards

Equipment/Device	UL Listing	Other Standard
Access Control Server	UL 294, UL 1076	
Access Control Workstation	UL 294, UL 1076	
System Controllers	UL 294, UL 1076	FCC Part 15
Access Door Controllers	UL 294, UL 1076	IEEE 802.3af/at
Card Readers	UL 294	ISO 14443A, ISO 15693
Request-to-Exit Detectors/ Switches	UL 294	
Request to Exit Switches	UL 294	
Door Position Switches	UL 10C, UL 294	
Auxiliary Power Supplies	UL294, UL603	
PoE Injectors	UL294B	
Power Transfer Hinges	UL 294	

1203.7 ENGINEERING MANAGEMENT REQUIREMENTS (NOT USED)

1203.7.1 Interface and Integration Management

1203.7.2 Design Management

1203.7.3 Manufacturing and Construction Management

1203.7.4 Installation Management

1203.7.5 Inspection and Testing Management

1203.7.6 Training, Pre-Revenue Operations

1203.7.7 Certification Management

1203.8 APPENDICES (NOT USED)

END SET - 1203